SMARTGREENS 2024

International scientific and practical conference “Smart cities and sustainable development of regions”

IDE
INSTITUTE of DIGITAL ECONOMICS and LAW

SCITEPRESS DIGITAL LIBRARY

UDC 00, 1, 33, 34, 36, 37,39, 50, 51, 57, 60, 61, 62, 63, 67, 68, 7
BBK 1
M 43

International scientific and practical conference “Smart cities and sustainable development of regions” (SMARTGREENS 2024): LLC Institute of Digital Economics and Law [OOO «Institut tsifrovoy ekonomiki i prava»], 2024. – 1005 p.
ISBN: 978-5-6050374-8-5

Reviewers:

1. Echeverri, Luis, Gomez International Institute for Applied Systems Analysis, Laxenburg, Laxenburg, Austria Oslo, Norway
2. Feria Toribio, José María Universidad Pablo de Olavide, Sevilla, Spain
3. Mohammadi-Ivatloo, Behnam,University of Tabriz, Tabriz, Iran
4. Siarry, Patrick, Université Paris-Est Créteil, Creteil, France

The International Scientific and Practical Conference "Smart Cities and Sustainable Regional Development" (SMARTGREENS 2024) aims to bring together leading experts from academia, industry, and public sectors to exchange knowledge and best practices in the field of sustainable development and innovation. The goal is to foster knowledge exchange, research collaboration, and the sharing of best practices among scientists, practitioners, policymakers, and entrepreneurs across sectors such as sustainable development, energy, ecology, education, and technology. The conference is focused on promoting innovative ideas and solutions for creating smart cities and regions that can efficiently utilize resources while minimizing environmental impact and ensuring a high quality of life for all residents.

This event marks a significant milestone in the global advancement of smart city concepts and sustainability, offering a platform for discussion, networking, and collaboration between international experts.

Conference Tracks:

1. Economics and Management of Sustainable Development
2. Sustainable Regional Development: Economic Aspects
3. Natural Resource Management
4. Engineering Project Management
5. Agro-Industrial Complex Management
6. Energy and Ecology
7. Sustainable Energy Development
8. Renewable Energy Sources
9. Sustainable Development and Ecology
10. Energy and Earth Sciences
11. Engineering and Environmental Protection
12. Technology and Innovation
13. Smart Cities and Robotics
14. Fuzzy Systems, Intelligent Networks, and Machine Learning
15. Data and Analytics
16. Big Data and Intelligent Data Analysis
17. Applied Mathematics and Statistics
18. Digital Transformation and Education
19. Digital Economy
20. Digital Education
21. Digital Technologies in Law

SMARTGREENS 2024 will provide a vital opportunity to discuss innovative strategies for smart city development and sustainable regional growth, addressing critical issues that affect the future of urban and rural environments.

.

Content

Analysis of the Impact of Emissions from the Blagoveshchensk Asphalt Concrete Plant “Nikko Cbd-100”Jsc“Asphalt”on the Atmospheric Air and Measures to Protect it

Tatiana V. Ivanykina [1][a], Natalia V. Shkrabtak [1][b] and Julia A. Praskova[1][c]
[1] Amur State University, 21 Ignatievskoe highway, Blagoveshchensk, Russia
tat-ivanykina@yandex.ru, mmip2013@mail.ru, stenna09@rambler.ru

Keywords: Asphalt concrete plant, Emissions of pollutants, Sanitary protection zone, Noise·Air protection, Environmental measures.

Abstract: Air pollution is caused by the release of gaseous, liquid and solid substances in quantities that damage the environment, adversely affecting flora and fauna, water, soil and human health. The main air pollutants are nitrogen compounds (NO, NO2), carbon compounds (CO, CO2), sulfur dioxide (SO2), heavy metals (mercury, nickel, lead, arsenic, cadmium), hydrocarbons and their derivatives, as well as PM 10, PM 2.5 and PM 1.0. Solid pollutants negatively affect human health both directly, penetrating the body, causing allergies and lung diseases, and indirectly, acting as a carrier of heavy metals, microorganisms and bacteria. It is widely believed that large industrial plants, power plants and combined heat and power plants are the main sources of point emissions, affecting both local and global air quality. Strong corporate environmental and sustainability commitments are based on reliable assessments of corporate impacts and realistic mitigation plans. The purpose of this study was to analyze the emissions of pollutants into the atmosphere from the asphalt concrete plant (ABP) “NIKKO CBD-100” (Blagoveshchensk, Amur region, Russia). The results show that the gases emitted by each type of material can influence design criteria from an environmental point of view. From the results obtained, it can be concluded that at the production stage, emissions of methane, carbon dioxide and carbon monoxide increase and decrease depending on the materials used in the operation of the asphalt concrete plant.

1 INTRODUCTION

The infrastructure construction industry, which has been continuously developing in recent years around the world for both construction and maintenance, requires a corresponding consumption of precious materials with enormous consequences for the natural ecosystem (Burlak, Belaya, 2020). These environmental concerns are also associated with the sheer volume of sidewalk construction and the required mining and production technologies for materials that traditionally have high impacts.

Asphalt is one of the oldest building materials. The advent of polymers for asphalt modification has had a major impact on the development of pavement technology.

Over the past five years, total asphalt production in the United States, Japan and 30 European countries has reached 5485.3 million tonnes. Asphalt production in the world exceeds the above figures. These data show that the production of asphalt material worldwide is enormous, and therefore analyzing the environmental impact of producing this amount of asphalt is important for the preservation of the environment.

Asphalt concrete plants (hereinafter - ABZ) are the main production enterprises of the road sector. They are part of the automobile and road complex and are designed for the production of asphalt concrete mixtures. The result of the activity of the ABZ is the release of pollutants into the environment: hydrocarbons, soot, phenol, nitrogen and carbon

[a] https://orcid.org/0000-0002-7727-3790
[b] https://orcid.org/0000-0002-5193-452X
[c] https://orcid.org/0000-0001-9898-1617

oxides, formaldehyde, etc. (Moore, Lopes, 1999; Burlak, Belaya, 2020).

One of the significant environmental problems of ABZ technologies is the lack of special devices for cleaning emissions from harmful gases under conditions of an increasing environmental load on the atmosphere. In this regard, the selected research topic is of particular relevance and practical importance.

Asphalt concrete plant NIKKO KBD-100 for the production of asphalt concrete mixture is located west of Blagoveshchensk and north of the village Verkhneblagoveshchenskoe. The nearest building is located at a distance of 1200 m from the ABZ. The plant's productivity is 100 t/h of commercial asphalt.

The process of preparing an asphalt concrete mixture includes four main stages:

- Preparation of mineral materials (feeding by a loader of mineral materials from a warehouse to a mixer; feeding sand and gravel into a drying drum; drying and heating mineral materials; separating them into fractions; precise final dosing of gravel, sand, powder);
- Preparation of bitumen (supply from a warehouse to a bitumen plant, heating to operating temperature, dosing of heated bitumen);
- Mixing mineral materials with bitumen;
- Inloading the finished asphalt concrete mixture into a bunker or a car.

Most of the previous studies (Butt, Mirzadeh, Toller, 2014; Sisi, Zhijuan, Minrui, 2019) have focused on the effects of air pollution. Mediation analysis is a statistical technique commonly used to study the relationship between independent, mediating and dependent variables in order to obtain direct and indirect effects of the independent variable on the dependent variable.

The construction and maintenance of roads has a large impact on the environment due to the enormous amount of resources involved. Consequently, existing manufacturing procedures and technologies must be properly investigated to identify and quantify the environmental impacts produced during the life cycle.

2 MATERIALS AND METHODS

In the presented work, the purpose of the study is to analyze the emissions of pollutants into the atmosphere from the asphalt concrete plant “NIKKO CBD-100”, and also proposed measures to reduce emissions. To achieve this goal, the following tasks have been identified:

1) analyze the sources of impact on the atmosphere;

2) analyze the calculation of surface concentrations of pollutants;

3) to identify the main share of gross emissions;

4) to propose an action to reduce emissions into the air.

The research methodology is based on comparative analytical methods, methods of generalization and formalization, coefficient analysis. To write the article, we used normative **legal acts (**Atamaleki, Zarandi, Fakhri, 2019; Standartinform, 2014**)**, periodicals (Atamaleki , Zarandi , Fakhri, 2019; Hamidi, Bahman , 2020; Santero, Masanet, Horvath , 2011; Tumminia, Guarino, Longo, 2018), local documents of the organization.

The calculation of ground-level concentrations of the main pollutants was carried out at the PVEM using the ERAv 2.0 software package (PC), developed by the Novosibirsk enterprise LOGOS-PLUS LLC.

3 RESULTS

At the Blagoveshchensk ABZ, 51 sources of pollutant emissions have been identified, of which 12 are organized sources and 39 are unorganized sources. During the operation of the ABZ, 24 types of pollutants are emitted into the atmosphere. Some of these substances form 5 summation groups. The gross emission of pollutants is 29.064 t/year. Sources of emission of pollutants at the plant are technological units that are part of the installation, etc., emitting pollutants during operation (Table 1). Sources of pollutant emissions are a chimney, aeration lantern, a bunker, a ventilation shaft, a hatch, and other devices through which pollutants are released into the atmosphere (Huang , Bird, Bell, 2009).

Table 1: Sources of emission and emissions of harmful substances at the NIKKO CBD-100 plant.

Site name	**Selection sources**	**Sources of emissions**
Cold section	Inclined belt conveyor	Fugitive emissions

Drying section	Dryer drum	Chimney
Dust collection section	Dust feed rotor, chimney	
Mixing section	Hot hopper	
Inert feed section	Horizontal belt conveyor	Fugitive emissions
Road transport	Engine	Exhaust pipe

Source: Compiled by the authors.

The list of harmful substances that are released into the atmosphere during the operation of the ABZ, their qualitative and quantitative characteristics are presented in Table 2. Analysis of calculations of surface concentrations revealed that ABZ is a source of impact on the environment for nitrogen dioxide (0301), sulfur dioxide (0330), limit hydrocarbons C12-19 (2754), inorganic dust (2908), 31 and 41 groups of summation, whose contribution in atmospheric air pollution at the border of the nearest residential development exceeds 1,0 maximum permissible concentration (MPC).

Also, according to the analysis of the obtained calculations, there is an excess of the MPC in the territory of the Blagoveshchensk Asphalt concrete plant ABP for nitrogen dioxide, xylene, methylbenzene, butyl alcohol, butyl acetate, saturated hydrocarbons C12-19, inorganic dust (70% -20% silicon dioxide), 31 and 41 groups of summation.

Table 2: Short cut keys for the template.

Code	Na-me impurities	Concentration of contaminants in the surface layer in fractions of maximum permissible concentration			
		Background concentration (MPC)	Max. concentration	Max. Concentration at the border of the residential area	Contribution of sources to pollution at the border of residential area
123	Iron oxide	0,20	0,352	0,204	0,004
301	Nitrogen dioxide	0,40	1,628	0,790	0,390
304	Nitrogen oxide	0,20	0,299	0,213	0,013
328	Soot	0,20	0,529	0.262	0,062
330	Sulfur dioxide	0,022	0,359	0,188	0,166
337	Carbon monoxide	0,58	0,656	0,621	0,041
616	Xylene	0,20	1,425	0,211	0,011
621	Methyl benzene	0,20	1,411	0,211	0,011
042	Butyl alcohol	0,20	2,376	0,219	0,019
119	Ethyl cellosolve	0,20	0,365	0,201	0,001
210	Butyl acetate	0,20	1,651	0,213	0,013
401	Acetone	0,20	0,490	0,202	0,002
732	Kerosene	0,20	0,250	0,208	0,008
752	White Spirit	0,20	0,445	0,202	0,002
754	Hydrocarbons, pr. S12-19	0,20	13,864	0,472	0,272
902	Suspended substances	0,20	0,606	0,201	0,001
908	The dust is inorganic. 70-20%	0,20	4,087	0,356	0,156
1 гр.	Nitrogen dioxide + Sulfur dioxide	0,40	1,235	0,733	0,333
1 гр.	Carbon monoxide + Inorganic dust 70-20%	0,58	4,499	0,778	0,198

Source: Compiled by the authors.

Distances from the production sites of the Blagoveshchensk ABZ to the nearest residential area with. Verkhneblagoveshchenskoe are:

- Intermediate storage of sand and gravel mixture - 400 m;
- Area with warehouses for sand and gravel mixture, crushed stone, sand - 400 m;

- The site of the ABZ - 700 m;
- Garage - 800 m;
- BRU site - 880 m.

Table 3: Short cut keys for the template.

Pollutant		Hazard Class	MPCs.s, MPCmax *, OBUV **, mg / m3	Total release of matter	
Code	Name			g /s	t / year
123	Iron oxide	3	0,04	0,0127	0,0263
301	Nitrogen dioxide	3	0,04	1,5403	6,4840
304	Nitrogen oxide	3	0,06	0,2502	1,0536
328	Soot	3	0,05	0,1027	0,9953
0330	Sulfur dioxide	3	0,05	1,6381	2,7077
337	Carbon monoxide	4	3,00	4,0197	9,5905
616	Xylene	3	0,2*	0,0104	0,0675
621	Methylbenzene	3	0,6*	0,0309	0,2500
042	Butyl alcohol	3	0,1*	0,0093	0,075
119	Ethyl cellosolve	-	0,7**	0,0049	0,0400
210	Butyl acetate	4	0,1*	0,0062	0,0500
401	Acetone	4	0,35*	0,0043	0,0350
732	Kerosene	-	1,2**	0,2195	1,3879
752	White Spirit	-	1**	0,0104	0,0675
754	Hydrocarbons, pr. S12-19	4	1*	1,3976	5,2397
902	Suspended substances	3	0,15	0,0061	0,0198
908	The dust is inorganic. 70-20%	3	0,10	0,4129	0,9238
123	Iron oxide	3	0,04	0,0127	0,0263
301	Nitrogen dioxide	3	0,04	1,5403	6,4840
Total substances: 17				**9,677**	**29,064**
of which solid: 4				0,535	2,016
liquid / gaseous: 13				9,142	27,048

Source: Compiled by the authors.

Estimated concentrations of pollutants in 1 MPC outside the territory of the Blagoveshchensk ABZ spread over distances:

1) Nitrogen dioxide - 75-185 m;
2) Xylene - does not go beyond the boundaries of the enterprise;
3) Methylbenzene - does not go beyond the boundaries of the enterprise;
4) Butyl alcohol - 0-35 m;
5) Butyl acetate - 0-20 m;
6) Saturated hydrocarbons C12-19 - 30-280 m;
7) Inorganic dust (70% -20% silicon dioxide) - 0-95 m;
8) 31 summation groups - 0-100 m;
9) 41 summation group - 0-210 m.

At the same time, the excess of maximum permissible concentration for all substances and groups of summation in residential buildings with Verkhneblagoveshchenskoe is notobserved.

The estimated SPZ for the factor of chemical pollution of atmospheric air is determined by the combined isoline of 1 MPC from various substances and is:

- In the north direction - 150 m;
- Eastward - 250 m;
- Southward - 200 m;
- In the western direction - 300 m.

The distance between the boundaries of the territory of the Blagoveshchensky ABZ and residential buildings with. Verkhneblagoveshchenskoe, 400 m away, ensures the observance of the hygienic indicators of the quality of atmospheric air in the standardized territories.

In addition to the chemical impact, 22 sources of noise impact on the atmospheric air have been installed on the territory of the industrial site of the enterprise. According to the results of the calculations, it was found that during the operation of the facility in the mode of main production, the maximum sound levels at the border of the design SPZ and outside it do not exceed the maximum permissible concentration.

To protect the environment from pollution at the plant, organizational, technological, engineering and technical environmental protection measures are envisaged, which allow preventing or minimizing the negative impact on the natural environment.

The NIKKO CBD-100 monitoring system of the Blagoveshchensk ABZ includes control over the quality of atmospheric air at the border of the SPZ and the nearest residential development, on the territory of an industrial site, and also includes monitoring of emissions from pollution sources. The concentration of the following pollutants is subject to control: nitrogen dioxide, xylene, sulfur dioxide, methylbenzene, butyl alcohol, butyl acetate, a mixture of saturated hydrocarbons C12-19, inorganic dust (70% -20% silicon dioxide), 31 and 41 groups of summation.

The facility carries out an inventory of emissions of harmful pollutants into the air every 5 years, and there is also a Schedule for monitoring compliance with the MPE standards. The main activities carried out for the protection of atmospheric air at the NIKKO CBD-100 ABZ: control over the technical condition of equipment, timely technical inspection and its repair; non-admission of idle operation of engines of machines during their parking and mechanisms with internal combustion engines; prohibition of washing machines and mechanisms, draining of fuels and lubricants on the territory of the facility; corrosion protection of technological equipment by applying anti-corrosion coatings; equipping equipment with instrumentation and automation systems to prevent emergencies, as well as to reduce emissions of pollutants into the atmosphere due to the exact observance of the specified technological parameters; during the period of repair work - the use of shut-off and control valves and technological equipment corresponding to the parameters of the working process and corrosiveness of the environment.

According to the analysis, the NIKKO CBD-100 ABZ is a source of air pollution with various harmful substances. The emissions from the plant are in many ways similar to those from the energy sector - concentrations of nitrogenous and sulfur compounds prevail, and large amounts of dust are emitted (from vibrating screens) (Kota, Zhang, Chen, 2014).

To reduce the negative impact of the ABZ in the atmospheric air, the following measures can be proposed:

- To apply reinforcement with shields made of fine-mesh construction non-metallic mesh along the perimeter of small-sized fugitive dust sources and completely cover the stored sources of fugitive emissions;
- To reduce organized emissions of pollutants, use a device for wet cleaning of exhaust gases and dusty air - a Venturi scrubber in combination with droplet separators (Nikkko, 2019).

At present, at the ABZ, the emission purification system is represented by a dry dust collector and a bag filter chamber. The cleaning factor is 91%.

The Venturi scrubber allows to provide cleaning efficiency up to 98-99% on dusts with an average particle size of 1-2 microns at an initial dust concentration of up to 100 g / m3. Specific water consumption for irrigation with a composition of 0.4-0.6 l / m3. The calculation of the Venturi scrubber was carried out according to the methodology given in the interstate standard GOST 31826-2012.

Modernization of the treatment facilities system will increase the efficiency of cleaning pollutant emissions from 91% to 99.8%.

It is also recommended to use water reuse (circulating water supply) for the Venturi pipe in order to reduce the amount of polluted water released into the environment and avoid paying fines for violation of environmental legislation.

According to the calculations obtained, the total costs of upgrading the emission treatment system at the plant will amount to 268,000 rubles. The economic effect of the measure is to reduce the company's expenses for payments for negative environmental impact. According to the results of calculations, the installation of an additional treatment facility - a Venturi scrubber - will lead to a reduction in payments for negative impact on the environment by 88% and will amount to 327 rubles per year.

4 DISCUSSION

All data collected is real data obtained at the production site, in a real operating asphalt plant. Comparisons of different inventory analyzes among different studies available in the literature are not immediate, especially when they relate to different regions. The raw data collected for the environmental audit of the plant can also be used to provide a preliminary discussion of current generally accepted practice. To improve air quality, action must be taken to reduce the amount of pollutants emitted from all sources. Despite some positive results, the main problem with such studies is that the relevant case studies are based on specially optimized models that cannot be easily applied to other countries and scenarios (Santero, Masanet, Horvath, 2011) or immediately compared (Hamidi, Bahman, 2020). Future parallel results will increase the reliability and accuracy of the linked dataset and can also be used for statistical analysis and analysis, as has already been done for other geographic and industrial contexts.

5 CONCLUSIONS

An experimental study of the effect of emissions from an asphalt concrete plant was carried out. ABZ NIKKO CBD-100 is designed and built taking into accountsanitary and hygienic requirements and has established boundaries of the sanitary protection zone. The ABZ has a two-level emission purification system: a dry dust collector and a bag filter. The cleaning factor is 91%. The results of the analysis show that the analyzed enterprise is a source of environmental impact. To reduce the negative impact of the ABZ on the atmospheric air, measures are proposed to reduce organized and fugitive emissions of pollutants. Based on the results of calculations, a Venturi scrubber of type SV 210 / 120-1200 with a capacity of 7-2 thousand m^3/h was selected. This will increase the efficiency of cleaning emissions from the NIKKO CBD-100 plant to 99.8%: the volume of pollutant emissions will decrease from 29.01 tons up to 6.45 tons. A recommendation was made to use recycled water (recycled water supply) for the Venturi pipe in order to reduce the volumetric discharge of polluted water into the environment and avoid paying fines for violation of the law.

REFERENCES

Moore, R., Lopes, J., 1999. Paper templates. In *TEMPLATE'06, 1st International Conference on Template Production*. SCITEPRESS.

Atamaleki, A., Zarandi, S., Fakhri, Y., et al, 2019. Estimation of air pollutants emission (PM10, CO, SO2 and NOx) during development of the industry using AUSTAL 2000 model: A new method for sustainable development. MethodsX 6:1581–1590.

Burlak, S.D., Belaya, I., 2020. Analysis of problems of ecological safety of technological processes at asphalt concrete plants. Scientific Works of KUBSTU 1:75–82.

Butt, A., Mirzadeh, I., Toller, S., et al 2014. Life cycle assessment framework for asphalt pavements: Methods to calculate and allocate energy of binder and additives. *International Journal of Pavement Engineering* 15(4):290–302.

Hamidi, A., Bahman, R., 2020. Evaluation and scientometric analysis of researches on air pollution in developing countries from 1952 to 2018. *Air Quality, Atmosphere & Health* 13:797–806.

Huang, Y., Bird, R., Bell, M., 2009. A comparative study of the emissions by road maintenance works and the disrupted traffic using life cycle assessment and micro-simulation. Transportation Research Part D: Transport and Environment 14(3):197–204.

Kota, S., Zhang, H., Chen, G., et al 2014. Evaluation of on-road vehicle CO and NOx National Emission Inventories using an urban-scale source-oriented air quality model. *Atmospheric Environment* 85:99–108.

Lupanov, A.P., Silkin, V.V., Bayartogtoh, D., et al 2017. Ensuring environmental safety in the production of asphalt concrete mixtures at the asphalt concrete plant ABZ . News of the KSAGU 42(2):424–431.

Ministry of Health of the Russian Federation (2000) Sanitary and epidemiological rules and standards SanPiN 2.2.1/2.1.1.1200-03 "Sanitary protection zones and sanitary classification of enterprises, structures and other facilities". https://docs.cntd.ru/document/1200006118.

Nikkko, 2019. Asphalt Mixing Plant Specification Model CBD-100ABD. https://www.nikko-net.com/en/asphalt/cbd/PZGO (nd) Flue gas cleaning: Methods and equipment.https://gas-cleaning.ru/article/ochistka-dymovyh-gazov-metody-i-oborudovanie .

Russian Federation, 2016. Resolution "On rates of payment for negative impact on the environment and additional coefficients", No 913, 13 September 2016, Moscow.

Russian Federation, 2020. Resolution of the Government of the Russian Federation "On approval of the criteria for classifying objects that have a negative impact on the environment to objects of categories I, II, III and IV", No 2398, 31 December 2020, Moscow.

Santero, N.J., Masanet, E., Horvath, A., 2011. Life-cycle assessment of pavements. Part I: Critical review. *Resources, Conservation and Recycling* 55(9–10):801–809.

Sisi, P., Zhijuan, S., Minrui, F., et al 2019. Spatial distribution of the public's risk perception for air pollution: A nationwide study in China. *Science of the Total Environment* 655:454–462.

Standartinform, 2014. Gas cleaning and dust collecting equipment. Sleeve filters. Dust collectors are wet. http://docs.cntd.ru/document/1200102307 .

Standartinform, 2014. Gas-cleaning and dust-collecting equipment. Sleeve filters. Dust collectors are wet. Safety requirements, GOST 31826-2012, 1 January 2014, Moscow.

Tumminia, G., Guarino, F., Longo, S., et al 2018. Life cycle energy performances and environmental impacts of a prefabricated building module. *Renewable and Sustainable Energy Reviews* 92:272–283.

In Fluence of Socio-Economic Factors on Spatial Development of Territories of Asian Russia (on the Example of the Tyva Republic)

Motoshkina M.A.[1][a], Norboeva B.S.[1,2][b] and Gomboev B.O.[1][c]
[1]*Baikal Institute of Nature Management SB RAS, Sakhyanova str., Ulan-Ude, Russia*
[2]*Buryat State University, Smolina str., Ulan-Ude, Russia*
maralmot@yandex.ru

Keywords: Socio-economic geography, spatial development, Tyva Republic, Asian Russia.

Abstract: This paper examines how socio-economic factors shape the spatial development of regions that are part of the Asian part of Russia, the study was conducted on the example of socio-economic indicators of development of the Republic of Tyva. It characterises the current socio-economic state of the region, strengths and weaknesses affecting the prerequisites for further spatial development.

1 INTRODUCTION

The Republic of Tyva is a border subject of the Russian Federation, which is part of the Siberian Federal District and the Angaro-Yenisei macro-region, bordering Mongolia to the south.

The Republic of Tuva is located in the south of Eastern Siberia, in the geographical Centre of

Asia and borders on Krasnoyarsk Krai in the north, Irkutsk Oblast in the north-east, the Republic of

Buryatia in the east, the Republic of Mongolia in the south and south-east, and the Republics of Altai

and Khakassia in the west. The capital of Tuva (the city of Kyzyl) is located at a distance of 4668 km

from Moscow in the geographical Centre of Asia at the confluence of the rivers Biy-Khem and Kaa-Khem.

The territory of the Republic of Tyva is characterised by unfavourable natural and climatic

conditions for living and belongs to the territories of the Far North and equated areas. Mountainous

relief occupies more than 80 percent of the entire territory of the Republic of Tyva, 20 per cent of

the territory falls on the intermountain basins, within which most of the population of the Republic

of Tyva lives. The Republic of Tyva is located in a seismically dangerous zone (8-10 points on the

Richter scale). The ecological situation is contrasting, from satisfactory in the mountainous areas to unfavourable in the hollows.

The territory of the Republic with an area of 168.6 thousand km2 stretches from east to west over 700 km, from north to south in the eastern part - 450 km, and in the central part - 100 km. Tyva is located in the zone of transition from the South Siberian taiga to the Mongolian steppes and is a mountainous country with an alternation of high ridges and deep intermountain hollows.

The Republic of Tyva has significant mineral reserves. The region has more than 47 percent of all-Russian reserves of zirconium, more than 30 percent of uranium, more than 5 per cent of copper, molybdenum and nepheline ores, significant reserves of non-ferrous, rare-earth and noble metals, and coal. At the same time, the Republic of Tyva is characterised by a low level of socio-economic development. According to the indicator of gross regional product per capita in 2021, the Republic of Tyva ranked 78th among the subjects of the Russian Federation with a value of 267 thousand rubles, which is almost 3 times less than the average indicator for the country (831 thousand rubles).

[a] https://orcid.org/0000-0002-1542-2439
[b] https://orcid.org/0000-0003-4756-8982
[c] https://orcid.org/0000-0002-9773-0151

2 METHOD OF RESEARCH

The social and economic development of the Republic of Tyva is characterised by the following indicators:

- The Republic of Tyva is among the ten subjects of the Russian Federation with the lowest average per capita cash income of the population (at the end of 2021, the indicator was 20.1 thousand rubles with the average Russian value of 54.6 thousand rubles);
- The Republic of Tyva is among the ten subjects of the Russian Federation with a high share of the population with monetary incomes below the subsistence minimum established in the subject of the Russian Federation (at the end of 2022, the indicator was 28.8 per cent with the national average of 9.8 per cent);
- there is a significant migration outflow of population in the republic (according to the results of 2021, the outflow totalled 1,358 people);
- unemployment rate in 2022 was 8 per cent, i.e. decreased by 3.3 per cent compared to 2021 (11.3 per cent) with the average Russian value of 3.7 per cent. It is noted that in the first quarter of 2021 the Republic of Tyva reached the mark of 18 per cent, during the coronavirus pandemic the level reached the mark of 20.4 per cent. The total number of unemployed was 10.5 thousand people with a decrease of 3 thousand people. Tuva ranks 78th among 85 subjects of Russia in terms of total unemployment.

In the Republic of Tyva there is a high level of natural population growth, which in 2022 was 9.3 (3130) people per 1,000 inhabitants with the average Russian indicator of 7.2 people per 1,000 inhabitants. By birth rate the Republic of Tyva in 2022 ranks 1st (17.9 per cent) per 1,000 population, in the Russian Federation with a rate of 9.6 persons per 1,000 inhabitants in 2021. And 1st place in terms of the total fertility rate - 2.97 children per 1 woman in 2020. During the analysed period, the number of population under working age increased by 1.0 thousand people and at the beginning of 2022 was 113.0 thousand people (34.0 percent of the total population). The number of the population of working age increased by 5.2 thousand people and amounted to 184.6 thousand people (55.5 per cent of the total population). The number of persons above working age decreased by 1,000 persons and amounted to 35,000 persons (10.5 per cent of the total population). In 2021, the average age of the population of the Republic was 30.0 years, including men - 28.1, women - 31.8, in the Russian Federation - 39.5, in the Siberian Federal District - 38.2 years.

The level of development of the social sphere in the republic and the quality of services have always been low, but this has hardly been reflected in standard statistical indicators. Due to the remoteness and inaccessibility of many districts and villages, almost all of them have health care and general education facilities. The network has not been reformed and is objectively hampered by settlement conditions.

The state of Tyva's economy shows that by the main socio-economic indicators the republic is in one of the last places among the regions of Russia and the Siberian Federal District. This is due to the fact that, compared to other subjects of the Russian Federation, the agro-industrial complex industries are the main donors to the regional budget. The systemic crisis in the country had a more acute impact on the economy of the republic, which led to a significant decline in living standards in the region. At that time, the state of socio-economic development in the republic reflects the general level of extremely high interregional differentiation in Russia, which, according to most experts, is unacceptable.

Due to the younger age structure of the population, including the employed, the coverage of vocational education is close to the Russian average, with 71 per cent of the Republic's employed population (the average for the Siberian Federal District is 70 per cent). The underdevelopment of industry has led to a low proportion of the employed having primary vocational education (working specialities). The share of those employed with secondary vocational education is higher than in the Siberian Federal District and the Russian Federation as a whole, while the share of those employed with higher education is close to the average.

The poverty rate in the Republic of Tyva is very high. The poverty rate is particularly high in the peripheral areas of the republic, where low-paid employment in agriculture and the public sector prevails, there are few other jobs and, in addition, the demographic burden is higher at the expense of children.

3 RESULTS AND DISCUSSION

The levels of socio-economic development of the Siberian republics naturally differ from each other, and during the period of the past reforms of the 1990s their differentiation has only intensified. In many respects, the determining factors of development are resource opportunities, primarily "natural" ones. The combination of external and internal factors affecting the development of the republics, production specifics, labour market, specialisation in the market of goods sales, ethno-social features, socio-economic capital of the Soviet period and many other things have led to the fact that each separate republic has its own specific socio-economic situation.However, the Republic's accession to Russia was of fundamental importance. The Republic of Tyva has changed significantly since becoming a part of Russia: by 1990, the population had more than tripled and industrial production had increased by almost 80 times. From an agrarian region in less than half a century, by the early 1990s it had become an agro-industrial region. Industrial output per capita was only five times less than the Russian average, while agricultural output was 75% of the Russian average. The average per capita income of the population was growing and in 1990 was already 75% of the Russian average.

However, the relatively intensive growth of the republic's economy still did not ensure the achievement of the lost level of development: the industrial production index. The main constraint on the development of goods-producing industries was not only the lack of investment and markets for products, but also the underdeveloped transport infrastructure, i.e. the republic's isolation from the economic space of Russia. First of all, the lack of a railway had an impact, which resulted in the low level of development of rich natural resources and the development of industrial production.

Favourable geographical position of the Republic in terms of transit opportunities. Prospects of creating an international air transport, road transport, railway corridor through the Republic of Tyva, linking Russia, Mongolia and China.

According to the diversity of natural conditions and natural resources, the nature of economic development and transport links, Tuva can be divided into 4 parts: central, western, southern and eastern. From the position of natural conditions the geographical position of the republic is favourable. It is located at the junction of Siberian taiga and Central Asian desert-steppe landscapes - in a wide band of mountains and intermountain plains. By the character of relief the territory is divided into 2 parts: the eastern part - mountainous, covering the basins of the rivers Bii-Khem and Kaa-Khem, and the western part, including the Tuva Basin and surrounding ridges (Western Sayan, Shapshalsky, Tsagan-Shibetu, Western and Eastern Tannu-Ola. In general, mountain systems occupy more than 80 per cent of the total territory of the republic and only less than 20 per cent are intermountain hollows: (dry-steppe Tuva, semi-desert Ubsu-Nur, taiga-forested Tojinskaya and Tere-Kholskaya). The average altitude of the hollows is 520-1200 m above sea level.

Economic assessment of the possibility of developing the mineral resource base of Tuva shows that the Central macro-region has the greatest potential of mineral resources, in the future it can become the centre of development of mining production of the republic, as it is here that the largest reserves of high-quality hard coal and building materials are concentrated.

The Republic of Tyva consists of 17 municipal districts, five of which are border districts: Erzinsky, Mongun-Taiginsky, Tes-Khemsky, Ovyursky and Kaa-Khemsky districts.

The Republic of Tyva, being a border region of Russia, attaches special importance to the development of mutually beneficial cooperation with the new centres of economic and political influence located in the Asia-Pacific region - the People's Republic of China and Mongolia and has prospects to become a significant transport and logistics centre. With the international status given to the Bulgan-Takishken border crossing on the border of the Kobdon aimag of Mongolia and XUAR of the People's Republic of China, it became possible to promote the Kyzyl-Urumqi cross-border corridor with a length of 1,790 kilometres. The most convenient and shortest transport route for access to the transcontinental transit transport corridors "Europe - Western China" and to the countries of the Asia-Pacific region is "Kyzyl (Tyva Republic, Russia) - Khandagaiti (Tyva Republic, Russia) - Ulangom (Mongolia) - Hovd (Mongolia) - Urumqi (China)".

The Republic of Tyva concluded an Agreement on cooperation between the Krasnoyarsk Krai and the Republic of Khakassia on the implementation of the "Yenisei Siberia" project (dated 17.04.2018, No. 3). The project "Yenisei Siberia" is an integration of economic, industrial, cultural potential, which sets the vector of spatial development of the Krasnoyarsk Krai, Khakassia and Tuva. The project is expected to form the Yenisei macro-region, which will provide additional effects of socio-economic development of the regions through coordination and joint management and spatial development. When fulfilling the tasks of the Yenisei Siberia project, spatial development of territories is possible by unlocking its potential, reducing infrastructural limitations to economic growth, developing promising specialisations in industry, ensuring the availability of basic social services within the macro-region, and reducing inter-regional inequality. For the successful implementation of this Agreement, the "Main" competitive advantages of the Republic of Tyva have been identified:

1. Favourable geographical position of the Republic in terms of transit opportunities;
2. Prospects of creating an international air transport, road transport, railway corridor through the Republic of Tyva, linking Russia, Mongolia and China;
3. Rich mineral resource base, availability of coal, non-ferrous, rare and rare-earth metals, polymetallic ores;
4. Large reserves of forestry stock;
5. Availability of tourist and recreational potential;
6. Large reserves of territories free for business development;
7. Stable socio-political situation, absence of inter-ethnic and inter-confessional conflicts.

Weaknesses of the region are determined by remoteness from the world markets, low transport and communication development of the districts, low share of deep processing industries, low level of innovative entrepreneurship development.

"Promising" areas of economic development in the Republic include:

1. Entry into international transport corridors, expansion of transport and logistics flows, creation of a transport hub;
2. Production of environmentally friendly agro-industrial products and access to new markets;
3. Growing demand for environmentally friendly tourist destinations;
4. Growing demand for natural resources (water, mineral, forestry);
5. Development of co-operation processes within the Siberian Federal District;
6. Development of industries related to renewable resources - forestry and agro-industrial complex;
7. Introduction of energy-saving technologies and development of energy production from alternative sources;
8. Emergence of joint infrastructural, spatial and technological projects in the sphere of cooperation between Russia, Mongolia and China;
9. Formation of active trade interaction with the regions and realisation of high value-added products.

Table 1: The main areas of development of the Republic of Tyva and their problems.

Main areas	Uniqueness, competitive advantages, strengths	Key issues
Resource potential		
Geographical location	Advantageous geostrategic position of Tuva (the centre of Asia) - border area with Mongolia (access to the countries of north-east Asia); Tyva borders the republics: Altai, Khakassia and Buryatia, Krasnoyarsk Krai and Irkutsk Oblast.	Transport isolation: no railway connection, poorly developed air route network.
Natural-resource potential	High mineral resource potential: – reservoirs of fresh and low mineralised groundwater; – mineral groundwater deposits; – Solid mineral deposits (gold, asbestos, mud, salts, polymetallic ores, sand, gravel and others); – Having its own raw material reserves for the development of the construction industry base; – Large forest reserves: more than 8 million hectares of Tuva's territory are covered by forests dominated by Siberian larch, cedar, pine, spruce, aspen. The total timber reserve is 1 billion cubic metres; – The presence of tourist-recreational and sanatorium-resort potential; – -Soil and climatic conditions allow for organic farming.	Insufficient utilisation of resource potential due to the lack of a railway; Weak investment activity.

4 CONCLUSION

Based on the results obtained, we would like to conclude that the Republic of Tyva has prerequisites and potential for spatial development in the socio-economic sphere. At the moment the region has certain difficulties, which it needs to solve for favourable development.

In solving the problems faced by the Tyva Republic, it is worth addressing the development and improvement of "promising" directions of economic development, which we have identified in the course of this study.

The work was carried out within the framework of the budget project "Geostrategic bases of balanced spatial development of Asian Russia and territories of neighbouring states in the conditions of cyclical natural and social processes (2022-2025). FWSU-2022-0001"

REFERENCES

Individual Programme of Socio-Economic Development of the Republic of Tyva for 2020 - 2024_ [Electronic resource] - Mode of access: http://pravo.gov.ru/proxy/ips/?doc_itself=&backlink=1&nd=102714639&page=1&rdk=1 . Date of circulation 14.05.2023.

KIP "Yenisei Siberia" [Electronic resource] - Access mode: https://ensib.ru/investments/yenisey-siberia-cip/ . Date of circulation 15.05.2023.

Inequality and Poverty_ Electronic resource] - Mode of access: https://rosstat.gov.ru/folder/13723. Date of circulation 01.04.2023.

Order of the Government of the Russian Federation from 10.04.2020 N 972-r (ed. from 12.09.2022) On approval of the individual programme of socio-economic development of the Republic of Tyva for 2020 - 2024 years [Electronic resource] - Mode of access: https://e-ecolog.ru/docs/CbEMqB6rQgHL8LcXh8EyP/41 Date of circulation 15 April 2023.

Dynamics of Machines for the Development of Hard-To-Reach Regions of the World

Irina Kuklina[1][1] and Alla Kuklina[1][2]
[1]Nizhny Novgorod State University of Architecture and Civil Engineering, NNGASU /Nizhny Novgorod, Russia
[2]Lobachevsky State University of Nizhny Novgorod /Nizhny Novgorod, Russia
igkuklina@yandex.ru, irinalg15@yandex.ru

Keywords: elastic suspension of machines, the dynamics of the machine, the machine on the screw

Abstract: Rotary screw machine (or a machine on the screw) has been widely used in Russia in 1960-1970. In contrast to vehicles equipped with conventional types of propulsion, the dynamics of screw machines is poor. The uniqueness of the calculation of screw machines in the geometric linear movement of the screw

1 INTRODUCCIÓN

Previous screw-propelled vehicles were designed and built with a rigid or semirigid suspension system. Within the framework of the investigation the design of a screw-propelled vehicle has been proposed with a novel visco-elastic suspension capable of decreasing the dynamic loads on the vehicle's body, which arise due to the unbalance of the screw rotors and the bearing surface.

The author's investigations in this direction have been carried out since 1996 resulting in the articles (Kuklina, 2011; Kuklina, 2013); for the last 20 years the mathematical theories obtained have been improved and put into practice.

2 SCREW GEOMETRY

Analysis of displacements of the screw-propelled vehicle permits one to obtain the scheme of interaction between the vehicle and the environment. Mathematical model displays a geometric line depending on the work front and rear suspensions. This effect is unique only for vehicles with rotor propulsion devices. The linearity of the contact of the bearing surface and the rotors is shown in Fig. 1. (Geometric parameters of the propulsion device of the screw-propelled vehicle when overcoming an obstacle.)

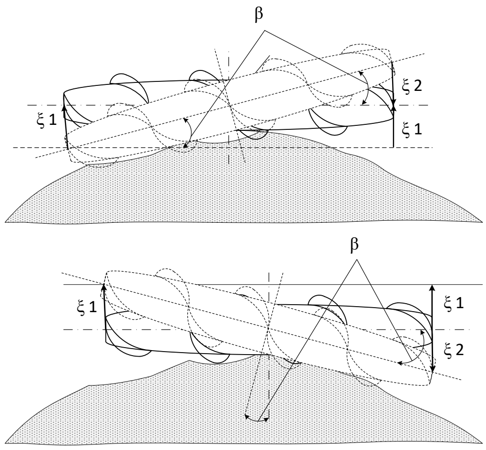


Figure 1: The geometric dependence of the rotor's parameters.

The vertical forces arising from irregularities of the pathway are transmitted to the vehicle's body only through springing elements and dampers, as shown in Fig. 2 (three-mass equivalent system of dynamics of the screw-propelled vehicle).

The coordinates describing the position of the sprung and unsprung masses undervibration conditions are chosen depending on the problem under consideration.Whenstudying the vibrations of the vehicle's body, it is appropriate to choose coordinates $Z_0, \varphi, X_0, \alpha, Y_0, \beta$ i.e., the displacements

[1]https://orcid.org/0000-0002-2397-4604
[2]https://orcid.org/0000-0003-3809-5247

of the center of gravity of the sprung partand the angles of its rotation. It is also necessary to consider:

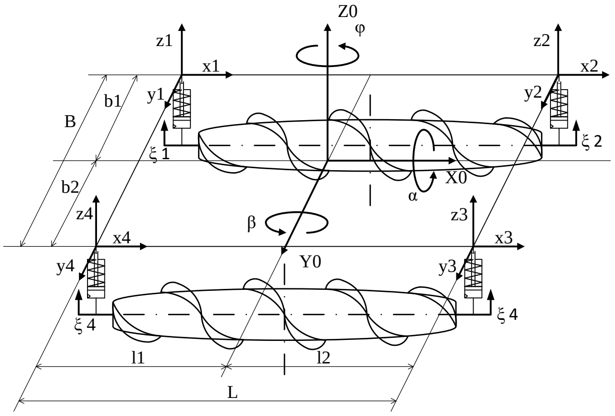


Figure 2: The three-mass vibration system of a screw-propelled vehicle.

- z_1, z_2, z_3, z_4 - the coordinates of displacement of the body's points above the axis of the front or back mountings of the rotor propulsion devices
- x_1, x_2, x_3, x_4 - the coordinates of horizontal lengthwise displacements of the body's points of the front or back mountings of the rotor propulsion devices
- y_1, y_2, y_3, y_4 - the coordinates of horizontal lateral displacements of the body's points of the front or back mountings of the rotor propulsion devices

Investigating the vibration system shown in Fig. 2, we infer the dependencies between the parallel displacement vectors $\vec{z}_1, \vec{z}_2, \vec{z}_3, \vec{z}_4$ and the system's resultant – $\vec{Z}_0$ Fig. 3:

$$Z_0 = \frac{\sum_i l_i z_i}{\sum_i l_i} \tag{1}$$

Using the above-mentioned formula, we obtain the system of dependencies between the geometric parameters of the sprung mass of the vehicle:

$$\left.\begin{aligned} \vec{Z}_0 &= \tfrac{1}{2L}[(\vec{z}_2 l_2 - \vec{z}_1 l_1) + (\vec{z}_3 l_2 - \vec{z}_4 l_1)] \\ \varphi &= \tfrac{1}{B}[(\vec{x}_4 - \vec{x}_1) + (\vec{x}_3 - \vec{x}_2)] + \tfrac{1}{L}[(\vec{y}_1 - \vec{y}_2) + (\vec{y}_4 - \vec{y}_3)] \\ \vec{X}_0 &= \tfrac{1}{B}[(\vec{x}_4 b_2 - \vec{x}_1 b_1) + (\vec{x}_3 b_2 - \vec{x}_2 b_1)] \\ \alpha &= \tfrac{1}{B}[(\vec{z}_1 - \vec{z}_4) + (\vec{z}_2 - \vec{z}_3)] \\ \vec{Y}_0 &= \tfrac{1}{L}[(\vec{y}_1 l_1 - \vec{y}_2 l_2) + (\vec{y}_4 l_1 - \vec{y}_3 l_2)] \\ \beta &= \tfrac{1}{L}[(\vec{z}_2 - \vec{z}_1) + (\vec{z}_3 - \vec{z}_4)] \end{aligned}\right\} \tag{2}$$

The vibrations of the unsprung masses of the vehicle (rotors) are given by the elements of displacements$\vec{\xi}_1, \vec{\xi}_2, \vec{\xi}_3, \vec{\xi}_4$.

The uniqueness of this vibration system isthat the displacements of the end points of the rotors are linearly dependent between themselves. During the collision with an obstacle, not only the front suspension is actuated but also the force is transmitted to the back suspension by the rotor's body, therefore, the quantities $\vec{\xi}_2, \vec{\xi}_3$ influence the quantities of displacements$\vec{\xi}_1, \vec{\xi}_4$ Fig. 2.

The linear dependence of displacements of the end points of the rotors is represented in the system of equations 3.

$$\left.\begin{aligned} \xi_1 &= \sin\beta \cdot L - \xi_2 \\ \xi_4 &= \sin\beta \cdot L - \xi_3 \end{aligned}\right\} \left.\begin{aligned} \vec{\xi}_2 &= \sin\beta \cdot L - \vec{\xi}_1 \\ \vec{\xi}_3 &= \sin\beta \cdot L - \vec{\xi}_4 \end{aligned}\right\} \tag{3}$$

To derive the dynamical equations, one should apply the forcesZ_n, X_n, Y_nacting on the masses of the vehicle (Fig. 2). The force$Z_n$transmitted through the suspension consists of two terms: Z_p - from the springing element andZ_a - from the damper. The forces $Z_n, X_n\ and\ Y_n$ replace the action of the suspension and their quantities are interdependent.

We obtain the system of equations 4 describing the dependencies of dynamic forces.

$$\left.\begin{aligned} Z_{n1} &= 2C_{p1}(z_1 - \xi_1) + 2k_1(\dot{z}_1 - \dot{\xi}_1);\quad Z_{n2} = 2C_{p2}(z_2 - \xi_2) + 2k_2(\dot{z}_2 - \dot{\xi}_2); \\ Z_{n3} &= 2C_{p3}(z_3 - \xi_3) + 2k_1(\dot{z}_3 - \dot{\xi}_3);\quad Z_{n2} = 2C_{p3}(z_3 - \xi_3) + 2k_3(\dot{z}_3 - \dot{\xi}_3); \\ X_{n1} &= Z_{n1}\tan\beta;\ X_{n2} = Z_{n2}\tan\beta;\ Y_{n1} = Z_{n1}\tan\alpha;\ Y_{n2} = Z_{n2}\tan\alpha; \\ X_{n3} &= Z_{n3}\tan\beta;\ X_{n4} = Z_{n4}\tan\beta;\ Y_{n3} = Z_{n3}\tan\alpha;\ Y_{n4} = Z_{n4}\tan\alpha. \end{aligned}\right\} \tag{4}$$

3 DIFFERENTIAL EQUATION OF OSCILLATIONS

Differential equations of vibrations are obtained by using Lagrange's equations.

For sprung and unsprung masses M and $m_{1,2}$ the following systems of equations ofequilibrium are derived.

$$\left.\begin{aligned} &(m\ddot{\xi}_1 - 2C_{p1}[z_1 - \xi_1] - 2k_1[\dot{z}_1 - \dot{\xi}_1]) + \\ &+(m\ddot{\xi}_2 - 2C_{p2}[z_2 - \xi_2] - 2k_2[\dot{z}_2 - \dot{\xi}_2]) = H_z(t); \\ &(m\ddot{\xi}_4 - 2C_{p4}[z_4 - \xi_4] - 2k_4[\dot{z}_4 - \dot{\xi}_4]) + \\ &+(m\ddot{\xi}_3 - 2C_{p3}[z_3 - \xi_3] - 2k_3[\dot{z}_3 - \dot{\xi}_3]) = H_z(t) \end{aligned}\right\} \tag{5}$$

The equations of motion for the coordinate systems (Figs. 1 and 2) are derivedusing the formulas of the systems 3 and 4 and the expressions for$Z_n$which are written in terms of the coordinatesz_1, z_2, z_3, z_4.

After substitution of theseexpressions into the differential equations of equilibrium we obtain the systems of differential equations 5 and 6 which represent the most complete and accuratecalculation of (linear and angular) displacements of points of the sprung and unsprungmasses of the screw-propelled vehicle.

$$\left.\begin{gathered}
M\ddot{Z}_0 + \left(2k_1\left[\dot{z}_1 - \dot{\xi}_1\right] + 2C_{p1}[z_1 - \xi_1]\right) + \\
\left(2k_2\left[\dot{z}_2 - \dot{\xi}_2\right] + 2C_{p2}[z_2 - \xi_2]\right) + \left(2k_3\left[\dot{z}_3 - \dot{\xi}_3\right] + 2C_{p3}[z_3 - \xi_3]\right) + \\
+\left(2k_4\left[\dot{z}_4 - \dot{\xi}_4\right] + 2C_{p4}[z_4 - \xi_4]\right) = H_z(t); \\
M\ddot{X}_0 + \tan\beta\left(2k_1\left[\dot{z}_1 - \dot{\xi}_1\right] + 2C_{p1}[z_1 - \xi_1]\right) + \\
+\tan\beta\left(2k_2\left[\dot{z}_2 - \dot{\xi}_2\right] + 2C_{p2}[z_2 - \xi_2]\right) + \\
+\tan\beta\left(2k_3\left[\dot{z}_3 - \dot{\xi}_3\right] + 2C_{p3}[z_3 - \xi_3]\right) + \\
+\tan\beta\left(2k_4\left[\dot{z}_4 - \dot{\xi}_4\right] + 2C_{p4}[z_4 - \xi_4]\right) = H_x(t); \\
M\ddot{Y}_0 + \tan\alpha\left(2k_1\left[\dot{z}_1 - \dot{\xi}_1\right] + 2C_{p1}[z_1 - \xi_1]\right) + \\
+\tan\alpha\left(2k_2\left[\dot{z}_2 - \dot{\xi}_2\right] + 2C_{p2}[z_2 - \xi_2]\right) + \\
+\tan\alpha\left(2k_3\left[\dot{z}_3 - \dot{\xi}_3\right] + 2C_{p3}[z_3 - \xi_3]\right) + \\
+\tan\alpha\left(2k_4\left[\dot{z}_4 - \dot{\xi}_4\right] + 2C_{p4}[z_4 - \xi_4]\right) = H_y(t); \\
M\rho_z^2\ddot{\varphi} + \begin{pmatrix} 2C_{p4}b_2[z_4 - \xi_4] + 2k_4b_2\left[\dot{z}_4 - \dot{\xi}_4\right] + \\ +2C_{p3}b_2[z_3 - \xi_3] + 2k_3b_2\left[\dot{z}_3 - \dot{\xi}_3\right] - \\ -2C_{p1}b_1[z_1 - \xi_1] - 2k_1b_1\left[\dot{z}_1 - \dot{\xi}_1\right] - \\ -2C_{p2}b_1[z_2 - \xi_2] - 2k_2b_1\left[\dot{z}_2 - \dot{\xi}_2\right] \end{pmatrix}\tan\beta + \\
+\begin{pmatrix} 2C_{p1}l_1[z_1 - \xi_1] + 2k_1l_1\left[\dot{z}_1 - \dot{\xi}_1\right] + \\ +2C_{p4}l_1[z_4 - \xi_4] + 2k_4l_1\left[\dot{z}_4 - \dot{\xi}_4\right] - \\ -2C_{p2}l_2[z_2 - \xi_2] - 2k_2l_2\left[\dot{z}_2 - \dot{\xi}_2\right] - \\ -2C_{p3}l_2[z_3 - \xi_3] - 2k_3l_2\left[\dot{z}_3 - \dot{\xi}_3\right] \end{pmatrix}\tan\alpha = M_\varphi(t) \\
M\rho_z^2\ddot{\alpha} + 2C_{p1}b_1[z_1 - \xi_1] + 2k_1b_1\left[\dot{z}_1 - \dot{\xi}_1\right] + 2C_{p2}b_1[z_2 - \xi_2] + \\
+2k_2b_1\left[\dot{z}_2 - \dot{\xi}_2\right] - 2C_{p4}b_2[z_4 - \xi_4] - 2k_4b_2\left[\dot{z}_4 - \dot{\xi}_4\right] - \\
-2C_{p3}b_2[z_3 - \xi_3] - 2k_3b_2\left[\dot{z}_3 - \dot{\xi}_3\right] = M_\alpha(t) \\
M\rho_z^2\ddot{\beta} + 2C_{p1}l_1[z_1 - \xi_1] + 2k_1l_1\left[\dot{z}_1 - \dot{\xi}_1\right] + 2C_{p4}l_1[z_4 - \xi_4] + \\
+2k_4l_1\left[\dot{z}_4 - \dot{\xi}_4\right] - 2C_{p2}l_2[z_2 - \xi_2] - 2k_2l_2\left[\dot{z}_2 - \dot{\xi}_2\right] - \\
-2C_{p3}l_2[z_3 - \xi_3] - 2k_3l_2\left[\dot{z}_3 - \dot{\xi}_3\right] = M_\beta(t)
\end{gathered}\right\} \quad (6)$$

The system of equations 6 shows the calculation of forces and describes thedynamics of the actuated mechanisms of visco-elastic suspensions. The forces horizontal to$X$and$Y$, are then reduced to the vertical forces via trigonometryequations Z.

The solution to the systems of equations 5 and 6 by numerical methods becomes possible if we know the values of the vibrations, i.e., if the boundary values of the quantities$z_1, z_2, z_3, z_4, Z_0, X_0, Y_0, \varphi$, α, β, $\xi_1, \xi_2, \xi_3, \xi_4$.

Have been obtainedexperimentally, the vehicle's parameters ($L$and$B$), have been specified in advance, and one should determine the drag coefficients of the dampers k_1, k_2, k_3, k_4 andthe spring rate for the elements$C_{p1}, C_{p2}, C_{p3}, C_{p4}$. Having an exact solution to the system of equations 6, we can find numericallyC_p.

Assuming that the screw-propelled vehicle is geometrically symmetric and thecharacteristics of the visco-elastic suspension are completely of the same type, performing mathematical operations permits us to reduce the system of equations 5and 6 to the form of the systems of differential equations 7 and 8.

Thus, the generalized systems of differential equationstake the form for the unsprung masses:

$$\left.\begin{gathered}
m(2\ddot{\xi}_1 + \sin\beta/L) + 2k(2\dot{\xi}_1 - (\dot{z}_1 + \dot{z}_2) + \sin\beta/L) + \\
+2C_p(2\xi_1 - (z_1 + z_2) + \sin\beta/L) = H_z(t); \\
m(2\ddot{\xi}_4 + \sin\beta/L) + 2k(2\dot{\xi}_4 - (\dot{z}_4 + \dot{z}_3) + \sin\beta/L) + \\
+2C_p(\xi_4 - (z_4 + z_3) + \sin\beta/L) = H_z(t).
\end{gathered}\right\} \quad (7)$$

And for the sprung body of the vehicle:

$$\left.\begin{array}{c} M\ddot{Z}_0 + 2k(\dot{z}_1 + \dot{z}_2 + \dot{z}_3 + \dot{z}_4) - 2k(\dot{\xi}_1 + \dot{\xi}_2 + \dot{\xi}_3 + \dot{\xi}_4) + \\ +2C_p(z_1 + z_2 + z_3 + z_4) - 2C_p(\xi_1 + \xi_2 + \xi_3 + \xi_4) = H_z(t); \\ M\rho_z^2\ddot{\alpha} + 2C_p b(z_1 + z_2 - z_4 - z_3) - 2C_p b(\xi_1 + \xi_2 - \xi_4 - \xi_3) + \\ +2kb(\dot{z}_1 + \dot{z}_2 - \dot{z}_4 - \dot{z}_3) - 2kb(\dot{\xi}_1 + \dot{\xi}_2 - \dot{\xi}_4 - \dot{\xi}_3) = M_\alpha(t) \\ M\rho_z^2\ddot{\beta} + 2C_p l(z_1 + z_4 - z_2 - z_3) - 2C_p l(\xi_1 + \xi_4 - \xi_2 - \xi_3) + \\ +2kl(\dot{z}_1 + \dot{z}_4 - \dot{z}_2 - \dot{z}_3) - 2kl(\dot{\xi}_1 + \dot{\xi}_4 - \dot{\xi}_2 - \dot{\xi}_3) = M_\beta(t) \end{array}\right\} \quad (8)$$

Evaluation of solutions to the systems of differential equations was performedusing the software for modern mathematical calculations MathCAD in solving theCauchy problem. The result of the solution was the amplitude-frequency characteristicof the visco-elastic suspension.

The amplitude-frequency characteristics are shown in Fig. 3 (amplitude-frequencycharacteristics at point 2 of attachment of the visco-elastic suspension and the rotorpropulsion devices for various values of the spring rates and drag coefficients ofdampers).

The analysis and construction of many amplitude-frequency characteristics willallow theorists and practitioners to choose the best values for the spring rates anddrag coefficients of dampers. Depending on the requirements, one can manipulate theparameters of the visco-elastic suspension and specify the comfort characteristics ofthe driver's operation.

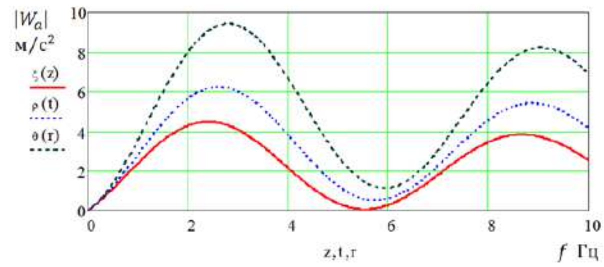


Figure 3: The amplitude-frequency characteristic for the visco-elastic suspension of the screw–propelled vehicle.

4 MACHINE DESIGN SOLUTIONS

To ensure the best possible contact between the propulsion devices and thebearing surface, a new design of the screw-propelled vehicle (Fig. 4) is developedwithin the framework of this study. This design comprises a body (1), a rotorpropulsion device (5), a visco-elastic suspension (12) of rotors with springs anddampers, wherein the dampers (13) and springs (14) of the visco-elastic suspensionare aligned and rigidly attached to the vehicle's frame and coupling elements (15) installed on a fixed spindle (6) bearing electric motors (7) and harmonic driveunits (8), the latter are rigidly connected with the rotor (5) through the bushes (9) towhich trapezoidal roddings (11, 16) hinged to the frame (10) elements are attached.

This vehicle has not two but four rotor propulsion devices, which, by virtue ofthe visco-elastic suspension, provide the greatest tractive force due to an increasedcontact point between the rotors and the bearing surface.

For the purpose of increasing the vehicle's vibroprotection and the comfort ofthe driver, quite a number of design concepts for hydraulic vibratory bearings (Gordeev, Kuklina, 2023; Kuklina, 2022) have been proposed. Evaluation of the quantities of vibration displacements of rotorpropulsion devices in the bearings by the method of measurement without contactbecomes possible through the application of an ultrasonic phase vibrationtransducer (Gordeev, Kuklina, 2020). The design concept was awarded the bronze medal in Seoul.

Thus, significant practical and theoretical experience has been gained ininvestigating and adjusting the parameters of the visco-elastic suspension of vehicleshaving a linear contact between the propulsion devices and the bearing surface.

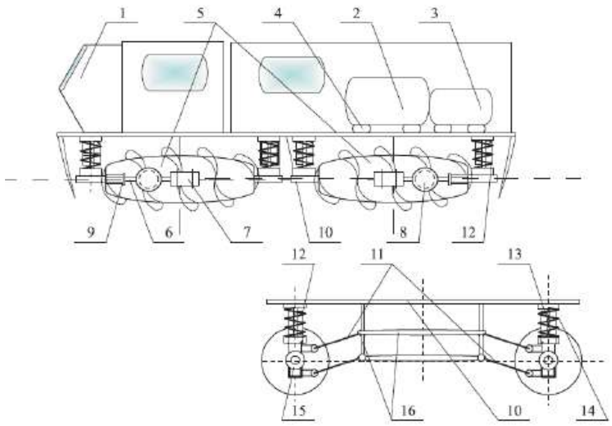


Figure 4: The design of the screw-propelled vehicle with four propulsion devices.

ACKNOWLEDGEMENTS

This work was carried out in Nizhny Novgorod State Technical University. RE Alexeyev, with financial support from the government in the face of the Ministry of Education of Russia (a unique identifier of the project: RFMEFI57714X0105).

REFERENCES

Gordeev, B.A., Kuklina, I.G., 2023. Adaptive hydraulic vibration support. Utility model patent №127847 RU MKI F16 F9/53 /

Kuklina, I.G., 2022. Hydraulic vibration support. Utility model patent №132848 RU. MKI F16 F13/10, F16 F5/00, F16 F9/10.

Kuklina, I. G., 2011. Estimation of oscillations inrotary screw machine taking into account the parameters of suspension and the line contact of its thrusters with the ground. Construction and Road Building Machinery, no. 7, pp. 45–52.

Kuklina, I.G., 2013. Kelvin–Voigt elements in studying dynamics of special machines. NauchnoeObozrenie, no. 4, pp. 59–67.

Kulyashov, A.P., Kuklina, I.G., 2019. Cross-country vehicle. Certificate of utility model №15185 RU. MKI B63 D57/00, B60 F3/00.

Kuklina, I.G., 2021. Cross-country vehicle. Utility model patent №134896 RU. MKI B62 D57/036, B60 F3. State Technical University of Nizhny Novgorod.

Gordeev, A. B., Kuklina, I.G., 2020. Ultrasonic phase vibration transducer. Patent №2472109 RU. MKI G01 B17/00 /.

Land Management of Preferential Territories

Karabanova Natalia Yuryevna[a], Akimova Maria Sergeevna[b]
Federal State Budgetary Educational Institution of Higher Education Penza State University of Architecture and Construction, Penza, Russia
terramarket58@yandex.ru, tereshkina_mariy@mail.ru

Keywords: land management, land management objects, land management activities, land management documentation, land resources, organizational and legal regulation, strategic and spatial planning, investment policy, preferential territories, special economic zones, territories of advanced development, regional investment projects, municipal investment sites.

Abstract: The involvement of a significant area of land (about 30% of the country's territory) in investment activities of residents of preferential territories requires a revision of the state's approach to land management. The purpose of the study is to try to substantiate the need for land management of preferential territories as a state instrument for the protection of land resources. Research methods: analysis, synthesis of scientific literature, content analysis of legal norms, statistical analysis of open data, analogy method. Results of the study: the regression of modern land management is shown, the tendency of creating preferential territories is shown, recommendations are given for carrying out land management activities with the development of land management documentation for different preferential territories, directions for improving federal legislation on land management, preferential territories and strategic planning are proposed. The study allows to define a new vector for the development of land management for both Russian legislators and theoretical scientists and industrial land managers.

1 INTRODUCTION

In Russia, land management, especially for agricultural purposes, has long been of great strategic importance for the implementation of public policy, where the main tool was land management, ensuring the rational use of land, environmental protection and landscape improvement.

With the transition to market conditions, the importance of land management has been practically reduced to the level of carrying out a small number of activities, and has largely been replaced by territorial planning (Volkov, 2020).

Thus, the law on land management does not give a generalized definition of land management, but excessively describes on-farm land management (Articles 1 and 18), which emphasizes its importance for the organization of traditional land use by the indigenous small population of the North, Siberia and the Far East (Borisov, Poiseev, 2020), but is not disclosed further in the text. At the same time, territorial land management has been completely abolished since 2009. It turns out that the law only interprets on-farm land management, which is not mandatory for implementation.

In practice, land management activities are currently carried out when describing the boundaries of subjects of the Russian Federation and municipalities, which does not relate to on-farm land management, but to territorial land management. The Federal Service for State Registration, Cadastre and Cartography (Rosreestr), which is an institute of organizational and legal regulation of land management, maintains a fund of data obtained as a result of land management, enters information into the register of boundaries, and carries out an examination of land management documentation. An analysis of the activities of Rosreestr, which implements, among other things, a state policy to increase the investment attractiveness of Russia, shows that land management activities

[a] https://orcid.org/0000-0001-9892-9421
[b] https://orcid.org/0000-0002-3899-5870

are funded on a residual basis, the number of land management objects is decreasing, land management documentation is rarely updated (Ulitskaya, Akimova, Ulitskaya, 2020).

That is, there is a chronic problem of institutional regulation of land management (Burov, 2023), which requires a radical revision of the issues of regulatory support with the introduction of a modern organizational mechanism for conducting land management activities (Bryzhko, Bryzhko, 2020).

At the same time, the transition to a market economy has created the need to form a significant number of new territories with preferential status in order to increase investment attractiveness and sustainable development of the Russian economy (Ananicheva, Kievskaya, 2019). The basis of all such territories, naturally, are land plots of various intended purposes and permitted types of use. However, the issues of ensuring the preservation of land in the implementation of investment projects through land management activities are not considered in the legislation. In addition, many other problems of the functioning of preferential territories have not been sufficiently resolved (Pronyaeva, Kruzhkova, 2024).

Therefore, there is an objective need to orient land management towards preferential territories, clarify activities and types of land management documentation regarding different types of preferential territories.

2 RESEARCH METHODOLOGY

The purpose of the study is to substantiate the need to carry out land management activities in relation to preferential territories for the preservation of land resources.

Research methods:

Stage 1 – identification of problems of legislative regulation of land management objects. The content analysis of legal regulation and activities of Rosreestr in relation to land management objects allows to objectively present the problems of modern land management.

Stage 2 – determining the prospects of land management. Statistical analysis of preferential territories, showing the dynamics of their growth and species diversity. Analysis and synthesis of the opinions of researchers on the issue of land management of preferential territories, which contributes to the scientific reasoning of the need for land management in the formation of land plots for investment projects, the development of land management documentation for the protection of land resources.

Stage 3 – development of recommendations justifying the role of land management in the operation of preferential territories. The analogy method makes it possible to implement land management norms into the mechanism for managing preferential territories.

Theoretical postulates of the study:

Land management is the main state instrument for the protection, conservation and improvement of land resources (Enemark, 2005), consisting of a single accounting and registration system, providing for the needs of society for information on the quantitative and qualitative characteristics of land (Williamson, 1986).

The growth of the species diversity of preferential territories and the spaces they occupy (Neizhkasha, 2023) requires the state not only to economically stimulate the activities of residents, but also to take measures to protect the land resources involved in investment processes (Vilenskij, 2022), especially agricultural land (ZHukovskij, Orlov, 2023), and land management activities here serve as a tool for forming and preserving the sustainability of the eco-socio-natural space (Tyurina, Ignatova, 2021).

3 RESULTS OF THE STUDY

Within the meaning of legal norms, land management objects are those territories in respect of which land management activities are carried out. However, the content analysis of the versions of the law on land management shows the systematic legislative destruction of land management in Russia (Table 1). Thus, the exclusion of land plots from the composition of land management objects makes it pointless to conduct on-farm land management. And the opposite situation: land management is carried out according to the description of the boundaries of the subjects of the Russian Federation and municipalities, but the norms on territorial land management are excluded from the law.

Table 1: Legislative reduction of land management objects.

Date of revision / Land management objects	18.06.2001	13.05.2008	22.10.2014	13.07.2015	31.12.2017
territories of the subjects of the Russian Federation and their parts	+	+	+	+	+
territories of municipalities and their parts	+	+	+	+	+
territories of administrative-territorial entities and their parts	+	-	-	-	-
territories of settlements and their parts	-	+	+	+	-
territorial zones and their parts	+	+	+	+	-
zones with special conditions for the use of territories and their parts	-	+	-	-	-
zones with special conditions for the use of territories and their parts, with the exception of zones for the protection of cultural heritage sites (historical and cultural monuments) of the peoples of the Russian Federation	-	-	+	-	-
land plots and their parts	+	-	-	-	-
Total land management objects	**5**	**5**	**5**	**4**	**2**

At the same time, there is a state "fever" in the country for the introduction of all lands into economic and business circulation, going along with the increase in negative factors of land use and soil deterioration.

Thus, the study of the norms of the current land management legislation and statistical indicators of Rosreestr from 2005 to 2023 allows us to identify the following problems:

– land management legislation does not stand up to any criticism, requires urgent, radical revision and the adoption of a new, adequate law on land management;

– the land management activities carried out run counter to the norms of the current law on land management, which makes them illegitimate and reduces the effectiveness of the entire land management to zero;

– the lack of normal institutional regulation of land management leads to the non-binding nature of development and compliance with land management documentation, disregard for the norms of rational and efficient use of land, their conservation, which ultimately leads to the deterioration of the environment and landscapes.

Since the 2000s, Russia has begun to create preferential territories, implementing an investment-oriented land use policy, which, among other things, stimulates entrepreneurial activity in involving land in circulation. Figure 1 shows the main types and levels of preferential territories.

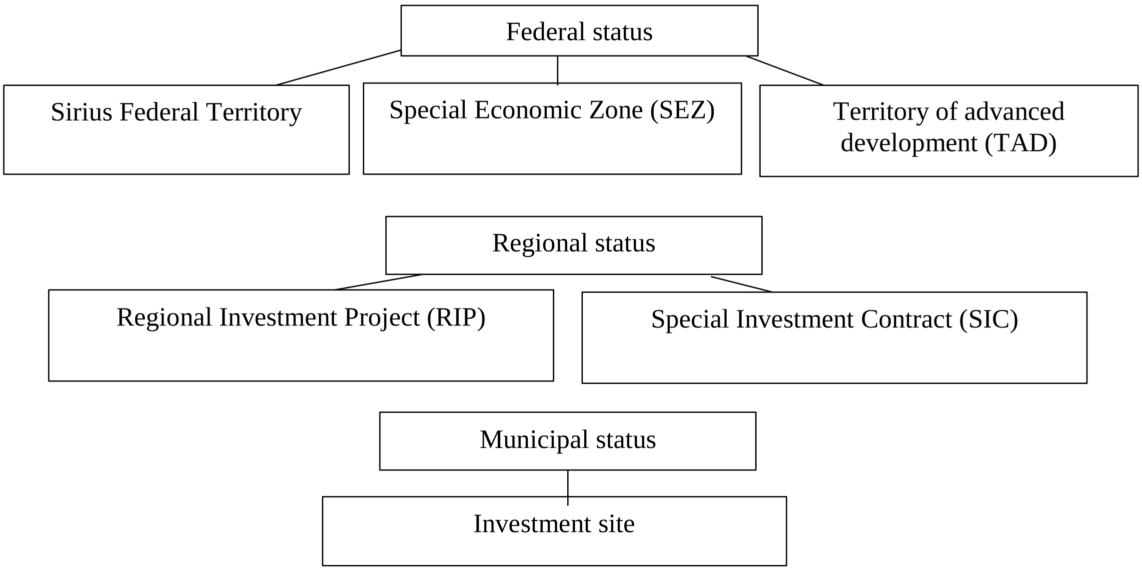


Figure 1: Preferential territories.

The first type of preferential territories at the federal level in Russia was the formation of special economic zones (SEZ) with a life cycle of 49 years, where a preferential regime for entrepreneurial activity and a free customs zone procedure apply. The creation of 4 types of SEZ is legally established:

– industrial and production type (IPT) (by 2023, 31 IPTs with 367 resident companies have been created);

– technology and innovation type (TIT) (as of 2023, 7 TITs with 516 resident companies are operating);

– tourism and recreation type (TRT) (10 TRT with 111 resident companies);

– Harbour (2 Harbour-type Special Economic Zones with 51 resident companies).

In 2020, the largest economic zone was created – the Arctic Zone of the Russian Federation (AZRF), which occupies about 22% of the country's territory. Harsh natural conditions contributed to the fact that the indigenous population here traditionally engaged in reindeer husbandry, hunting, fishing and other crafts. The land resources of this zone are particularly susceptible to negative factors (exploration of deposits and extraction of natural resources; climate change causing permafrost melting, etc.), which requires compliance with environmental and land management standards of land use. However, the legislation on the AZRF does not provide for land management measures to protect lands.

The next type of preferential territories are territories of advanced development (TAD) or priority social and economic development areas (PSEDA), which are industrial zones formed on land plots with appropriate infrastructure, where tax incentives and other types of state support are available to residents. At the same time, it is no secret that during construction and industrial production, the soil cover is significantly disturbed and the condition of landscapes deteriorates. As of 2023, 92 TADs have been created, where more than 1,200 residents are registered.

The authorities attach particular importance to the creation of TADs in the Far East and in single-industry cities, seeing them as a mechanism for economic diversification. Even a separate ministry has been created to manage the economy of the Far East. Various types of activities are permitted in the TADs. For example, in the Far East TAD and in the free port of Vladivostok (FPV), residents are implementing 82 projects in the field of agriculture. But the legislative acts do not mention the development of proper land management documentation.

The newest type of preferential territory is the Sirius Federal Territory, created to preserve the Olympic heritage, as a center of science and innovation, surrounded by unique landscapes. To ensure its functioning, in addition to preferential regimes, documentation on territorial planning and urban zoning has been developed. But not a single act mentions the need for land management documentation in order to preserve the natural heritage of this territory.

Preferential territories at the federal level form the spatial framework of investment-oriented land use (Domnina, 2023), occupying about 30% of the country's territory (Maevskaya, 2023). However, from the perspective of strategic planning, they are not fully involved in this system (Odintsova, 2023), which does not allow to properly rely on them when developing strategies, schemes, forecasts, plans, programs (Sorokina, 2023). The lack of appreciation of preferential territories as growth points for agglomerations does not contribute to the effective planning of their development. In addition, the analysis shows that land management is not applied to federal preferential territories. Therefore, the following innovations are proposed:

– in Federal Law No. 172-FZ dated 28.06.2014 "On Strategic Planning in the Russian Federation": to identify the connection between the creation of preferential territories and the target indicators for the development of the country and its regions, the system of monitoring and evaluation of the effectiveness; to introduce provisions on the composition of strategic documentation in relation to federal preferential territories, including land management documentation in the list;

– to take into account federal preferential territories as growth points and constituent elements of the supporting framework for the development of agglomerations when developing the Strategy for the Spatial Development of the Russian Federation for the new planning period;

– to include a section on the provision of land management documentation and measures for the protection, improvement and restoration of lands in federal laws on preferential territories.

The authorities of the subjects of the Russian Federation have the right to make decisions on the creation of regional territories with various preferential regimes (special investment contracts, regional investment projects). However, an analysis of legislation and research in the field of management of regional preferential territories has shown that such territories are even less integrated into the system of strategic and spatial planning (YUshkova, 2021). Land management activities and documentation related to them are not provided.

It should be noted that initially the formation of investment sites was a priority tool for attracting investors to regions and municipalities. Currently, investment sites remain primarily under the control of municipal authorities. According to the level of infrastructure development, investment sites are divided into white (without the possibility of connecting to communications), green (without communications, but with the possibility of connecting), brown (with infrastructure), black (with operating production). There is the same problem of non-settlement of land management issues for the operation of investment sites, lack of legislative regulation of preferential territories in strategic and spatial planning documents at the municipal level (Harchenko, 2020).

Given the unfavorable state of modern land management and the insufficient development of legislative support for preferential territories of all levels in Russia, scientists are increasingly and more deeply exploring ways to include land management, as one of the mechanisms, in the management of preferential territories with their registration in the state cadastral register (Lipski, 2015). Land management will then reveal its untapped potential to a greater extent, and this will contribute to more competent strategic and spatial planning in the country (Papaskiri, 2023).

Relying on the analysis of legislation and scientific research, we propose to organize the implementation of relevant land management activities with the development of land management documentation for various types of preferential territories in a mandatory manner (Table 2).

Table 2: Land management of preferential territories.

No.	**Type of preferential territory**	**Land management activities**	**Land management documentation**
1.	AZRF	- study of the state of lands; - planning and organization of rational use of lands and their protection	- projects of on-farm land management of lands used by communities and individuals of indigenous peoples of the North, Siberia and the Far East of the Russian Federation to ensure their traditional way of life; - materials of soil, geobotanical and other surveys and investigations, land quality assessment, land inventory;

			- thematic maps and atlases of the condition and use of lands
2.	TAD, PSEDA; SEZ; federal territories	- land inventory; - study of the state of lands; - description of the location and establishment of boundaries on the ground	- land management scheme; - map (plan) of the land management object
3.	RIP, SIC	- works on land restoration, reclamation of disturbed lands; - work on the improvement of agricultural land, the development of new lands	- reclamation project; - scheme of land use and protection
4.	Municipal investment sites	- works on land restoration, reclamation of disturbed lands; - work on the improvement of agricultural land	- reclamation project; - scheme of land use and protection

As part of territorial land management, it is recommended to describe the boundaries of preferential territories with the preparation of a map (plan) of the land management object for registration with the state cadastral register. To ensure the protection and improvement of lands, it is recommended to carry out on-farm land management activities; to restore disturbed lands, reclamation is recommended. An important land management activity is the study of the state of lands with their description in thematic maps and atlases.

Land management, as an activity to ensure land protection, will force residents to comply with land management requirements during construction, industrial and agro-industrial production.

4 RESULTS AND DISCUSSION

Land management of preferential territories is a scientifically based state instrument for ensuring competent land use, consisting of a system of territorial land management activities for describing and establishing on the ground the boundaries of preferential territories (with the preparation of a map (plan) of the land management object) for their subsequent registration with the state cadastral register and on-farm land management for studying the condition of lands, planning and organizing the rational and efficient use of lands by residents of preferential territories (with the preparation of an on-farm land management project, a land management scheme, a land use and protection scheme, a reclamation project, etc.).

Land management activities and preparation of land management documentation should be carried out by the authorities jointly with resident investors interested in the development of the territory. Thus, public authorities should initiate land management work to describe the boundaries of preferential territories with cadastral registration. Along with a package of other documents, investors should prepare land management documents as a guarantee of security measures for the preservation, improvement and restoration of land.

The implementation of land management of preferential territories will be possible only with the adoption of a new law on land management or a fundamental revision of the current one, and will also require changes to the legislation on strategic planning and preferential territories.

5 CONCLUSIONS

Modern land management has practically dissolved into territorial planning and cadastral works, which does not at all ensure the protection of land resources from illiterate land use, thereby exacerbating the growth of unfavorable natural and anthropogenic factors in the environment.

A new active form of land use is the activity of residents in a preferential territory. As a rule, land plots that have been unused for a long time are used for investment needs. However, residents aim to extract benefits from investment activities without caring about the preservation and improvement of land characteristics. Therefore, the primary task of the state here should be the creation of land management security obligations that residents will be obliged to comply with.

The inclusion of preferential territories in land management objects will give a new round to the development of both land management and strategic management aimed at preserving and improving the environment.

REFERENCES

Volkov, S.N., 2020. Razvitie zemleustrojstva v Rossijskoj Federacii. Zemleustrojstvo, kadastr i monitoring zemel'. 7 (186). S. 1.

Federal'nyj zakon ot 18.06.2001 N 78-FZ (red. ot 30.12.2021) "O zemleustrojstve". – URL: https://www.consultant.ru/document/cons_doc_LAW_32132/?ysclid=lst7xdakue520707489 (data obrashcheniya: 19.02.2024).

Borisov, E.A., Poiseev, I.I., 2020. Razvitie zemle- i prirodopol'zovaniya severnyh territorij posredstvom mekhanizma zemleustrojstva. V sbornike: Zemleustrojstvo, kadastr nedvizhimosti i monitoring zemel'nyh resursov. Materialy mezhdunarodnoj nauchno-prakticheskoj konferencii. Ulan-Ude, S. 110-113.

Gosudarstvennyj (nacional'nyj) doklad o sostoyanii i ispol'zovanii zemel' v Rossijskoj Federacii (po godam): oficial'nyj sajt Rosreestra. – URL: https://rosreestr.gov.ru/activity/gosudarstvennoe-upravlenie-v-sfere-ispolzovaniya-i-okhrany-zemel/gosudarstvennyy-natsionalnyy-doklad-o-sostoyanii-i-ispolzovanii-zemel-rossiyskoy-federatsii/ (data obrashcheniya: 18.02.2024).

Ulitskaya, N. Yu., Akimova, M. S., Ulitskaya, M. V., 2020. Efficiency of Rosreestr as a factor in increasing Russia's investment attractiveness./ Revista Inclusiones. 7. Especial. - P. 560-572.

Burov, M.P. 2023. Sovershenstvovanie gosudarstvennogo regulirovaniya provedeniya zemleustrojstva v Rossijskoj Federacii: metodologicheskie aspekty. Ekonomicheskie sistemy. Tom 16, 3 (62). S. 12–26.

Bryzhko, V.G., Bryzhko, I.V., 2020. Razvitie normativnogo obespecheniya sovremennogo zemleustrojstva. Aktual'nye problemy ekonomiki, sociologii i prava. 3. S. 32-35.

Ananicheva, E.P., Kievskaya, E.S., 2019. Territoriya operezhayushchego razvitiya kak faktor investicionnoj privlekatel'nosti i uskorennogo razvitiya ekonomiki dlya uluchsheniya zhizni naseleniya. Mezhdunarodnyj sel'skohozyajstvennyj zhurnal. 4. S. 6-8.

Pronyaeva, L.I., Kruzhkova, I.I., 2024. Tendencii i problemy razvitiya infrastruktury osobyh preferencial'nyh territorij. Regional'naya ekonomika: teoriya i praktika. T. 22. 1 (520). S. 107-133.

Enemark, S., 2005. Understanding the land management paradigm. Fig com 7 symposium on innovative technologies for Landadministration 19 – 25 June 2005, Madison, Wisconsin, USA. URL: https://www.researchgate.net/publication/228342504_Understanding_the_land_management_paradigm (data obrashcheniya: 15.03.2024).

Williamson, I. P., 1986. Cadastral and Land Information Systems in Developing Countries. The Australian Surveyor, Vol. 33 No. 1.

Neizhkasha, I.S., 2023. Territorii s osobym publichno-pravovym statusom v Rossijskoj Federacii: evolyuciya vidovogo mnogoobraziya i kriterii klassifikacii. YUridicheskij vestnik Kubanskogo gosudarstvennogo universiteta. 4. S. 60-71.

Vilenskij, A.V., 2022. Preferencial'nye ekonomicheskie zony v rossijskoj ekonomike. Vestnik Rossijskoj akademii estestvennyh nauk. 4. S. 110-114.

ZHukovskij, A.D., Orlov, S.L., 2023. Usloviya i principy realizacii potenciala preferencial'nyh zon kak instrumenta razvitiya neurbanizirovannyh territorij. Modeli, sistemy, seti v ekonomike, tekhnike, prirode i obshchestve. 4. S. 32–55.

Tyurina, T., Ignatova, O., 2021. Formation of the habitat as a complex eco-social-natural space of an ecologically oriented person. E3S Web of Conferences. 14th International Scientific and Practical Conference on State and Prospects for the Development of Agribusiness, INTERAGROMASH 2021. Rostov-on-Don. S. 10009.

Osobye ekonomicheskie zony: oficial'nyj sajt Minekonomrazvitiya Rossii. – URL: https://www.economy.gov.ru/material/directions/regionalnoe_razvitie/instrumenty_razvitiya_territoriy/osobye_ekonomicheskie_zony (data obrashcheniya: 18.02.2024).

Territoriya operezhayushchego razvitiya: oficial'nyj sajt Minekonomrazvitiya Rossii. – URL: https://www.economy.gov.ru/material/directions/regionalnoe_razvitie/instrumenty_razvitiya_territoriy/tor/ (data obrashcheniya: 18.02.2024).

Domnina, I.N., 2023. «Vklyuchennost'» preferencial'nyh zon v sistemu strategirovaniya prostranstvennogo razvitiya: problemy i ogranicheniya. Vestnik Instituta ekonomiki Rossijskoj akademii nauk. 4. C. 25–44.

Maevskaya, L.I., 2023. Preferencial'nye ekonomicheskie zony: ih rol' v prostranstvennom razvitii Rossii. Ekonomika: vchera, segodnya, zavtra. T. 13. 4A. S. 348-360.

Odincova, A.V., 2023. Preferencial'nye territorii v prostranstvennom razvitii Rossijskoj Federacii. Federalizm. T. 28. 2 (110). S. 27-46.

Sorokina, N.YU., 2023. Strategii razvitiya preferencial'nyh territorij v sisteme dokumentov strategicheskogo planirovaniya Rossii. Nauchnye issledovaniya i razrabotki. Ekonomika. T. 11. 5. S. 46-50.

YUshkova, N.G., 2021. Regional'nye sistemy rasseleniya i territorii s preferencial'nymi rezhimami: principy vzaimodejstviya i razvitiya. Stroitel'stvo i rekonstrukciya. 4 (96). S. 91-106.

Harchenko, K.V., 2020. Investicionnye ploshchadki: prostranstvennyj faktor investicionnoj deyatel'nosti. Upravlenie gorodom: teoriya i praktika. 2 (36). S. 15-25.

Lipski, S.A., 2015. Osobye ekonomicheskie zony kak ob"ekt kadastrovogo ucheta i zemleustrojstva. Izvestiya vysshih uchebnyh zavedenij. Geodeziya i aerofotos"emka. 1. S. 104-107.

Papaskiri, T.V., 2023. Realizaciya potenciala zemleustrojstva v osushchestvlenii prostranstvennogo razvitiya Rossijskoj Federacii. V sbornike: Prostranstvennoe razvitie gorodskih i sel'skih territorij. Sbornik materialov mezhdunarodnoj nauchno-prakticheskoj konferencii, K 245-letiyu Gosudarstvennogo universiteta po zemleustrojstvu. Moskva. S. 8-16.

Use Of Digitalization Tools In Questions Operational Management Of The Company Taken Into Account Of Step-By-Step Implementation Of The Technological Process

Lapshina M.L.[1] [1], Lukina O.O.[2] [2], Lapshin D.D.[3] [3]

[1]*Doctor of Technical Sciences, Professor, Voronezh State Forestry Engineering University named after G.F. Morozov, Voronezh*

[2]*Candidate of Economic Sciences, Associate Professor, Voronezh State University of Engineering Technologies, Voronezh*

[3]*Candidate of Technical Sciences, Associate Professor, Director of the municipal budgetary educational institution "Novousmansky Educational Center", Novaya Usman village, Voronezh region*

Keywords: Digital analogue, algorithms, model, formalization, production.

Abstract: In connection with various crisis situations in the activities of enterprises, various types of problems arise that have to be solved both strategically and operationally. Methodological problems lie in choosing a set of effective methods and tools that allow, based on digitalization tools, to provide solutions to specific management issues. This article discusses the issues of modeling, planning and creating a digital system of planned calculations at different levels of economic management of a company using simulation analogs that take into account such model parameters as the technological sequence used in the production of a specific type of product, quantitative parameters, as well as the resulting indicators for specific types of work and throughout the entire production time interval. As a result, a digital analog and algorithms were built that made it possible to determine the optimal performance of product production. In the constructed model, a significant part of the analysis of results and decision-making is a function of a team of specialists or, according to common terminology, an expert, and the developed digital model is aimed at strengthening the economic justification of planned indicators and ensuring the storage and automated search of the company's regulatory framework and its periodic updating.

1 INTRODUCTION

Management methodology in modern conditions should be built on the following basic elements: approaches, guidelines, priorities; resources, means, restrictions; criteria, models, adjustments. In Western literature, the vast majority of theoretical and applied scientific articles in the field of economic modeling contain as a central part one or another mathematical model (Ashmanov, 1984), developed to test or illustrate hypotheses and identify effects. According to a number of economists, the likelihood of recognition of almost any new economic theory or concept almost to a decisive extent depends on the extent to which this concept allows for mathematical formalization and its further digitalization, as well as the adequacy of the apparatus used and the effectiveness of the mathematical models obtained during the study results.

2 ANALYSIS OF EXISTING TOOLS FOR PROSPECTIVE ENTERPRISE MANAGEMENT

Companies engaged in the production of the same type of products, in the course of choosing a strategy for analyzing their own

[1] https://orcid.org/0000-0002-5057-1069
[2] https://orcid.org/0000-0003-2658-1512
[3] https://orcid.org/0000-0001-5412-3434

macroenvironment, it is better to use an algorithm implemented through the following steps (Ashmanov, 1984): establishing the main financial features of the industry environment. The sectors of the economy differ significantly among themselves, so at the initial stage we are building a "portrait" of the economic sector according to key financial components. These include the volume and speed of economic market formation, the development and stages of the life cycle, the number of competing counterparties, etc. Based on this "portrait", the vector of prospective management of the company is formed in the future, as well as the forecast of the strategic line of competitors.

On the basis of these data acquired in the process of analysis, it is possible to make a comprehensive assessment of the prospects of the economic sector and to detect its difference from other sectors of the economy, which in the future will enable the most correct choice of the company's business strategy in a particular economic sector and assess its validity. However, this approach to conducting strategic analysis is very time-consuming and professional skills. It provides a wide range of information about the external macro environment of a commercial company, which affects the functioning of large companies in a strategic perspective. Note that for small and medium-sized businesses, this approach is the least effective. For small firms, in the course of implementing a strategic choice, a situational test should be conducted, which is used to assess the strategic vector of the company, taking into account inter-corporate relations.

The analysis of situations consists of a sequence of the following actions: assessment of the company's current strategy (the volume of the market managed by the company increases or decreases; the direction of the company's "net" benefits and the speed of return on capital investments, etc.); implementation of SWOT analysis capabilities and assessment of the company's competitive status; evaluation of price positions from the point of view of competitiveness; finding alternative strategies and the advantages of the company's strategic capabilities. Such an analysis reveals those features of the external and internal environment that have the most significant impact on the company's prospective opportunities and abilities to establish the business orientation of the company as a whole. At the same time, situational and industry analysis for competitiveness is considered to be systemic and multifactorial ways of evaluating possible strategic plans, based on the results of which strategic alternatives are being developed.

It becomes clear that the management of any company implies the use of a wide range of strategic analysis tools. The choice of the most appropriate method and the analysis of the reasons that most significantly affect the future development of the company is directly dependent on such characteristics as the size of the company, the stages of the life span of the economic sector, the time interval of the state of the external and internal environment that most affect the company's work. Systematization of the tools of prospective management of the company, with the subsequent choice of the vector of development, makes it possible to recognize that all the methods considered have a number of limitations in terms of practical use. The classification of the considered restrictions is presented in Table 1.

Table 1: Limitations of strategic analysis tools.

Method of analysis	Environment factor	Company Size	Stages of the product life cycle
SWOT	External and internal environment	Small, medium, large	Origin, growth, maturity, decline
PEST	External environment (macroenvironm ent)	Medium, large	Origin, growth, maturity, decline
STP	External environment	Small, medium, large	Growth, maturity, decline
PIMS	External environment	Large	Growth, maturity, decline

SNW	Internal environment	Small, medium, large	Origin, growth, maturity, decline
Industry and competitive analysis	External environment (macroenvironment)	Large	Origin, growth, maturity, decline

In order to conduct strategic analysis and form strategic alternatives, it is advisable to use the integration mechanisms of industry and competitive analysis. They provide information about the macroenvironment of the company, as well as the possibility of conducting situational analysis, providing intra-company analysis of the company and analysis of financial activities (Fig. 1).

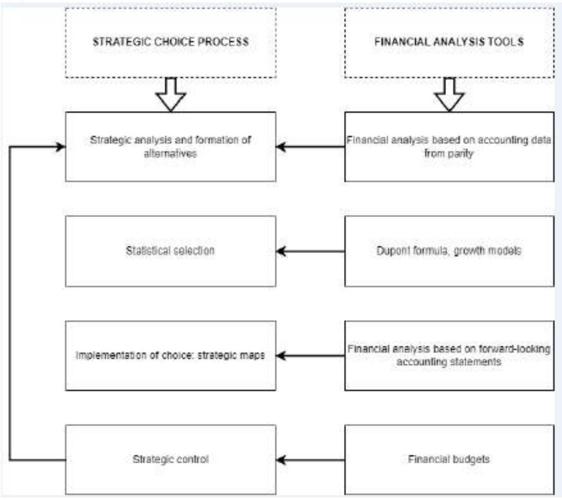


Figure 1: Financial analysis in the structure of the company's strategy selection.

Economic analysis, which provides information about the economic component of a strategic alternative, also carries the function of evaluating the company's strategic alternatives. At the same time, it is a methodological basis for modeling the likely growth of sales, monitoring income and related risks, monitoring the movement of capital and its optimization, the need for external financing. Therefore, at the stage of implementation of strategic choice, this type of analysis is crucial for the formation of the vector of strategic development of the company. The strategic choice should be justified from the point of view of the budget, and its implementation should contribute to achieving optimal economic results. Basic models of strategic management are used as additional tools for strategic analysis (Danfrd, 1962).

Despite a good analytical apparatus, these models take into account a limited number of alternatives, but, nevertheless, they allow determining the company's place in the market with acceptable accuracy (Danfrd, 1962). Table 2 shows the growth matrix according to I. Ansoff.

Table 2: Growth vector matrix (I. Ansoff).

Market	Products	
	Existing	New
Existing	Market penetration	Market development
New	Product development	Diversification

In the process of strategic analysis, the growth vector matrix helps to establish alternative directions of business growth by the method of market formation or product modernization, although at the same time, the company's investment opportunities, limited financial, labor and other types of resources are not analyzed. The use of the generic strategy model makes it possible to find external forces for the company that characterize the level of its readiness for competition: the danger from novice market representatives, supplier requirements, the company's market power, the threat of substitute products, the level of competition between rival companies (Table 3) (Dubov, Travkin, Yakimets, 1986).

Table 3: M. Porter's model of generic strategies.

		Source of benefits	
		Low costs	Differentiation
Competition framework	Wide	The company is a market participant with low costs and wide market coverage	A company with a wide market coverage, differentiating its products

	Narrow	The company is a market participant with low costs and a focus on a narrow circle of consumers	A company differentiating its product with a focus on a narrow circle of consumers

The model allows you to identify the exact place of the company in the economic sector, give comparative characteristics of the company and determine competitive advantages. However, this approach is not applicable for products that are at the initial stage of the life of the economic sector. The BCG model corresponds to the place of the strategic position of the business, which can be described on a plane using 2 coordinate axes: the first characterizes the growth rate of the market of the corresponding products, and the second - to determine the conditional part of the products on the market (Table 4) (Dubov, Travkin, Yakimets, 1986).

Table 4: Boston Matrix (BCG).

		Relative market share	
		Low	Tall
Market Growth	Low	"Cash cows"	"The dog"
	Tall	"Stars"	"Difficult children"

The BCG model as a strategic choice tool allows you to essentially find a niche for a company in the business community. In practice, such a model is used as a product classification tool, taking into account its ability to attract financial flows, which is aimed at a reasonable allocation of resources between possible strategic structures using a detailed analysis of products and the market. The main disadvantage of this model is considered to be a very controversial message concerning the fact that at the stage of maturity, the costs of creating products are reduced, and, in fact, the maximum market share corresponds to the indicator of the largest profit. At the same time, other components that have an impact on profit are ignored. It should be noted that high growth rates are sometimes considered a defining characteristic of the attractiveness of the market. The BCG model should not be used in sectors of the economy where the level of competition is low or the size of production is insignificant. The GE/McKinsey model is focused on the prospect of companies making a profit or return on capital investments in the future, which have the potential to receive them from the sale of a specific type of products or services (Table 5) (Kolemaev, 2002).

Table 5: GE/McKinsey matrix structure.

	Comparative advantage in the market		
Attractiveness of the market	Win ner (1). Using additional investment as a protection of market position	Winne r (2). Investment intervention to gain strategic advantages from strengths and improve weaknesses	Quest ion
	Win ner (3). Financial investments in the most attractive market segments	Mediu m-sized businesses	Loser (1). Develop business in low-risk areas
	Profi t Maker	Loser (2). Business Protection	Loser (3). Maximize profits and avoid direct investments

In order to form alternative strategies, all the analyzed types of the company's products undergo a ranking procedure to determine the need for additional investments in both quantitative and qualitative characteristics. Consequently, the strategic approach of the GE/McKinsey model consists in increasing the amount of resources allocated for the development and strengthening of economic activity in priority sectors of the economy in the case when the company has specific advantages in the market, and, conversely, in reducing the resources allocated for this type of business, in the case when the positions of the market itself or the company on it turn out to be weak. For any type of activity located between these two positions, the strategy becomes selective, taking into account adequately established criteria.

In the analysis, the reasons under consideration are ranked based on their significance, which makes the assessment of any type of economic activity of the company the most objective. The model provides the company's management with a large amount of analytical data to select a strategic management line.

A significant disadvantage of this model is that it does not provide for such a moment as the feasibility of a certain strategic alternative. Since the strategies proposed in the model are considered preliminary, they can also be considered solely as a guideline, which is not enough for making managerial decisions.

The future frontier of strategic choice is considered to be the formulation of other strategies based on the matrix approach. At the turn of the formulation of strategic alternatives in the course of strategic choice, it is advisable to use such matrix models as: the Shell/DPM model, the Hofer/Shendel model, the ADL/LC model, the Thompson-Strickland model, the SPACE model, the Efremov V.S. model.

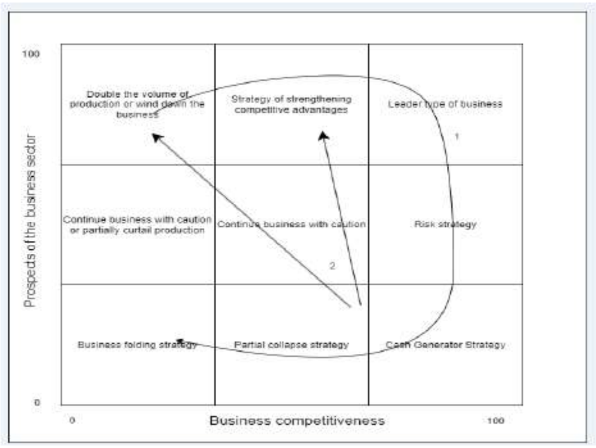


Figure 2: Model Shell/DPM.

The main distinguishing feature of the Shell/DPM model is the principle of the uniqueness of the company's strategy with guaranteed maintenance of a balance between an excess of financial resources and their deficit through the formation of new promising types of business (Fig. 2) (Litvak, 1998). When considering the phases of the formation of industry markets, the Hofer/Schendel model can be used as a tool for developing alternative strategies (Fig. 3) (Malinetsky, 1996).

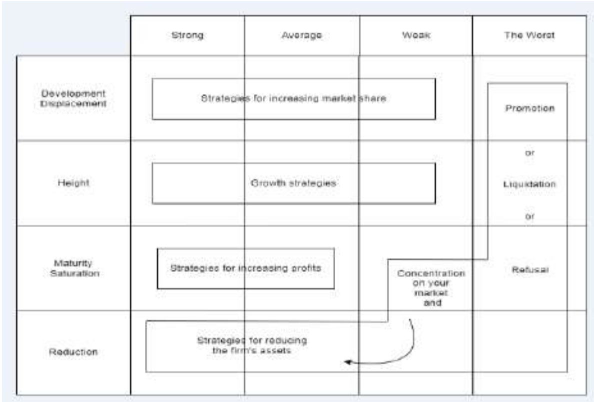


Figure 3: The Hofer-Schendel model.

The Hofer/Schendel model carries within itself both positive factors and significant negative ones. The positive factors include, first of all, the desire to formalize the criteria for the feasibility of a business strategy. In addition to a visual representation of the current state of the business, the model allows you to evaluate strategic sales opportunities and sufficient financial investments. Moreover, both the strategic capabilities of the company are considered, and the exact strategic alternatives to achieve them are implied. At the same time, we note that the disadvantages of the model arise from the peculiarities of adaptation of the strategic adaptation of the strategic choice of a particular company. First of all, the model is based on the assumption that all types of business activities of a commercial organization are connected to each other and their lifetimes are identical.

This circumstance narrows the number of possible strategic alternatives. Secondly, the key strategies proposed by this model are suitable simultaneously for several competitive positions of the business - powerful, weak or medium. The matrix approach based on the ADL/LC model is based on the consideration that it does not matter which sector of the economy methodically passes the boundaries of birth, formation, maturity and regression in its own existence. Therefore, the conditional position of a business in the market can be leading, powerful, visible, durable, weak. The task of strategic choice is formed from 3 steps.

At the first step, which is called "natural selection", the strategy is chosen according to the position of an adequate choice of the type of work, which is related to the position of the organization in the market and the stage of the life of the proposed product. At the second stage, a "specific choice" is made, which is considered, in addition, a cumulative strategic direction. At the 3rd step, a "refined" strategy is selected that is suitable for the selected path of business formation (Fig. 4) (Saaty, 1993).

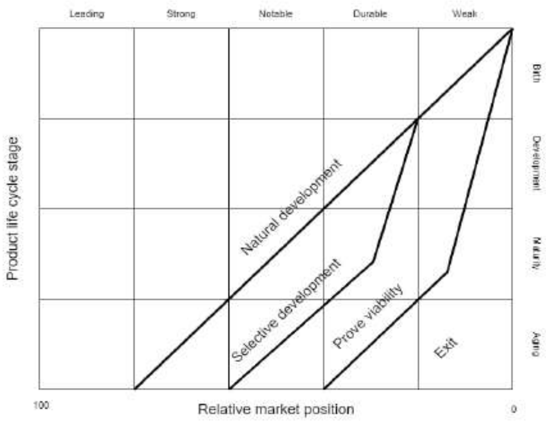


Figure 4: ADL/LC model.

From the point of view of the strategic choice process, the ADL/LC model has an area of application both for the study of the practical competitive position of any type of business and the stage of its life in a particular sector of the economy, and the choice of precise strategies of a commercial organization. Of fundamental importance for strategic choice is the introduction by the creators of the model of the very concept of "choice", its decomposition into stages of working out the choice of strategies in a specific situation.

However, the ADL/LC model implies that the bulk of the sectors of the economy fall under the scheme of life in the prescribed manner, although the form of the cycle may vary from sector to sector of the economy. It should be noted that this model is limited only by those strategies in which no efforts are made to adjust the life span, although mature markets have every chance to transform into younger ones, therefore automatic adherence to the ADL/LC model prevents the creation of strategic candidates and the implementation of the choice taking into account such transformation. Also, despite the external diversity of strategic alternatives, the strategies themselves in this model can be reduced to 5 strategic probabilities: the protection of the market position, the strategy of rapid growth in the market or in the market sector, leadership in tariffs, expansion of production or withdrawal from the market. The SPACE matrix model also deserves attention when forming alternative strategies (Dubov, Travkin, Yakimets, 1986).

As follows from this model, strategic alternatives are developed taking into account the following reasons: the strategic potential of a commercial organization, external business criteria, the competitive advantages of the organization, the attractiveness of the economic sector. The SPACE matrix is divided into 4 areas, each of which represents the all-possible nature of strategic alternatives: offensive, expectant, competitive and defensive.

Therefore, from the perspective of the SPACE model, it is allowed to implement the choice of strategy taking into account the largest number of factors than those of the previously considered models. It takes into account the strategic potential of the organization, its external conditions, competitive advantages, and the seductiveness of the economic sector. The model is supposed to use a wide range of precise strategic alternatives.

3 OBJECTIVE PREREQUISITES AND MEANS FOR FORMALIZING THE CONSTRUCTION OF A DIGITAL ANALOGUE

The processes of development and application of analogue models must ensure the accumulation and integration of various empirical, theoretical and subjective information in the models, as well as the movement of information from one area to another. The model for calculating digital analogues is intended to determine labor and material costs by type, period and in general throughout the entire cycle of work for the full volume for each type of product. It takes into account the totality of technological measures used in the production of a specific type of product and their quantitative parameters (production rate, number of standard shifts, labor costs by type of work), as well as final indicators by period and throughout the entire production interval. An element of a digital analogue is a set of production and technological measures for the production of specific products. The quality and acceptability of the digital analogue is determined by the choice of activities, expressed through the names of the works, and methods of their implementation. The set of such activities is determined by the set, the elements of which are codes of work, ordered by the sequence of their implementation in the production of products of type α. Other indicators that quantitatively reflect production technology are calculated using an algorithm, taking into account labor and economic resources, as well as the logistics of a particular company. The total scope of work is established on the basis of data describing the initial parameters and features of technological production used in the production of a specific type of product and differing by type of product, standard indicators adopted in the company for the production of a specific type of product (Dubov, Travkin, Yakimets, 1986).The algorithm for calculating the amount of work in general can be written as follows: $O_{\downarrow} i^T((\alpha)) = F_{\downarrow} i(B_{\downarrow} 8^{\uparrow}((\alpha)), H^{\uparrow}((\alpha)),$ where F_i is an operator identifying the amount of work i, transforming input - planned $(B\,8(\alpha))$ and regulatory $(H(\alpha))$ data. Let's move on to the description of the algorithms that determine the indicators of the digital analog of product production. The scope of work for each technical device in physical $(Q_{ij}^{(\alpha)})$ and conventional $(M_{ij}^{(\alpha)})$ units of measurement is calculated

$$Q_{ij}^{(\alpha)} = \frac{Y_{ij} Q_i^{(\alpha)}}{10o}, M_{ij}^{(\alpha)} = Q_{ij}^{(\alpha)} K_{ij}, i \in m^{(\alpha)}, j = 1, ..., I_j;$$

volume of automated work in conventional units of measurement by period $(M_{ij}^{(\alpha)})$ and in general $(M^{t(\alpha)})$ for the production of a product of type α

$$M^{t(\alpha)} = \sum_{i \in m^{t(\alpha)}} M^{t(\alpha)}, j = 1, ..., I_i, \ M^{B(\alpha)} = \sum_{t=1}^{n} M^{t(\alpha)};$$

expressions for calculating labor costs for automated $(P_{ij}^{(\alpha)})$ and manual work $(P_i^{(\alpha)})$

$$P_{ij}^{(\alpha)} = Q_{ij}^{(\alpha)} E_{ij}, i \in m_M^{(m)}, j = 1, ..., I_i, \ P_i^{(\alpha)} = Q_i^{(\alpha)} E_i, i \in m$$

number of standard shifts for performing automated $(D_m^{t(\alpha)})$ and manual work $(D_p^{t(\alpha)})$ by period

$$(D_m^{t(\alpha)}) = \sum_{i \in m_M^{t(\alpha)}} D_{i,j}^{(\alpha)}, j = 1, ..., I_i, D_p^{t(\alpha)} = \sum_{i \in m_M^{t(\alpha)}} D_i^{(\alpha)};$$

labor costs for performing automated $(P_m^{t(\alpha)})$ and manual $(P_p^{t(\alpha)})$ work by period

$$P_m^{t(\alpha)} = \sum_{i \in m_M^{t(\alpha)}} P_{i,j}^{(\alpha)}, j = 1, ..., I_i, D_p^{t(\alpha)} = \sum_{i \in m_M^{t(\alpha)}} P_i^{(\alpha)};$$

number of standard shifts $(D_m^{t(\alpha)})$ and labor costs $(P^{t(\alpha)})$ by period

$$D^{t(\alpha)} = D_M^{t(\alpha)} + D_p^{t(\alpha)}, P^{t(\alpha)} = P_M^{t(\alpha)} + P_p^{t(\alpha)};$$

number of standard shifts for performing automated $(D_M^{b(\alpha)})$ and manual $(D_p^{b(\alpha)})$ work in general for the manufacture of products of type α

$$D_M^{b(\alpha)} = \sum_{t=1}^{n} D_M^{t(\alpha)}, D_p^{b(\alpha)} = \sum_{t=1}^{n} D_p^{t(\alpha)};$$

labor costs for automated $(P_M^{b(\alpha)})$ and manual $(P_p^{b(\alpha)})$ work in general for the production of a product of type α

$$P_M^{b(\alpha)} = \sum_{t=1}^{n} P_M^{t(\alpha)}, P_p^{b(\alpha)} = \sum_{t=1}^{n} P_p^{t(\alpha)};$$

the number of standard shifts $(D^{b(\alpha)})$ and labor costs $(P_m^{t(\alpha)})$ in general for the production of a product of type α

$$D^{b(\alpha)} = D_M^{b(\alpha)} + D_p^{b(\alpha)}, P^{b(\alpha)} + D_p^{b(\alpha)};$$

electricity consumption by type, period, and in general for the manufacture of a product of type α

$$\sigma_{ij}^{t(\alpha)} = Q_{ij}^{(\alpha)}, i \in m_M^{(\alpha)}, j = 1, ..., I_i, \sigma^{t(\alpha)} = \sum_{i \in t_M(\alpha)} \sigma_{ij}^{(\alpha)}, j = 1, ..., I_i, \sigma^{t(\alpha)} = \sum_{t=1}^{n} \sigma_{ij}^{(\alpha)}$$

The main indicators of economic planning, as well as the wage fund of workers and engineers, are calculated using digital analogues. The development of company plans based on a multi-level model is formed in stages, as follows:

1) calculation of standards for the manufacture of a specific type of product (implementation of block 3, Fig.);

2) determining the potential of each company included in the association of similar industries, taking into account the development of other industries (implementation of block 4);

3) identifying optimal parameters for the

company's development, taking into account the capabilities of service enterprises (implementation of block 2);

4) development of an optimal company plan (implementation of block 4);

5) drawing up plans for economic units in conjunction with the indicators of the optimal economic plan (implementation of blocks 5, 6).

Based on a multi-level model, a corresponding simulation model was created that allows you to build economic plans for the company (Fig. 5).

1 - user (DM); 2 - database; 3 - adjustment of input parameters; 4 - calculation of cost standards for the manufacture of a specific type of product; 5, 8 - analysis of results; 6 - checking the acceptability of standards; 7 - calculation of the company plan and printing of key indicators; 9 - checking the acceptability of the plan; 10 - printing a detailed plan of the company and recording intermediate information in the database; 11 - calculation of the sector plan and printing; 12 - calculation of the department plan and printing; 13 - end of calculation

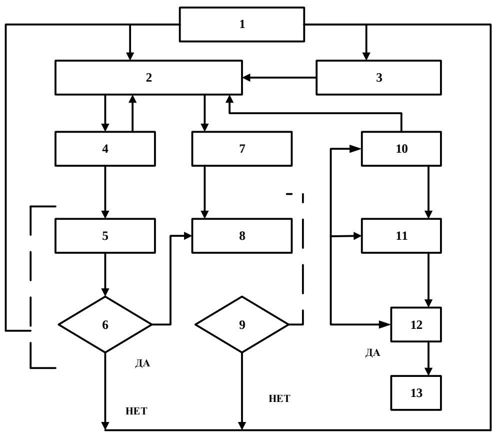


Figure 5: Simulation model for drawing up economic plans.

4 RESULT AND CONCLUSIONS

In the proposed model, a significant part of the analysis of results and decision-making is a function of a team of specialists or, according to common terminology, the decision maker (Kolemaev, 2002). The main executor is the company economist; he is guided by computer data on the growth rate of the industry, savings in labor and material resources, as well as the optimal parameters determined during the implementation of the model.

The decision maker monitors deviations of optimal parameters from the calculated ones and compares the estimated growth rates of the industry with the observed main economic indicators, while having the opportunity to change specialization, placement within the enterprise, and the use of material and labor resources. The model operation consists of the following stages. The decision maker determines the input values of control parameters: the technology adopted in the company for the production of a specific type of product, specialization within the company and other indicators that reflect the initial state of production in the company.

In addition, it provides benchmark figures obtained on the basis of intermediate monitoring, taking into account the introduction of innovative technologies (Malinetsky, 1996; Smolyak, 1997). The criteria for calculating the input values of control parameters are the rational use of technological capacities and the rational specialization of the company with the efficient use of labor and technical resources. Input and control indicators are entered into the computer. The computer determines cost standards per unit of work volume by type according to production technology and prints them out. The decision maker pays special attention to the calculated indicators and the sequence of execution of types of work according to technological and technical requirements. If, in his opinion, the results are acceptable for a given company, then he instructs the computer to write the regulatory information onto external media and proceed to the next stage of calculation (Bag, Dasgupta, 1995). Otherwise, he adjusts the input values, after which the calculation process is repeated from stage 2. Using a computer, digital analogues are compiled for the entire volume of work and the main indicators of the plan for the production of a specific type of product are determined (Chazelle, Edelsbrunner, 1985; Johnston, DiNardo, 1997). The results are printed by product type with a comparison of calculated and control indicators. The decision maker reviews the calculation results. If the results satisfy him, then he instructs the computer to print detailed information about the plan and record it on magnetic media to store intermediate information for further use in planning at the sector and department levels. Then it proceeds to the next stage of calculation, it adjusts the input parameters and repeats the calculation process from stage 4.

Calculation of digital analogues on a computer is carried out for the entire volume of work and task plans of the sector and department. Thus, the developed simulation model allows: to strengthen the economic justification of planned indicators; carry out variant calculations taking into account the additional use of reserves to correctly establish the scope of work for the enterprise and select the optimal plan option; ensure storage and automated search of the company’s regulatory framework, its periodic updating.

REFERENCES

Ashmanov, S.A., 1984. Introduction to mathematical economics. 292 p.

Danfrd, N., 1962. Linear operators. 82 p.

Dubov, Yu.A. Travkin, S.I., Yakimets, V.N., 1986. Multicriteria models for the formation and selection of system options. 65 p.

Kolemaev, V.A., 2002. Mathematical Economics. 399 p.

Litvak, B.G., 1998. Management decisions. 109 p.

Malinetsky, G.G., 1996. Nonlinearity. New problems, new opportunities. New in synergetics. Mysteries of the world of nonequilibrium structures. 76 p.

Saaty, T., 1993. Decision making. Method of analysis of hierarchies. 86 p.

Smolyak, S.A., 1997. Features of the use of financial leasing in investment projects. 75 p.

Bag, P.K., Dasgupta, S., 1995. Strategic R&D Success Announncements. Econom. Lett. V.47. №1. P. 38-45.

Chazelle, B.M., Edelsbrunner, H., 1985. Optimal solutions for a class of point retrieval problems. J. Symbol Comput. 1, p. 47-56.

Johnston, J., DiNardo, J., 1997. Econometric Methods .

A New Hardware-Implemented Stream Encryption Algorithm

Rakhmatullayev Ilkhom Rakhmatullayevich[a]
Samarkand branch of the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Samarkand, Uzbekistan
Ilhom9001@gmail.com

Keywords: AND, XOR, NHSA, algebraic cryptanalysis, differential cryptanalysis, algorithm cycle, NIST statistical tests.

Abstract: This article describes a streaming encryption algorithm called NHSA consisting of a total length of 3 shift registers, 6 AND elements and 14 XOR elements. The results of evaluating sequences developed using this algorithm for the level of randomness and conclusions about the portability of certain cryptanalysis methods, as well as information about the number of elements required to implement the algorithm on hardware devices are presented.

1 INTRODUCTION

Stream cipher algorithms are a category of encryption techniques that encrypt plaintext one bit or byte at a time, creating a stream of encrypted data. They are distinguished by their use of a keystream generator, which produces a pseudo-random sequence of bits known as the gamma key. Each bit of the plaintext is encrypted by performing an XOR (exclusive OR) operation with the corresponding bit of the gamma key (SHnajer, 2003).

$$c_i = p_i \oplus k_i \tag{1.1}$$

Exactly, the decryption process in stream cipher algorithms mirrors the encryption process, leveraging the symmetry of the XOR operation to recover the plaintext from the ciphertext. This symmetry hinges on both the sender and the recipient using the same pseudo-random keystream, which is generated by a keystream generator initialized with a shared secret symmetric key.

$$c_i \oplus k_i = p_i \oplus k_i \oplus k_i = p_i \tag{1.2}$$

Absolutely, the resilience of cryptosystems employing stream ciphers against different types of attacks hinges significantly on the properties of the keystream generator at the heart of the algorithm. The security and effectiveness of these ciphers are closely tied to two critical aspects of the generator: the period of the generated sequence and its degree of randomness. If the generator produces the same sequence in each session or has a short repetition period, it becomes possible to XOR two encrypted texts using the XOR operation, resulting in the XOR sum of two plaintexts $p_1 \oplus p_2$. Comparing the complexity of decrypting stream cipher encrypted text to that of decrypting a polyalphabetic cipher sheds light on how advances in cryptanalysis influence the security assessment of cryptographic algorithms. Polyalphabetic ciphers, such as the Vigenère cipher, are a step up from simple monoalphabetic substitution ciphers because they use multiple substitution alphabets, significantly increasing their resistance to frequency analysis. However, with the advent of more sophisticated cryptanalytic techniques, even the complexity of polyalphabetic ciphers has been effectively reduced, making them more vulnerable to decryption without the key (Knellwolf, Meier, Naya-Plasencia, 2011; De Canni`ere, Preneel, 2008; Quedenfeld, Wolf, 2014; Hitachi, 2001; Watanabe, Furuya, Yoshida, Takaragi, Preneel, 2002; Dawson, Carter, Gustafson, Henricksen, Millan, Simpson, 2002; Wong, Carter, Dawson, 2010; Orumiehchiha, Pieprzyk, Shakour, Steinfeld, 2013; Lee, Lee, Park, 2008; Zaynalov, 2020; Zaynalov, 2021; Zaynalov, 2020; Zaynalov, 2020;Rakhmatullaevich, Mardanokulovich, 2024; Kilichev, 2024; Huang, Susilo, Seberry, 2010).

The NHSA stream cipher algorithm, with its potential for hardware implementation, signifies a

[a] https://orcid.org/0000-0002-4872-4265

strategic development in the realm of cryptographic algorithms. Implementing cryptographic algorithms in hardware can offer several advantages over software implementations, including increased speed, lower power consumption, and enhanced security against certain types of attacks.

2 METHODS

The description of the New Hardware Stream Algorithm (NHSA) outlines a promising approach to stream ciphering that combines both hardware efficiency and cryptographic robustness. The initial state configuration, involving three shift registers with a total length of 269 bits, alongside the use of a 128-bit key and an initialization vector (IV), suggests a carefully designed mechanism to ensure both security and performance. The execution strategy of the New Hardware Stream Algorithm (NHSA), running the algorithm 4 times for each bit in the initial state, leading to a total of 1076 iterations, is an intriguing approach to ensuring a thoroughly mixed and secure initial setup. This method highlights a comprehensive mixing and diffusion strategy, aimed at maximizing the cryptographic strength of the cipher before actual data encryption begins.

The operational mechanism outlined for the New Hardware Stream Algorithm (NHSA) after its initialization phase showcases the fundamental principles of stream cipher encryption and decryption, focusing on the generation of keystream bits and their combination with the plaintext and ciphertext via XOR operations. This process encapsulates the core of stream ciphering, highlighting both its simplicity and elegance in securing data.

3 INITIALIZATION

To illustrate the initialization process of the New Hardware Stream Algorithm (NHSA) with a focus on loading the 128-bit key and the 128-bit initialization vector (IV) into the 269-bit shift registers, let's consider a structured approach to pseudocode. This process involves distributing these values across the registers, ensuring the algorithm begins with a richly mixed initial state. The total length of the shift registers is broken down into three distinct sizes: 89 bits, 83 bits, and 97 bits, respectively.

For the case where the indices of register cells are expressed sequentially:

$(K_0, K_1, \dots, K_{79}, 0, \dots, 0) \to (a_0, a_1, a_2, \dots, a_{88})$
$(I_0, I_1, \dots, I_{79}, 0,0,0) \to (a_{89}, a_{90}, a_{91}, \dots, a_{171})$
$(K_{80}, \dots, K_{127}, I_{80}, \dots, I_{127}, 0)$
$\to (a_{172}, a_{173}, \dots, a_{268})$
$for\ i = 0\ to\ 1075\ do$
$a_{55} + a_{80} \cdot a_{81} + a_{82} + a_{72} \cdot a_{74} + a_{161} \to t_0$
$a_{151} + a_{164} \cdot a_{165} + a_{166} + a_{155} \cdot a_{157} + a_{259}$
$\to t_1$
$a_{232} + a_{263} \cdot a_{264} + a_{265} + a_{242} \cdot a_{244} + a_{68}$
$\to t_2$
$(t_2, a_0, \dots, a_{87}) \to (a_0, \dots, a_{88})$
$(t_1, a_{89}, \dots, a_{170}) \to (a_{89}, \dots, a_{171})$
$(t_0, a_{172}, \dots, a_{267}) \to (a_{172}, \dots, a_{268})$
$end\ for.$

For the case where the indices of register cells are expressed in a separate order for each register:

$(K_0, K_1, \dots, K_{79}, 0, \dots, 0) \to (a_0, a_1, a_2, \dots, a_{88})$
$(I_0, I_1, \dots, I_{79}, 0,0,0) \to (b_0, b_1, b_2, \dots, b_{82})$
$(K_{80}, \dots, K_{127}, I_{80}, \dots, I_{127}, 0) \to (c_0, c_1, \dots, a_{96})$
$for\ i = 0\ to\ 1075\ do$
$a_{55} + a_{80} \cdot a_{81} + a_{82} + a_{72} \cdot a_{74} + b_{72} \to t_0$
$b_{62} + b_{75} \cdot b_{76} + b_{77} + b_{66} \cdot b_{68} + c_{87} \to t_1$
$c_{60} + c_{91} \cdot c_{92} + c_{93} + c_{70} \cdot c_{72} + a_{59} \to t_2$
$(t_2, a_0, \dots, a_{87}) \to (a_0, \dots, a_{88})$
$(t_1, b_0, \dots, b_{81}) \to (b_0, \dots, b_{82})$
$(t_0, c_0, \dots, c_{95}) \to (c_0, \dots, c_{96})$
$end\ for.$

4 GENERATION

The stream generation phase of the New Hardware Stream Algorithm (NHSA) leverages a fascinating and intricate design, ensuring that the key and initialization vector (IV) significantly influence the generated keystream. This approach, using 21 specific bits from the 269-bit state to modify 3 bits of the state and compute 1 bit of the keystream, underscores a sophisticated method of ensuring security and randomness in the cipher. The process of generating an N-bit key N ($N \leq 2^{64}$) required for encryption can be expressed using the following pseudocode.

For the case where the indices of register cells are expressed sequentially:

$for\ i = 0\ to\ N\ do$
$a_{55} + a_{82} \to t_0$
$a_{151} + a_{166} \to t_1$
$a_{232} + a_{264} \to t_2$
$t_0 + t_1 + t_2 \to exit_i$
$a_{55} + a_{80} \cdot a_{81} + a_{82} + a_{161} \to t_0$

$a_{151} + a_{164} \cdot a_{165} + a_{166} + a_{259} \rightarrow t_1$
$a_{232} + a_{263} \cdot a_{264} + a_{265} + a_{68} \rightarrow t_2$
$(t_2, a_0, \dots, a_{87}) \rightarrow (a_0, \dots, a_{88})$
$(t_1, a_{89}, \dots, a_{170}) \rightarrow (a_{89}, \dots, a_{171})$
$(t_0, a_{172}, \dots, a_{267}) \rightarrow (a_{172}, \dots, a_{268})$
$end\ for.$

For the case where the indices of register cells are expressed in a separate order for each register:
$for\ i = 0\ to\ N\ do$
$a_{55} + a_{82} \rightarrow t_0$
$b_{62} + b_{77} \rightarrow t_1$
$c_{60} + c_{93} \rightarrow t_2$
$t_0 + t_1 + t_2 \rightarrow exit_i$
$a_{55} + a_{80} \cdot a_{81} + a_{82} + a_{72} \cdot a_{74} + b_{72} \rightarrow t_0$
$b_{62} + b_{75} \cdot b_{76} + b_{77} + b_{66} \cdot b_{68} + c_{87} \rightarrow t_1$
$c_{60} + c_{91} \cdot c_{92} + c_{93} + c_{70} \cdot c_{72} + a_{59} \rightarrow t_2$
$(t_2, a_0, \dots, a_{87}) \rightarrow (a_0, \dots, a_{88})$
$(t_1, b_0, \dots, a_{81}) \rightarrow (b_0, \dots, b_{82})$
$(t_0, c_0, \dots, c_{95}) \rightarrow (c_0, \dots, c_{96})$
$end\ for.$

In the context of stream ciphers and bitwise operations, using XOR and AND operations as analogs for addition and multiplication modulo 2 aligns perfectly with the principles of finite field arithmetic, specifically within the field GF(2). In this finite field, the elements are {0, 1}, and the addition and multiplication operations are defined as XOR and AND respectively. This alignment is due to the properties of XOR and AND operations mirroring those of addition and multiplication in a modulo-2 system. Using this algorithm, it is recommended to generate keys of length 2^{64} bits using a single key and initialization vector.

Below is an example of the correct organization of the generation process using the algorithm.

Input Parameters:

*Key:*0001110000000110001101100001100100001011000100100110000000100011001110110011010100010010010111110001111000011101000011100010111 1

*IV:*1111000011100000110100001100000010110000101000000100100001000000000111000001100000010101000000000110000000100000000010000000000000000

Values of the registers before the initialization process:

*a:*000111000000011000110110000110010000101100010010011000000001000110011101100110100000000000

*b:*1111000011100000110100001100000010110000101000000100100001000000000111000001100000000

*c:*000100100101111110001111000011101000011100010111110101010000000001100000010000000010000000000000000000

Values of the registers after the initialization process:

*a:*101100100100110101101010011011101101011000111100000100101111111000111010110110010110100000

*b:*0100111001110010011001100011010001101000001110100011101000011011010101001101111 0100

*c:*00000010000001010100110100010010011110010010111110100101000111010100100100010011111101101000000000

*output:*00100101110100111110111110111011010110110110000110001100101000010110101000001110…

5 RESULTS

The New Hardware Stream Algorithm (NHSA) is conceptualized as a state-of-the-art solution catering to the modern demands of cryptographic security, particularly in environments where hardware resources are at a premium. Its design philosophy, focusing on compactness, energy efficiency, and speed, makes it especially suitable for a wide array of applications, from embedded systems to IoT devices and high-speed communication channels.

The requirement for a compact implementation of the New Hardware Stream Algorithm (NHSA), emphasizing a bit-oriented approach, non-linearity, energy efficiency, and rapid processing, sets a clear direction for its design and optimization strategies. These considerations are crucial for the algorithm's suitability in constrained environments, where the trade-offs between security, performance, and resource utilization are most acute.

Based on the figures provided in (ano, J., Mentens, Preneel, Verbauwhede, 2004) (i.e., 12 NAND gates for each flip-flop (shift register element), 2.5 NAND gates for XOR, and 1.5 NAND gates for AND), calculate the number of gates required for a possible hardware implementation. Comparative analysis results with the Trevium algorithm (De Canniere, Preneel, 2008), which is one of the top stream cipher algorithms participating in the EStream competition, are presented in Table 1.

Table 1: The number of gates required for the hardware implementation of the NHSA and Trevium algorithms is as follows.

Algorithm	Trevium	NHSA
Key length	80	128
IV length	80	128
Internal status register	288*12=3456	269*12=3228
AND gate	3*1.5=4.5	6*1.5=9
XOR gate	11*2.5=27.5	14*2.5=35
Total number of gates	**3488**	**3272**

Period of NHSA algorithms.

As the internal state of the algorithm evolves non-linearly, determining its exact period is challenging. However, the period of the algorithm's operation can be estimated through a series of observations. Firstly, it can be shown that any key/IV pair can produce a stream with a period of at least 2^{83-3}-1 if a complete linear circuit without NAND gates is obtained. This doesn't directly impact NHSA but can be considered an indication that the register lengths have been chosen correctly.

Secondly, the internal state of NHSA is updated in reverse order, and the initialization of the register $(c_0,..,c_{96})$ prevents state changes in fewer than 96 iterations. Assuming that NHSA behaves like a random permutation after a sufficient number of iterations (in this case, 269*4=1076 iterations), all cycle lengths up to 2^{269} are equally likely. Thus, for this key/IV pair, the probability that it generates a cycle shorter than 2^{128} is $2^{269-128}=2^{141}$.

However, it's recommended to generate a 2^{64} bit key using a single key/IV pair to ensure maximum reliability of the generated keys.

An algebraic attack on the NHSA algorithm.

At first glance, NHSA may appear to be a lightweight algorithm that could be efficiently targeted by algebraic attack methods. The complete scheme could be represented by very sparse low-order equations. However, due to the non-linear evolution of the algorithm's internal state, applying effective linearization methods used to solve equation systems created for schemes based on sufficiently long selected registers like LFSRs can be quite challenging.

Nevertheless, conducting research to draw conclusions about the algebraic properties of the algorithm would be prudent. It's known that the initialization process in the NHSA algorithm consists of 1076 steps. When applying algebraic cryptanalysis to this algorithm, the main goal is to construct and solve algebraic equations representing register cells after a certain iteration. From the following equations, it can be observed that in iterations 1 and 2, the bits of the key and initialization vector are involved in the equations representing the register cells.

Algebraic equation for iteration-1:

$$t_0 = k_{55} + 0 \cdot 0 + 0 + k_{72} \cdot k_{74} + IV_{72}$$

$$t_1 = IV_{62} + IV_{75} \cdot IV_{76} + IV_{77} + IV_{66} \cdot IV_{68} + IV_{119}$$

$$t_2 = IV_{92} + IV_{123} \cdot IV_{124} + IV_{125} + IV_{102} \cdot IV_{104} + k_{68}$$

Algebraic equation for iteration-2:

$$t_0 = k_{54} + 0 \cdot 0 + 0 + k_{71} \cdot k_{73} + IV_{71}$$

$$t_1 = IV_{61} + IV_{74} \cdot IV_{75} + IV_{76} + IV_{65} \cdot IV_{67} + IV_{118}$$

$$t_2 = IV_{91} + IV_{122} \cdot IV_{123} + IV_{124} + IV_{101} \cdot IV_{103} + k_{67}$$

$$(t_0, a_{172}, \ldots, a_{267}) \rightarrow (a_{172}, \ldots, a_{268})$$

Based on the formula provided, where the value of t_0 calculated from a quadratic nonlinear equation is written to the 172nd-order register cell before the 2nd iteration, the equations representing the cells of the third register begin to take on a quadratic form. Since the length of the third register is 97, 97 cycles are sufficient to transition this register to a quadratic form. In the second register, starting from the 63rd cycle, and in the first register, starting from the 73rd cycle, the algebraic level of equations representing the cells begins to increase. Thus, to achieve a complete quadratic representation, 73 + 89 = 162 iterations are required. The key bits are fully involved in the unknowns representing the equation system. The following table shows the change in the level of the equation system and the number of unknowns depending on the number of initialization process cycles:

Table 2: Parameters of the equations formed using the algebraic cryptanalysis method for the NHSA algorithm.

The minimum level of the equation system.	Iteration step	The number of unknowns	Complexity O(n^3)
Level-2	162	2^{14}	2^{42}
Level-3	162+97=259	2^{21}	2^{63}
Level-4	259+97=356	2^{28}	2^{84}
Level-5	356+97=453	2^{35}	2^{105}
Level-6	453+97=550	2^{42}	2^{126}
Level-7	550+97=647	2^{49}	2^{147}

It is evident that every 97 cycles after the 162nd iteration, the level of equations representing the register cells in algebraic form increases. From the Table 2 above, it is clear that the

NHSA encryption algorithm is resistant to algebraic cryptanalysis due to the sharp increase in the number of unknowns (2^{49}) and the complexity of solving (2^{147}) after the 647th iteration of the initialization process.

Correlation attack on the NHSA algorithm.

In the security analysis of a synchronous stream cipher, cryptanalysts typically consider two different types of correlations. The first type is the correlation between the key stream bits and linear combinations of bits in the internal state, which potentially could lead to a complete state recovery. The second type of correlation attack involves the correlation between the key stream bits themselves.

It is evident that finding a linear correlation between the current key bits and the bits of the internal state is straightforward, as the i output bit is assumed to be equal to 〖output 〗_i=a_55+a_82+b_62+b_77+c_60+c_93. However, unlike other ciphers based on LFSR , the internal state of NHSA changes non-linearly, making the process of combining these equations for efficient state recovery a rather complex problem.

The simplest way to find correlations of the second type is to traverse the linear paths of the cipher and set the output values of all encountered AND gates close to 0. However, the organization of operations in NHSA is designed in such a way that any path leads to the complete prediction of the values of at least 144 AND gate outputs in this specific type of observation. Below is an example of a linear combination to determine the correlation of key stream bits:

If we assume that the correlation of this linear combination is fully expressed in the considered specific manner, this equation will have a correlation coefficient of 2–144. To determine such a correlation, at least 2288 key stream bits are required, which significantly exceeds the security requirements and the fu6`ll key selection method (2128).

6 DISCUSSION

Comparing the differential cryptanalysis method with the NHSA algorithm.

The idea of conditional differential cryptanalysis was expanded and applied to constructions based on NLFSR (Non-Linear Feedback Shift Registers).

In the main concept of the differential cryptanalysis method, when applied to the NHSA algorithm, it involves observing two key values that differ only by a few bits and determining the probability of the difference value after each iteration. The difference between the key values is referred to as the increment.

Let the considered increment be Δf(k,x) and the 1-bit difference x in the i-th bit state be e_i. By neutrality of x_i in Δf, we understand the probability that Δf(k,x)=Δf(k,x⊕e_i) for a random key k. Using a single neutral variable as a differentiator requires estimating Δf at least twice. If the neutrality of x_i is p, then the overall probability is |1/2 - p|.

To determine the conditions for data collection, the following algorithm proposed in (Knellwolf, Meier, Naya-Plasencia, 2010) was utilized:

Input: $a_1, a_2, \dots, a_d, r$
$J \leftarrow \emptyset$
foreach $a \in \{a1, . . . , ad\}$ **do**
for i ← 0 **to** r - 1 **do**
$f \leftarrow \triangle_a\, s_i(k, x)$ mod J
if f = 1 **then**
add f to J
return J

In this case $a_1, a_2, \dots, a_d$ are binary vectors defined in space F_2^n.

During the analysis, we utilize a 24-bit adder. Conditions for 24 differences were determined using the algorithm mentioned above. We use the abbreviation $\triangle z_j = \triangle^{(24)}_{a_1,a_2,\dots,a_d} z_j$, here $z_j - j$ refers to the key stream generated in this iteration.

Using the algorithm provided above, conditions were analyzed for the case r = 200, where each increment is controlled for the first 200 iterations. After processing the first increment, the first increment (increment at point x_0) is generated as follows:

$$J = \langle x_0, x_{10}x_{11} + x_{13}, x_{13}x_{14} + x_{15}, x_{76} + k_{64}, x_{61} + x_{74}x_{75} + x_{74}k_{63} + x_{75}k_{62} + k_{49} + k_{62}k_{63} + k_{74}k_{75} + k_{76}, x_{63} + k_{51} + k_{76}k_{77} + k_{78}, k_{11}k_{12} + k_{13} + k_{55}, k_{13}k_{14} + k_{15} + k_{57}\rangle$$

At different algebraic parameters J, all pairs (k, x) have the same differential characteristic with respect to a_1 up to $r = 200$ periods. After processing all the increments, the value of J looks as follows:

$$J = \langle x_0, x_1, x_3, x_4, x_6, x_7, x_9, x_{10}, x_{12}, x_{13}, x_{15}, x_{16}, x_{18}, x_{19}, x_{21}, x_{22}, x_{24}, x_{25}, x_{27}, x_{28}, x_{30}, x_{31}, x_{33}, x_{34}, x_{36}, x_{37}, x_{39}, x_{40}, x_{42}, x_{43}, x_{45}, x_{46}, x_{48}, x_{49}, x_{51}, x_{52}, x_{54}, x_{55}, x_{57}, x_{58}, x_{60}, x_{61}, x_{63}, x_{64}, x_{66}, x_{67}, x_{69}, x_{70}, x_{72}, x_{73}, x_{75}, x_{76}, x_{78}, x_{79}, x_{81}, x_{82}, x_{84}, x_{85}, x_{87}, x_{88}, x_{90}, x_{91}, x_{93}, x_{94}, x_{96}, x_{97}, x_{99}, x_{100}, x_{102}, x_{103}, x_{105}, x_{106}, x_{108}, x_{109}, x_{111}, x_{112}, x_{114}, x_{115}, x_{117}, x_{118}, x_{120}, x_{121}, x_{123}, x_{124}, x_{126}, x_{127}, k_0, k_1, k_3, k_4, k_6, k_7, k_9, k_{10}, k_{12}, k_{13}, k_{15}, k_{16}, k_{18}, k_{19}, k_{21}, k_{22}, k_{24}, k_{25}, k_{27}, k_{28}, k_{30}, k_{31}, k_{33}, k_{34}, k_{36}, k_{37}, k_{39}, k_{40}, k_{42}, k_{43}, k_{45}, k_{46}, k_{48}, k_{49}, k_{51}, k_{52}, k_{54}, k_{55}, k_{57}, k_{58}, k_{60}, k_{61}, k_{63}, k_{64}, k_{66} + 1, k_{67}, k_{69}, k_{70}, k_{72}, k_{73}, k_{75}, k_{76}, k_{78}, k_{79}, k_{81}, k_{82}, k_{84}, k_{85}, k_{87}, k_{88}, k_{90}, k_{91}, k_{93}, k_{94}, k_{96}, k_{97}, k_{99}, k_{100}, k_{102}, k_{103}, k_{105}, k_{106}, k_{108}, k_{109}, k_{111}, k_{112}, k_{114}, k_{115}, k_{117}, k_{118}, k_{120}, k_{121}, k_{123}, k_{124}, k_{126}, k_{127}\rangle.$$

Only the bits $x_{61}, x_{64}, x_{67}, x_{70}$ in x are not specified and do not affect the increment. When all other variables x_i are set to zero, this makes them candidates for neutral bits for $\triangle z_j$. Empirical results confirm that they are likely to be neutral up to the 537th round. Table 3 shows the neutrality obtained in the experiment with 100 random keys. Note that neutrality equal to zero or one means that $\triangle z_j$ is linear in the corresponding variable (which can be used as an amplification coefficient with neutrality).

Table 3: Neutrality indicators defined for the bits $x_{61}, x_{64}, x_{67}, x_{70}$.

□	□$_{61}$	□$_{64}$	□$_{67}$	□$_{70}$
501	1.0	1.0	1.0	1.0
514	0.10	0.15	0.05	0.10
525	0.25	0.30	0.20	0.30
537	0.40	0.35	0.35	0.40
550	0.495	0.502	0.499	0.505

If experiments are conducted using weak keys, these neutrality values can be preserved until the iteration process (550+162=712), which is necessary before the complete update of the algorithm's register values. In subsequent cycles, the neutrality values approach 0.5. This parameter provides tolerance in statistical cryptanalysis methods. Therefore, it is sufficient to conclude the resilience of the NHSA stream cipher to differential cryptanalysis from the 712th cycle of the initialization loop.

Resynchronization Attack on the NHSA Algorithm.

Another type of attack is the resynchronization attack, where an attacker is allowed to manipulate the IV value and tries to gain information about the key by checking the corresponding key stream. The NHSA algorithm attempts to prevent this type of attack by performing a sufficient number of iterations in the initialization process before generating the key used for encryption. It can be shown that each bit of the state is nonlinearly dependent on each key and IV bit after two full cycles (i.e., $2 \cdot 269$ iterations). It can be noted that an additional two cycles are sufficient to protect the cipher from resynchronization attacks.

NHSA is a simple synchronous stream encryption algorithm that is well suited for applications requiring flexible hardware implementation. Despite the general rule to avoid sparse update functions at each algorithm iteration, only a few state bits are used. As a result, prediction and attack detection are undoubtedly complicated. A direct attack involves guessing the common 128-bit secret key (presumably the open key IV). Further research is needed to determine the extent to which more complex attacks can reduce this number. The conducted studies are crucial to draw conclusions about its security compliance.

Since the NHSA algorithm is analogous to the Trivium encryption algorithm in terms of its operation and structure, the evaluation results of cryptanalysis methods were compared with the Trivium algorithm (Table 4).

Table 4: The evaluation results of the Trivium and NHSA algorithms for cryptanalysis methods are as follows.

Algorithm	**Trivium**	**NHSA (this case)**
Algebraic cryptanalysis	$2^{42.2}$ is unknown in the 625th iteration of the initialization cycle 110	2^{42} is unknown in the 550th iteration of the initialization cycle

Differential cryptanalysis	Resilient after the 961st iteration of the the initialization cycle.	Resilient after the 712th iteration of the initialization cycle.
Resynchronization attack	2^{80} need to choose	2^{128} need to choose
Correlational cryptanalysis	A key stream of 2^{144} bits is required to determine the correlation coefficient of 2^{-72}	A key stream of 2^{-144} bits is required to determine the correlation coefficient of 2^{288}

The results of evaluating sequences generated by the NHSA algorithm using NIST statistical tests for randomness.

The sequences generated using the mentioned key and IV in the NHSA algorithm were evaluated for randomness using NIST statistical tests. Below are the results of the approximate entropy test (Figure 1) and a total of 15 tests (Figure 2):

```
TEST: approximate_entropy_test
  n          =  2000000
  m          =  3
  Pattern 1 of 8, count = 249284
  Pattern 2 of 8, count = 250346
  Pattern 3 of 8, count = 249738
  Pattern 4 of 8, count = 250015
  Pattern 5 of 8, count = 250346
  Pattern 6 of 8, count = 249407
  Pattern 7 of 8, count = 250015
  Pattern 8 of 8, count = 250849
  phi(3)     = -4.382025
  Pattern 1 of 16, count = 124270
  Pattern 2 of 16, count = 125014
  Pattern 3 of 16, count = 124951
  Pattern 4 of 16, count = 125395
  Pattern 5 of 16, count = 125373
  Pattern 6 of 16, count = 124365
  Pattern 7 of 16, count = 124513
  Pattern 8 of 16, count = 125502
  Pattern 9 of 16, count = 125014
  Pattern 10 of 16, count = 125332
  Pattern 11 of 16, count = 124787
  Pattern 12 of 16, count = 124620
  Pattern 13 of 16, count = 124973
  Pattern 14 of 16, count = 125042
  Pattern 15 of 16, count = 125502
  Pattern 16 of 16, count = 125347
  phi(3)     = -5.075169
  AppEn(3)   = 0.693144
  ChiSquare =  11.61932763649176
  PASS
  P=0.16901368121036756
```

Figure 1: The calculated result of the entropy test.

```
SUMMARY
-------
monobit_test                              0.3828976248514478  PASS
frequency_within_block_test               0.6354841415737159  PASS
runs_test                                 0.48512504500511644 PASS
longest_run_ones_in_a_block_test          0.4084594094693384  PASS
binary_matrix_rank_test                   0.08050322562050827 PASS
dft_test                                  0.6543472577764083  PASS
non_overlapping_template_matching_test    1.00000828105159    PASS
overlapping_template_matching_test        0.03940335533694327 PASS
maurers_universal_test                    0.9991531960785148  PASS
linear_complexity_test                    0.6468061465110148  PASS
serial_test                               0.16944057962301154 PASS
approximate_entropy_test                  0.16901368121036756 PASS
cumulative_sums_test                      0.16791543598886172 PASS
random_excursion_test                     0.04385947941605159 PASS
random_excursion_variant_test             0.12339191184909339 PASS
```

Figure 2: Results of evaluation of NHSA algorithm by Nist statistical test.

From these results, it can be observed that the sequences generated using the NHSA algorithm meet the security requirements in terms of randomness.

7 SUMMARY

The description of the NHSA stream cipher algorithm, consisting of 3 shift registers with a total length of 269 bits, 6 AND gates, and 14 XOR gates, is provided. The evaluation results of sequences generated using the proposed algorithm in terms of randomness are presented, along with conclusions about the applicability of various cryptanalysis methods and information about the required hardware resources for implementing the algorithm.

It has been established that the NHSA encryption algorithm is resistant to algebraic cryptanalysis, differential cryptanalysis, correlation cryptanalysis, and resynchronization attacks. The sequences generated by the algorithm satisfy randomness criteria based on the evaluation of randomness levels using NIST statistical tests.

REFERENCES

SHnajer, B., 2003. Prikladnaya kriptografiya. Protokoly, algoritmy, iskhodnye teksty na yazyke Si. 816 b.

De Canniere, C., Preneel, B., 2008. Trivium – A Stream Cipher Construction Inspired by Block Cipher Design Principles.

Lano, J., Mentens, N., Preneel, B., Verbauwhede, I., 2004. Power Analysis of Synchronous Stream Ciphers with Resynchronization Mechanism. ECRYPT Workshop, SASC – The State of the Art of Stream Ciphers, pp. 327–333.

Knellwolf, S., Meier, W., Naya-Plasencia, M., 2010. Conditional Differential Cryptanalysis of NLFSR-Based Cryptosystems. In: Abe, M. (ed.) ASIACRYPT 2010. LNCS, vol. 6477, pp. 130–145. Springer, Heidelberg.

Knellwolf, S., Meier, W., Naya-Plasencia, M., 2011. Conditional Differential Cryptanalysis of Trivium and KATAN, 18th International Workshop, SAC 2011, Toronto, ON, Canada, August 11-12.

De Canni`ere, Ch., Preneel, B., 2008. Trivium. In New Stream Cipher Designs - The eSTREAM Finalists, pages 244–266.

Quedenfeld, F.-M., Wolf, Ch., 2014. Advanced Algebraic Attack on Trivium, Cryptology ePrint Archive.

Meiser, G., Eisenbarth, Th.,Lemke-Rust, K., Paar, Ch., 2008. Efficient implementation of eSTREAM ciphers on 8-bit AVR microcontrollers. 58 - 66.

Hitachi, Ltd., 2001. MUGI Pseudorandom Number Generator, Self-evaluation Report Ver. 1.1 12. 18, Copyright c 2001 Hitachi, Ltd.

Watanabe, D., Furuya, S., Yoshida, H., Takaragi, K., Preneel, B., 2002. A New Keystream Generator MUGI. In: Daemen, J., Rijmen, V. (eds) Fast Software Encryption. FSE 2002. Lecture Notes in Computer Science, vol 2365. Springer, Berlin, Heidelberg.

Dawson, E., Carter, G., Gustafson, H., Henricksen, M., Millan, B., Simpson, L., 2002. Evaluation of the MUGI Pseudo-Random Number Generator, Information Security Research Centre Queensland University of Technology, July 31.

Wong, K. K.-H., Carter, G., Dawson, E., 2010. An Analysis of the RC4 Family of Stream Ciphers against Algebraic Attacks, 8th Australasian Information Security Conference (AISC 2010), Brisbane, Australia.

Orumiehchiha, M.A., Pieprzyk, J., Shakour, E., Steinfeld, R., 2013. Cryptanalysis of RC4(n, m) Stream Cipher, Proceedings of the 6th International Conference on Security of Information and NetworksNovember. Pages 165–172.

Lee, J.-K., Lee, D.H., Park, S., 2008. Cryptanalysis of Sosemanuk and SNOW 2.0 Using Linear Masks, International Conference on the Theory and Application of Cryptology and Information Security. https://api.semanticscholar.org/CorpusID:18719819

Zaynalov, N. R., 2020. UNICODE For Hiding Information In A Text Document. 2020 IEEE 14th International Conference on Application of Information and Communication Technologies (AICT). C. 1-5.

Zaynalov, N. R., 2021. Analysis of the Frequency of Letters of the Uzbek Language Based on the Cyrillic Alphabet. 2021 International Conference on Information Science and Communications Technologies (ICISCT). C. 1-4.

Zaynalov, N. R., 2020. Combining Invisible Unicode Characters To Hide Information In A Text Document. JOIV: *International Journal on Informatics Visualization.* T. 4. №. 3. C. 148-153.

Zaynalov, N. R., 2020. Manipulating The Rotation Of Ms Excel Cells To Hide Information. *International Journal of Advanced Science and Technology.* T. 29. №. 8s. C. 2270-2273.

Rakhmatullaevich, R. I., Mardanokulovich, I. B., 2024. Analysis of cryptanalysis methods applied to stream encryption algorithms. Artificial Intelligence, Blockchain, Computing and Security Volume 1. CRC Press. C. 393-401.

Kilichev, D., 2024. Errors in SMS to hide short messages. Artificial Intelligence, Blockchain, Computing and Security Volume 2. CRC Press, C. 735-740.

Huang, J., Susilo, W., Seberry, J., 2010. Differential Fault Analysis of LEX. 6280. 55-72.

The Capabilities of the Platforms in the Assessment of Personnel

Natalia Yu. Sinyagina[1]
ANO «Center for Scientific and Practical Developments and expertise in the field of education», Moscow, Project Director
nsinyagina@yandex.ru

Key words: platform, platform capabilities, personal and professional assessment.

Abstract: The article analyzes the possibilities of Internet platforms in personnel assessment. On the basis of content analysis and analytical synthesis of scientific research, an overview of the features of personal and professional assessment of personnel online is given. The data on the use of intelligent software and new service developments are presented. The pros and cons of platform solutions are described. The prospects of using platforms in the activities of HR services are characterized.

1 INTRODUCTION

Modern personal and professional diagnostics and assessment in the field of management is aimed at selecting an effective leader and their team, determining their resources, development paths and the necessary education. Active digitalization, which is the main trend in this direction today (Sinyagina, 2021), has provided a lot of technological opportunities to organize such a process on Internet resources, where the software for diagnostic and assessment procedures can be conditionally divided into point and platform solutions that differ in a number of characteristics, but each of them has its own strengths and weaknesses. This determined the essence of this article: based on the analysis of foreign studies, to characterize the capabilities of Internet platforms in personnel assessment, to describe the pros and cons of platform solutions and the prospects for their use in the activities of HR services.

2 METHODS AND RESULTS

The study of the capabilities of Internet platforms in personnel assessment within the framework of this article is based on content analysis and analytical synthesis of scientific research in this area. The use of these methods makes it possible to identify and classify the features of personal and professional assessment of personnel online, characterize the pros and cons of its individual parts and suggest the prospects for using such diagnostics in the activities of HR services. We have identified and studied more than 30 studies. Some of them, which seemed the most interesting and significant, formed the basis of the article.

As we have already noted, the platform capabilities in personnel assessment are divided into point and platform solutions. The first (point solutions) are defined as systems and programs created to perform one task, providing, for example, only automation of the personnel assessment process. The advantages of this approach include the insignificant (limited) volume of the software package, which can speed up both the deployment and launch of such a resource and the diagnostic process itself. Also, this option is usually cheaper than others that the market offers. The disadvantages of point solutions include, first of all, the fact that they work only for the initially intended use (solving a single point problem). For other tasks, additional software is required, which accordingly requires new resources, interaction with other solutions and applications. Also, point solutions usually do not scale as the tasks grow (in our case, personnel assessment), because it is difficult for them to adapt to new factors that add additional levels to processes. It should also be taken into account that multi-point solutions are cumbersome, which can lead to a break in the

[1] https://orcid.org/0000-0002-4297-6672

connection between the components of the assessment.

Unlike point solutions, the use of a platform provides the basis for more multi-faceted tasks, mass and massive, yet flexible tools used in assessment that can replace almost any paper processes or repetitive tasks. These solutions have a wide range of customization options in their design, making them widely applicable.

The main disadvantage of a platform solution is the significant financial costs for a comprehensive set of tools, which usually entails a higher initial investment than buying just one point solution. The advantages of platforms exceed this disadvantage: platforms can be adapted to various industry requirements, integrations, rules or equipment, scale along with the growth of requests and with the expansion of tasks, meeting new needs and solving more complex problems. The flexibility of their software implementation allows for optimization over time or as needed depending on the results, and the entire process can be organized in a single software package, increasing the transparency and efficiency of interaction between all necessary components. This also makes it easier for new employees to start working: they will get involved in the work faster, since they will only need to learn one system of processes. Platforms also allow storing user data on cloud servers, which helps protect information from loss in case of local storage failures or accidental deletion, and, if there is an Internet connection, make data accessible from anywhere in the world.

The most important characteristic of any platform is the issues of privacy and data security. This is another important advantage of platforms over other similar Internet resources. This is why, in recent years, more and more organizations have been giving preference to platforms in solving their problems. According to the Gartner platform, by 2024, 30% of enterprises (compared to less than 5% in 2019) will use platform solutions to ensure the security of their data and expand their service capabilities more quickly.

The range of tasks solved with the help of platforms in the field of personal and professional diagnostics, which is the main one in personnel assessment today, includes various types of assessments, interpretation of their results by specialists, consultations with experts, development and training, sharing video content, building career paths, etc. (Sinyagin, 2020).

There are a number of requirements for platform solutions. It is believed that the user interface of a platform should be bright, attractive and easy to use. All its basic functions should be easily accessible, and the tool itself should be easy to use and master. The interface should also contain functions designed for diagnostic procedures, further support and training of personnel, increasing their involvement and productivity, providing users with a reliable and secure database of customers and employees and the ability to provide and receive timely feedback. Part of a good real-time HR assessment and management software is analytics and reports, which must be presented visually and contain all the necessary data. And a tool hosted on the platform to improve the user experience should provide seamless integration with third-party applications.

Platform solutions for personal and professional diagnostics and assessment procedures not only simplify the work of selecting, assessing and appointing specialists, and provide options for their development, but also make it possible to search for candidates. According to the data provided by the Criteria diagnostic platform, on average, at least 250 resumes are submitted for each open vacancy. Some job seekers send out their CVs through mass mailings without paying attention to the required qualifications or suitability for the job. These candidates spend an average of just 76.7 seconds reading each job description, and recruiters then report that more than 50% of job applicants do not meet the basic requirements outlined in the job description. Automation of the assessment and appointment of specialists can be of great value for organizations seeking to find suitable personnel and significantly facilitates the work of recruiters.

As for the Criteria company itself, it specializes in personal and professional diagnostics of specialists from 60 countries. There is a whole range of personality tests aimed at diagnosing different aspects of personality, assessing a wide range of skills and abilities: analytical abilities, behavioral traits, communication skills, personal qualities such as conscientiousness, creativity, critical thinking, extroversion and introversion, honesty, IQ, leadership, learning ability, grammar, mathematics, teamwork, etc. There are also recommendations on how to prepare for testing. With the help of assessment tools, including video interviews, it is possible to identify talented professionals, measure the qualities necessary for highly effective activities and constructive cooperation, which ultimately leads to an increase in the effectiveness of the organization. The answers of test takers are compared with the traits needed for success in different professional roles.

The Criteria platform also contains a wide range of tools designed specifically to identify key team attributes, determine who will make a good leader, etc.

A number of tests on the platform measure emotional intelligence, providing a reliable characterization of how a person perceives and reacts to certain situations in the workplace. This assessment is considered important because employees who score high on emotional intelligence share key traits that contribute to success and high performance, for example, they are 20% more likely to respond adequately to a crisis. They are also 18% more likely to maintain self-control under pressure from managers or colleagues and are just as open to other people's opinions and willing to seek compromise. They are also 23% more likely to be kind to colleagues and clients.

Like all other reputable platforms, Criteria adheres to the relevant state and professional standards and recommendations in the field of assessment. First of all, they are guided by UGESP - Uniform Guidelines on Employee Selection Procedures in the United States. As part of the UGESP requirements, special work is being carried out to improve the reliability of assessments. For this purpose, dynamic (repeated) testing and adaptive technology are practiced, which presents tasks to test takers depending on their level of abilities, which improves the quality of assessment and allows for more accurate results.

The platform also describes risks and ways to describe "invalid" results (when a subject gives inconsistent or distorted answers) in different sections, allowing employers to make more informed hiring decisions or consider retesting.

In terms of security, a number of measures are applied here to reduce the vulnerability of IT systems and databases. To this end, Criteria adheres to the CCPA (California Consumer Privacy Act) and, since the platform has many European customers, GDPR (General Data Protection Regulation) compliance is mandatory. For example, it provides for the use of a minimum amount of personal information from the test taker. The Criteria platform is one of the most modern online resources for personal and professional diagnostics, assessment and development of specialists and job candidates.

Another well-known and popular international consulting firm with a similar platform in the field of leadership assessment and support is DDI (Development Dimensions International). The services of this platform are presented in three areas: 1) assistance in hiring and supporting the specialists the company needs (comprehensive support for growth from aspiring leaders to top managers), 2) identification and promotion of the best talent (based on assessment and analysis) and 3) development of leaders (education and training) so that they succeed now and in the future. All technologies presented on the DDI platform contain a range of solutions that can be combined individually to achieve specific customer goals.

The leadership exam on the platform includes a series of tests to assess different aspects of personality, the severity of leadership qualities and an assessment of leadership potential, which is also carried out on the "Leadership Career Battery" (LCB). This test is effectively used both at the initial stage of the recruitment process to assess new job candidates, and for working employees wishing to receive a promotion. LCB has proven its ability to accurately predict not only productivity of employees, but also the time period between hiring and the onset of productivity.

Work-related behavioral abilities are measured on the DDI platform using the Leadership Readiness Assessment (LRA) test. Another test, the Leader 3 Rating (L3R), is designed to identify mid-level leaders who are ready to take the next step and become managers. The test results help determine the necessary development plan for such specialists, which will allow them to improve their skills.

The two key aspects of personal qualities identified by DDI as essential for successful work in leadership positions include:

1. Personal Competence Assessment - assessed using DDI leadership tests based on the candidate's past experience. The subfactors that make up this characteristic include an assessment of: initiative; work experience; effectiveness of previous work in leadership

positions; characteristics of basic and additional education; focus on the need to develop new skills, such as mastering new technologies, computer applications, etc.

2. Study of judgments and decision-making methods – assessment of ways to solve problematic issues related to a specific job. Situations on interpersonal relationships are offered, the ability to control oneself, manage others and interact with them is tested. As a result, the following are assessed: attitude (positive, negative, not identified), decision-making style, dispositional stability, and constructiveness of communication.

DDI also developed Targeted Selection, a system for assessing candidates through interviews, as this is the most common method in the recruitment process. This platform offers a very solid content for training employees (Edge Training section) for their development.

Thus, modern technologies of personnel assessment are based on a number of technological solutions. One of such productive solutions is the capabilities of Internet platforms.

3 CONCLUSION

As our analysis has shown, platform solutions are increasingly being used in management, working with schemes and processes and providing tools to help organizations achieve their goals and objectives. Today, using the platform is one of the best ways for HR specialists in any industry to stay abreast of new trends, keep up with best practices, and implement digital technologies for assessing and developing specialists, including for management positions (Sinyagina, 2021). The conducted research is aimed at improving the personnel assessment system. Its results can be used in the activities of HR services.

REFERENCES

Diagnostics and professional development of public service management personnel: methodology and technologies: a collective monograph / [Yu. K. Barkova et al.]; under total. scientific ed. by Yu. V. Sinyagin. Moscow: Publishing house "Delo" RANEPA, 2021. 354c.

Sinyagin, Yu.V, 2020. Questionnaire for assessing managerial potential in complex personal and professional diagnostics. Moscow: Publishing House «Delo». RANEPA. 186 p.

Sinyagina, N.Y., 2021. Psychobiographical factors and predictors of the formation of individual psychological and personal characteristics (review of foreign studies). Education and self-development. Volume 16. No. 1. pp.102-115.

Assessing Data Silos: The Good, The Bad, and The Ugly. URL: https://www.protegrity.com/resource-center/assessing-data-silos-the-good-the-bad-and-the-ugly (дата обращения 14.09.2023).

Data Privacy Policy: What It Is & Why You Need One. URL: https://segment.com/resources/data-privacy/why-your-company-needs-a-data-privacy-policy/?utm_campaign=gg_nam_dg-all_search_generic_acquisition&utm_source=google&utm_medium=cpc&utm_content=data_privacy&utm_term=data%20protection&gclid=EAIaIQobChMI-vKZnePS9gIVCw2tBh1yXwWkEAAYAiAAEgIF0_D_BwE (дата обращения 09.09.2023).

California Consumer Privacy Act (CCPA). URL: https://oag.ca.gov/privacy/ccpa (дата обращения 09.09.2023).

Gartner Privacy Policy. URL: https://www.gartner.com/en/about/policies/privacy (дата обращения 27.12.2023).

Level up your team's performance. URL: https://www.criteriacorp.com/benefits/team-performance (дата обращения 18.12.2023).

Personality Tests. URL: https://www.criteriacorp.com/assessments/personality-tests (дата обращения 18.12.2023).

Platforms vs Point Solutions: Weighing Your Options. URL: https://www.docuphase.com/blog/point-solutions-v-platform-solutions (дата обращения 09.09.2023).

Sinyagina, N., 2021. New Trends in HR Technologies: overview of foreign studies. 01033. Published online: 04 May 2021. SHS Web of Conferences 103, 01033. Russian and Foreign Experience in the System of Humanities Education 2020 https://doi.org/10.1051/shsconf/202110301033

Uniform Guidelines. URL: https://www.uniformguidelines.com/uniform-guidelines.html (дата обращения 17.12.2023).

What are Pre-Employment Tests? URL: https://www.criteriacorp.com/resources/definitive-guide-validity-of-preemployment-tests/what-are-pre-employment-tests (дата обращения 15.12.2023).

Your Partner for Every Moment of Leadership. URL: https://www.ddiworld.com/ (дата обращения 11.12.2023).

The Concept of Change Management in the Marketing Activities of Enterprises

Berkutova T.A.[1] [1], Ivanova T.N.[2] [2], Yakimovich B.A.[3] [3]

[1]Doctor of Economics, Associate Professor, Chief Researcher, Federal State Unitary Enterprise "All-Russian Scientific Research Institute "Center"; Russian Federation, 123242, Moscow, Sadovaya-Kudrinskaya Street, 11/1

[2]Doctor of Engineering Science, Associate Professor, Professor of the Tchaikovsky branch of the Federal State Autonomous Educational Institution of Higher Education "Perm National Research Polytechnic University", 617764, Perm Territory, Tchaikovsky, Lenina str., 73, Federal State Budgetary Educational Institution of Higher Education "Udmurt State University"; Russian Federation, 426034, Izhevsk, Universitetskaya str., 1

[3]Doctor of Engineering Science, Professor, Professor of the Federal State Budgetary Educational Institution of Higher Education "Izhevsk State Technical University named after M.T. Kalashnikov"; Russian Federation, 426069, Izhevsk, Studencheskaya st., 7

tberkutova@yandex.ru, tatnic2013@yandex.ru, yakimovich52@gmail.com

Keywords: marketing activities, changes, management, concept.

Abstract: In the context of the formation of technological independence of Russia, the most important task is to ensure the market orientation of the production capabilities of domestic enterprises of the military-industrial complex. Possessing significant scientific, technological, production and personnel potential, they are capable of implementing large-scale goals for the production of high-tech civilian and dual-purpose products aimed at achieving the goals of import substitution and overcoming the sanctions regime against the Russian Federation. Without transformations in marketing activities at enterprises of the military-industrial complex, it is impossible to solve the set strategic tasks, which makes the task of change management relevant in terms of practical use. The article presents the proposed concept of managing changes in the marketing activities of enterprises. The author's interpretation of change management in the marketing activities of enterprises is proposed. The concept of "resource potential of change management in the marketing activities of enterprises" is introduced. The areas of change in marketing activities are defined. The principles of change management in marketing activities are formulated. The proposed change management concept takes into account the main components necessary to identify and implement effective changes, the targeted nature of marketing and business changes, coverage of all levels of marketing activities; and the relationship with the internal and external environment of an enterprise.

1 INTRODUCTION

The main tasks of change management in marketing activities are to coordinate the work of an enterprise with the state and development of the external environment, the selection and timeliness of changes, the coordination and approval of changes in marketing and an enterprise.

The goals of change management in the marketing activities of enterprises reflect its results *and* can be formulated as follows:

- improving the effectiveness of marketing activities, ensuring its compliance with the conditions of the external and internal environment of an enterprise based on the development of strategic marketing, changes in marketing policy and marketing management, transformations at the level of operational marketing activities;
- improving the efficiency of an enterprise, ensuring that the business meets the conditions of the external environment through developing of marketing factors of business value (marketing

[1] https://orcid.org/0000-0003-3357-7845
[2] https://orcid.org/0000-0003-2284-2949
[3] https://orcid.org/0000-0001-7363-1071

intangible assets, business partnerships), developing the orientation of all enterprise activities towards meeting market needs, and integrating marketing into the strategic management of an enterprise.

Achieving the stated goals makes it possible to increase the effectiveness of marketing activities and business.

However, it should be borne in mind that until a systematic marketing activity is organized at an enterprise, management cannot obtain reliable information about the state of markets, consumer and buyer preferences regarding the company's goods and the competitive environment and correctly determine the directions of changes in business strategies and goals, ways of its organization and development.

2 RESEARCH METHODS

The methodological basis is the traditional methods of scientific analysis, methods of economic and mathematical statistics, technical, economic and logical analysis, systematization and ranking.

The purpose of the study is to develop a concept for managing changes in the marketing activities of enterprises.

Tasks to be solved aimed at achieving the purpose. The study of the theory and methodology of change management, the genesis of the development of marketing activities in the context of the formation of business efficiency and the content of the effectiveness of marketing activities allows us to formulate the following conceptual provisions of change management in marketing activities:

1. **Setting goals for changes in marketing, defining the relationship between marketing activities and other enterprise systems, and allocating responsibilities.** Changes in marketing activities will bring results only with corresponding changes in decision-making mechanisms and the system of interactions at the tactical and strategic levels of other enterprise subsystems. Thus, the creation of a marketing information system will not bring results if such information is not used by the production, logistics, technological, economic and other services of an enterprise when creating goods, pricing them, bringing them to consumers, and forming enterprise strategies. At the same time, adequate mechanisms for allocating responsibility should be used, assuming that responsibility and authority are assigned to officials not only in the marketing service, but also in other services. The use of such mechanisms will result in the emergence of obligations on the part of the subsystems of an enterprise. Before proceeding with changes, it is necessary to determine not only what exactly needs to be transformed, but also why it is being done, that is, what results will be achieved in the future thanks to these transformations.

2. **Changes in marketing activities are aimed at increasing the organization, consistency and manageability of the marketing system and a business as a whole, taking into account the characteristics of the dynamics of the external environment.** The changes should ensure an increase in the consistency of subsystems both within marketing activities and the consistency of the marketing system with the business system as a whole. Marketing functions performed at the strategic level should be interconnected with the goals, strategies and structures of tactical and operational marketing. Marketing transformations are aimed at eliminating duplicative relationships, increasing efficiency in making management decisions, creating a mobile and adaptive business structure, which implies an increase in the organization and manageability of the system as a whole. The goal of strategic transformations is to increase the adaptability and mobility of the business, and its achievement is related to the level of manageability and consistency of an enterprise.

3. **Change management in marketing activities is carried out on the basis of an integrated approach** involving the formation of a single coordinated system of interdependent changes, both in marketing and in other enterprise systems (Berkutova, 2014). The program of changes in marketing activities should be accompanied by the formation of corresponding programs for other departments that use the results of the marketing service or participate in their formation.

4. **Marketing activities in the process of change management are considered in three aspects**: as a system for creating business efficiency, as a system of relationships with stakeholders and as a function of an enterprise. This approach allows, on the one hand, to develop a business at the level of interaction between enterprise management and strategic marketing, and on the other hand, to maintain the effective current functioning of an enterprise in existing markets. Improving the effectiveness of marketing activities requires coordination of actions at the operational, tactical and strategic levels of marketing. Thus, the absence of a tactical level of marketing will not allow to organize effective sales and communication activities even with correctly selected markets and products. The development of a marketing policy in this case should

determine the direction of sales and communications and the main criteria for choosing distribution and promotion channels.

5. **The choice of areas, directions and objects of change, both in marketing activities and in business, is carried out as a result of diagnostics**, involving an assessment of the effectiveness and efficiency of marketing activities and business, as well as an analysis of the external environment of an enterprise. In the diagnostic process, it is necessary to link the required changes in the marketing system with the planned results of the enterprise's market activity (market share, sales volumes, profit).

6. **The main components of the change management system in marketing activities are**:

- diagnostics of contradictions (problematic situations) in marketing and business;
- the changes themselves, aimed at reducing, eliminating or preventing these contradictions;
- the mechanism for implementing the changes;
- the resource potential of an enterprise for implementing the changes;

The purpose of diagnostics is to identify local and systemic contradictions in the marketing activities of an enterprise and in business. "In the theory of change management, there are local and systemic types of contradictions. Local contradictions are a non-equilibrium state of the system, in which only certain characteristics of the system lose quality, which leads to a deviation of the behavior model from the optimal one or the consolidation of an ineffective norm, but at the same time the system functions within the boundaries of its effectiveness. Systemic contradictions are a non-equilibrium dynamic state of a system in which the main elements of this system are ineffective. In the case of a systemic contradiction, the decline in the efficiency of individual subsystems increases to such an extent that the introduction of even radical local changes cannot change the course of development of the economic system" (Berkutova, Revenko, 2014). The system no longer meets the requirements of the environment. Systemic contradictions are expressed in the loss of adaptability of the system (Kone, 2018).

Contradictions are the driving force behind business development (SHepelenko, 2009). The sources of contradictions are found both in the external and internal environment of enterprises. External sources are related to changes in the market situation, while internal sources are related to changes in the internal environment of an enterprise, the complexity of processes, changes in goals and strategies, changes in interactions between personnel, top management, investors, shareholders and other stakeholders.

The main contradictions in a business and marketing activities are:

- contradiction between the state of a business and the characteristics of the external environment. This situation is observed when an enterprise cannot adapt to the changed market conditions in time. In this case, the contradiction is systemic;
- contradiction between the state of the marketing activity of an enterprise and the external environment, which arises when the marketing system at an enterprise does not correspond to the established market conditions and does not contribute to the development of adaptation, mobility and the strategic nature of the business. The contradiction is systemic in nature and manifests itself at the strategic and tactical levels of marketing activities;
- contradiction between the marketing system and the business system, which arises when the state of the marketing activity of an enterprise does not allow it to achieve its market goals and implement its strategies. The nature of the contradiction is systemic, the levels of marketing activity at which the contradiction manifests itself are tactical and strategic;
- contradictions within the marketing system at an enterprise, due to the state of its individual components, which does not allow effectively achieving the goals of marketing activities. Such contradictions are local in nature within the operational, tactical and strategic levels of marketing activities.

The elimination of systemic contradictions is associated with qualitative transformations in marketing activities and business, and the elimination of local contradictions leads to local transformations in marketing activities and subsystems of an enterprise. The types of contradictions in marketing activities and a business are shown in Fig. 1.

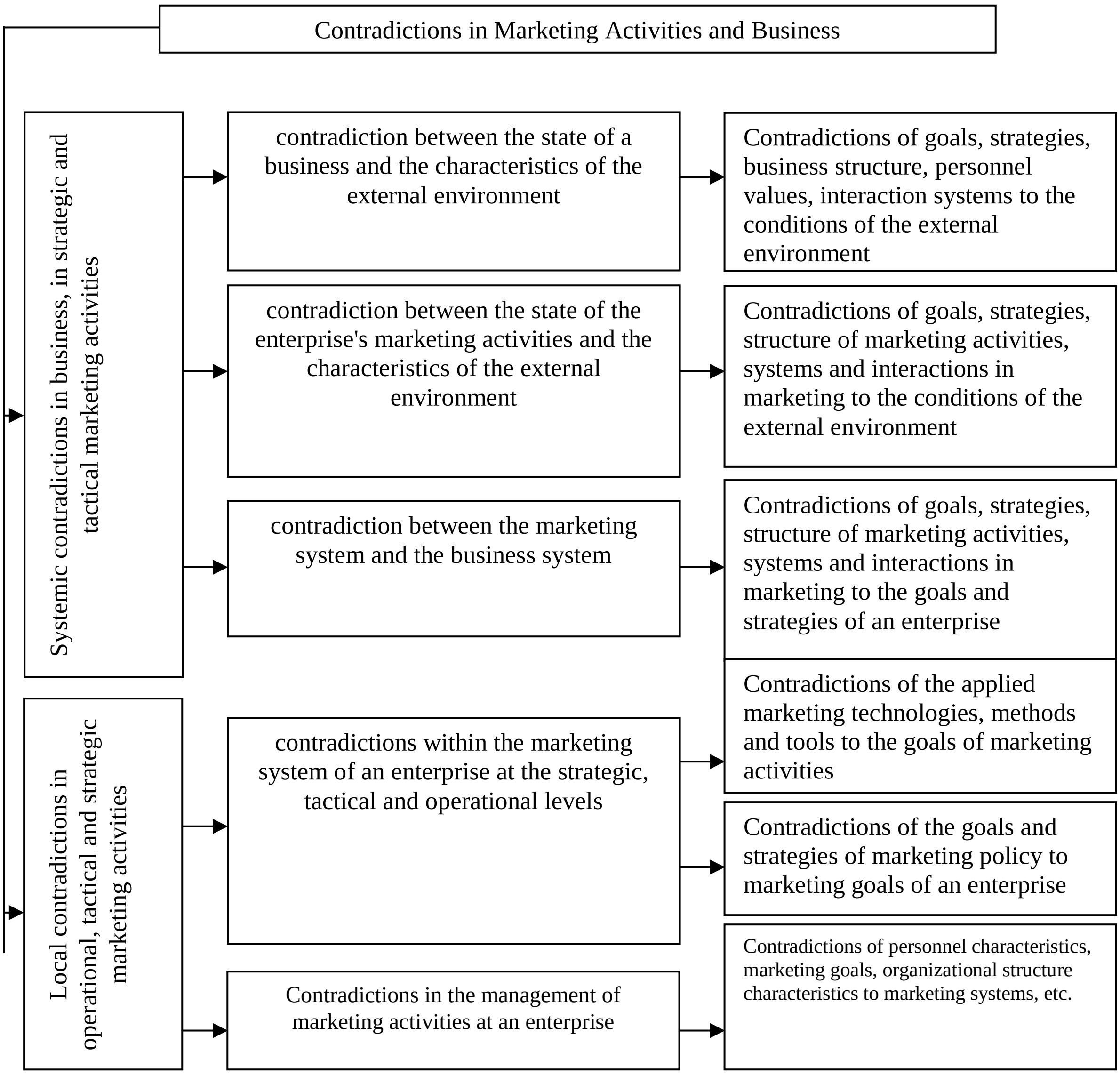


Figure 1: Classification of contradictions in marketing activities and business. *Source: according to 2, p. 98.*

In change management theory, the main focus is on the influence of organizational and managerial resources (organizational potential) on the success of transformation. In scientific and practical literature, the understanding and content of organizational potential is interpreted in different ways. M.V. Smirnova considers organizational potential "as a set of elements and mechanisms that ensure the ordering, coordination and effective use of the potential and resources of an enterprise, achieving dynamism, sustainability and its development based on modern management methods, including program-targeted and systemic approaches" (Smirnova, 2011). P.P. Taburchak defines organizational potential "as the total maximum possible organizational ability of an enterprise to comprehensively optimize the interaction of its structural elements and ensure the effective functioning of an enterprise in solving production tasks" (Taburchak, Mikitas', 2012). The result of any changes is largely determined by the state and level of enterprise resources involved in the process of transformation.

The definitions of the organizational potential of an enterprise include: “the total capabilities of the management staff, expressed in the volumes and types of work that the management of an enterprise can perform”, "the potential of the organizational structure and technical equipment of managerial work and information support", "the ability to make decisions and appropriate resources", "a complex set of interrelated elements that make up an organization, which includes a system of values, structure, personnel, information, processes, procedures, as a basis for the formation of changes to resolve contradictions, as the ability to overcome contradictions" (Taburchak, Mikitas', 2012; Taburchak, Mikitas', 2012; Berkutova, 2018; Petrov, 2015; Tret'yakova, Kuvshinov, 2017; SHirokova, 2013; SHirokova, Bystrova, 2014; Korotkov, 2015).

As M.V. Smirnova points out, “the potential of any enterprise lies in its resources, both production and financial. None of these resources will take effect on their own until they are put into action rationally, purposefully, in accordance with the mission and objectives for the implementation of the mission and goals. Such a mechanism capable of activating all resources is management, its qualitative characteristics and a number of organizational principles embedded both in the structure of an enterprise and in the personnel. The capabilities of these mechanisms are determined by the organizational potential aimed at improving the quality of management” (Smirnova, 2011).

The organizational potential of an enterprise is the source of its capabilities. The state of organizational potential is largely determined by the stage of the enterprise's life cycle.

Depending on the object, the organizational potential, according to different sources, includes innovative, human, production, technological, financial and other resources of an enterprise. A.V. Pavlova considers "the following elements of organizational potential:

- enterprise management system (management potential, its level of innovation);
- system of values;
- enterprise personnel management system (key competencies, level of qualification, level of innovation);
- information and communication system of an enterprise (interactions, knowledge, propensity for knowledge transfer)” (Pavlova, 2012).

P.P. Taburchak identifies enlarged blocks of organizational potential: labor (personnel), financial (economic), production, marketing, innovation (Taburchak, Mikitas', 2012; Taburchak, Mikitas', 2012).

M.V. Smirnova “includes the following elements of organizational potential:

- management potential;
- potential of the organizational structure of an enterprise;
- potential of organizational culture;
- key competencies of personnel, level of qualification and labor productivity;
- innovative potential of the enterprise personnel;
- level of management innovation;
- innovative potential of an enterprise” (Smirnova, 2011).

The study of the objects of changes in marketing activities, as well as interrelated objects of transformations in an enterprise, allows us to state that the changes being implemented are not limited to the use of organizational resources only. Managing changes in marketing activities requires the involvement of financial, material, information and production resources, which makes it possible to characterize their totality as a resource potential (Okorokova, 2010).

Thus, within the framework of this work, it is advisable to introduce the concept *of* ***resource potential for managing changes in marketing activities*** *as a set of organizational and managerial mechanisms and enterprise resources necessary for implementing changes in marketing and interdependent changes in business.* In this case, it is advisable to include in the resource potential:

- “managerial potential, determined by the ability of managers at various levels to make and implement management decisions in marketing activities and at an enterprise as a whole, the level of innovation of managers (the ability to perceive innovations and apply them in the development and implementation of decisions);
- personnel of the marketing service and an enterprise as a whole, determined by the composition of the key competencies of the employees of the service and the enterprise, the degree of innovation of employees, the presence of leaders capable of making changes;
- information and communication system of an enterprise that determines the nature of information interactions between employees, the availability of the necessary information for employees and managers when making decisions. Information support implies, in addition to creating and having the necessary search systems and information bases, the wide dissemination of information about the goals of changes, the progress of their implementation, and the results of intermediate stages” (Berkutova, 2018);
- financial resources necessary for the transformation of marketing activities and related transformations in an enterprise. In this context, both current and investment resources should be taken into account;
- production and technological resources used in the process of coordinated changes in enterprise

subsystems. It is advisable to include production equipment, the availability of proven technological processes, and the availability of innovative technologies in such resources.

In this context, management potential forms the mechanisms for transforming all other resources in order to increase the effectiveness of marketing at an enterprise (Fig. 2).

"Resource potential is characterized by exogenous and endogenous components ("intra-organizational potential" and "extra-organizational potential")" (Berkutova, 2018). "Depending on the state and dynamics of these components, as well as on the nature of the problem situation, various change management mechanisms can be formed" (Sokolov, 2015; Adizes, 2017; Glushakov, 2011).

The availability of resource potential and the possibility of attracting it from the external environment of an enterprise are largely determined by the stage of the life cycle of this enterprise. The further the enterprise is from the growth stage, the lower its internal potential for change.

The formation of a change management system requires detailing of each component, research and formalization of their interrelations, and coordination of management influences.

7. **Managing changes in marketing activities requires differentiating changes by scale: local and systemic in terms of their impact on qualitative changes in a business as a whole**. The scale of changes determines the composition of the resources involved in the transformation, the levels of changes (personal, team, corporate), the composition of officials and departments participating in changes, the scope of obtaining the results of changes, the qualitative and quantitative composition of the results.

8. **The focus of changes on improving efficiency involves taking into account aspects of efficiency, both in marketing activities and in a business as a whole.** This makes it possible to ensure business development, increase its scale, and expand strategic business zones based on improving the effectiveness and efficiency of marketing activities.

9. **Managing changes in marketing activities should be accompanied by an adequate policy regarding the resource potential of an enterprise.** Changes should not harm the potential of existing enterprise systems. The change management process involves determining the composition of resources for implementing changes, determining the sources of resources and time intervals for using resources.

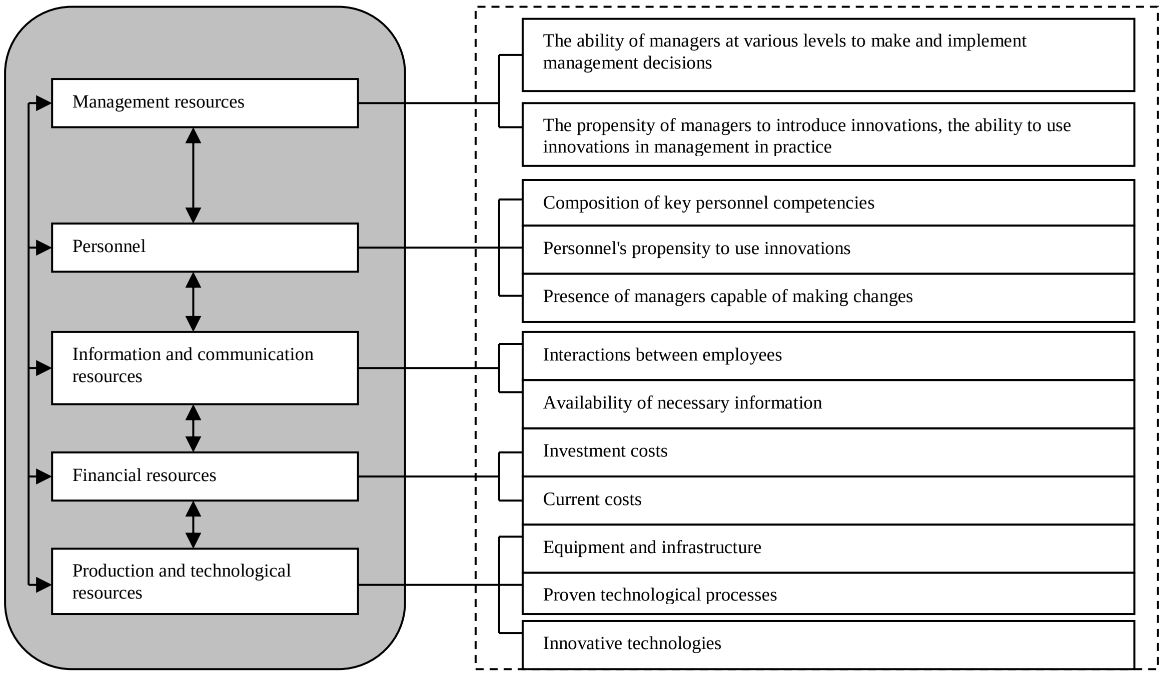


Figure 2: Composition of resource potential for managing changes in marketing activities. *Source: according to 8, p. 53.*

The development of a change management methodology involves the formation of a system of principles. The principles of change management in marketing activities should take into account the general principles of change management at an enterprise, the specifics of marketing activities that make up its effectiveness, the role of marketing in shaping business efficiency and establishing relationships with the internal and external environment of an enterprise.

From the point of view of the specifics of marketing activities, when formulating principles it is necessary to take into account the focus on achieving consumer satisfaction and enterprise goals; parameters of market conditions; marketing coverage of all processes of the enterprise (product development, design, testing, promotion, sales); integration of marketing with the strategic management of the enterprise, strategy formation and management of the enterprise based on marketing information; coordination of interests of interested groups; formation of interactive relations of the enterprise with participants of the external environment.

The conducted research of the theory and methodology of managing organizational change, as well as the systematization of changes in marketing, made it possible to propose the author's interpretation of change management in the marketing activities of an enterprise: ***change management in the marketing activities of an enterprise*** *is a targeted, organized process of transformation of tactical, operational and strategic marketing, based on the results of diagnostics, carried out in order to ensure compliance of marketing activities and enterprises with the conditions the external environment based on the development of marketing factors of business value, the integration of marketing into the strategic management system of the enterprise, structural and technological transformations of marketing, changes in its goals, strategies, systems and relationships, taking into account the implementation of interdependent changes in the enterprise.*

The analysis of the theory and methodology of change management allows us to formulate the following *principles of change management in marketing activities:*

- *consistency of changes in marketing activities and related changes at the enterprise.* The principle assumes that changes in marketing should be carried out unidirectionally and simultaneously with the corresponding changes in the enterprise. Failure to change the enterprise in response to changes in marketing will not lead to increased efficiency;

- *consistency of changes in tactical, operational and strategic marketing at the enterprise*. Autonomous development of various levels of marketing does not contribute to increasing its efficiency. Thus, the development of the strategic function is impossible without adequate changes in the analytical function of marketing and the establishment of effective relationships between participants in the marketing processes at the enterprise. The development of a sales policy will not yield results in the absence of a communication policy;

- *compliance of changes with the conditions of the external environment of an enterprise*. The focus of changes on improving efficiency implies an increase in the ability of an enterprise to adapt to market conditions, therefore the sources of the ongoing transformations must be in the external environment. Given the dynamic nature of the external environment, the directions of changes should be determined on the basis of forecasting markets and an enterprise's macroenvironment;

- *consistency with the current activities of an enterprise*. Making changes in marketing activities should not lead to an imbalance in the subsystems of an enterprise;

- *measurement of the results of changes*. This principle assumes a formalized description of the intermediate and final results of changes, the need to monitor them throughout the entire process of implementing changes;

- *the focus of changes on achieving consumer satisfaction*. Achieving the commercial goals of an enterprise, such as increasing the volume of sales of goods, ensuring the stability of financial flows, and making a profit is possible only if the goods and services produced are in demand by the market, that is, they meet the needs of final and intermediate consumers;

- *consistency of changes with the resource potential of an enterprise*, assuming the availability or possibility of attracting all necessary resources for making changes;

- *consistency of interests of stakeholders in the process of change.* This principle assumes that the changes affect the interests of various groups – enterprise personnel, managers, stakeholders. At the stage of preparing changes, it is necessary to determine the opinion of different stakeholders on the appropriateness *and* necessity of changes, the results of changes, to assess the degree of resistance to changes, the causes of resistance and methods of overcoming resistance to changes;

- *systemic nature of change management*. Marketing activity is a complex system that functions as a subsystem of an enterprise, taking into account the characteristics of the internal and external environment (Kotler, 2018). This determines the diversity of the composition of the objects of change and the relationships between them and the external environment of an enterprise, which should be taken into account when managing changes;

- *personnel involvement*. Changes cannot happen without the participation of personnel. The desire of employees to change their activities is of great importance for implementing changes, and significant resistance to changes will not allow achieving optimal results when implementing them. Therefore, in the process of transformation it is necessary to develop the understanding of personnel, create conditions for teamwork, work with opinion leaders, and ensure personnel awareness;

- *coordination of changes* implies that change programs for various processes, systems, technologies (both marketing and non-marketing) should be mutually coordinated in terms of the timing of changes and their composition. This necessitates the formation of an organizational change management mechanism and a specialized structure for the coordination and management of the transformations being carried out;

- *the relevance of changes* implies that the changes should be timely and lead to the solution of current and future problems of an enterprise. The implementation of changes should take into account the time factor of the effect of the results of changes, as well as the need to comply with the deadlines for completing the changes.

3 RESULTS OF THE STUDY

Based on the developed methodological aspects, the author's concept of change management in marketing activities is proposed (Fig. 3).

The choice of areas and directions of changes is based on the results of diagnostics of marketing activities at an enterprise. Making a diagnosis involves determining: the problem, the causes of the problem, other significant connections, the ability of an enterprise to resolve the problem, and directions for further action. The choice of diagnostic methods should ensure the reliability of the information used and the comprehensiveness of the diagnostics (Berkutova, 2014).

The results of the analysis of the theory of change management, the role of marketing activities in the formation of the effectiveness of an enterprise, as well as the interdependent nature of changes in an enterprise and marketing allow us to identify the following *areas of changes in marketing activities:* business adaptability; strategic enterprise management; partnerships; marketing intangible assets; marketing information systems; operational and tactical marketing activities.

The result of interdependent changes in marketing activities and at an enterprise is an increase in efficiency due to the formation of marketing intangible assets, partnerships, ensuring the stability of financial flows of an enterprise in the strategic period, reducing risks, increasing the competitiveness of goods and an enterprise, and increasing the efficiency of operational marketing of an enterprise.

4 CONCLUSIONS

The developed concept of change management takes into account the main components necessary for identifying and implementing effective changes, the targeted nature of marketing and business changes, coverage of all levels of marketing activities; and the relationship with the internal and external environment of an enterprise.

Objectives of change management in marketing activities:

Improving the efficiency of marketing activities of enterprises, ensuring its compliance with the conditions of the external and internal environment of an enterprise

Increasing the efficiency of an enterprise due to marketing factors of the formation of business value and the integration of marketing with strategic management

The main ideas of the concept

- setting goals for changes in marketing, defining the relationship between marketing activities and other enterprise systems, and allocating responsibilities;
- changes in marketing activities are aimed at increasing the organization, consistency and manageability of the marketing system and a business as a whole, taking into account the characteristics of the dynamics of the external environment;
- change management in marketing activities is carried out on the basis of an integrated approach involving the formation of a single coordinated system of interdependent changes, both in marketing and in other enterprise systems;
- marketing activities are considered in three aspects: as a system for creating business efficiency, as a system of relationships with stakeholders and as a function of an enterprise.
- the choice of areas, directions and objects of change is carried out as a result of diagnostics (evaluation of marketing activities and business and analysis of the external environment of an enterprise);
- managing changes in marketing activities requires differentiating changes by scale: local and systemic in terms of their impact on qualitative changes in a business;
- the focus of changes on improving efficiency involves taking into account aspects of efficiency, both in marketing activities and in a business as a whole;
- managing changes in marketing activities should be accompanied by an adequate policy regarding the potential of an enterprise.

Principles of change management in marketing activities:

- consistency between changes in marketing activities and changes at the enterprise;
- consistency of changes in tactical, operational and strategic marketing;
- compliance of changes with the conditions of the external environment of an enterprise;
- consistency of changes with the current activities of an enterprise;
- measurement of the results of changes.
- coordination of changes;
- focus on achieving customer satisfaction;
- consistency of changes with the resource potential of an enterprise,
- consistency of interests of stakeholders in the process of change;
- systemic nature of change management;
- involvement of personnel in changes.
- relevance of changes

Types of changes:

- local changes in marketing activities;
- systemic changes in marketing activities;
- systemic (qualitative) changes at an enterprise

Areas of change:

- business adaptability and mobility, profitability;
- strategic marketing (network interactions, marketing intangible assets, integration with strategic management);
- operational and tactical marketing;
- marketing information systems;
- marketing management.

Objects of changes:

- goals and strategies;
- organizational structures;
- systems;
- relationships;
- tools, methods and technologies;
- personnel.

Results:

- increasing the strategic and operational efficiency of marketing activities (increasing financial returns, developing intangible assets and partnerships, integrating with strategic management at an enterprise);
- increasing the efficiency of an enterprise (increasing adaptability, flexibility, expansion of strategic business areas, stability of financial flows);
- reduction of risks;
- increasing the competitiveness of goods and an enterprise.

Figure 3: Concept of change management in the marketing activities of an enterprise. *Source: developed by the authors.*

REFERENCES

Berkutova, T.A., 2014. Kompleksnyj podhod k povysheniyu effektivnosti marketingovoj deyatel'nosti predpriyatij na osnove teorii i metodologii upravleniya izmeneniyami. *Vestnik IzhGTU imeni M.T. Kalashnikova.* № 1 (61). S. 94-97.

Berkutova, T.A., Revenko, N.F., 2014. Instrumenty diagnostiki marketingovoj deyatel'nosti predpriyatiya v processe upravleniya izmeneniyami. *Vestnik IzhGTU imeni M.T. Kalashnikova.* № 1. S.97–101.

Kone, A.N., 2018. Upravlenie organizacionnymi izmeneniyami: povedencheskij i informacionnyj aspekty. Monografiya. Saratov: Izd-vo Vuzovskoe obrazovanie, 137 s.

SHepelenko, G.I., 2009. Protivorechiya kak vnutrennij istochnik razvitiya malogo predprinimatel'stva. *Vestnik RGEU «RINH».* №2. S.23-29.

Smirnova, M.V., 2011. Organizacionnyj potencial predpriyatiya … kak osnova ego strategicheskogo razvitiya. Vestnik SPbGU tekhnologii i dizajna. Seriya 3: Ekonomicheskie, gumanitarnye i obshchestvennye nauki. № 1. S. 14-16.

Taburchak, P.P., Mikitas', M.A., 2012. Mekhanizm vliyaniya organizacionnogo potenciala na effektivnost' deyatel'nosti promyshlennyh predpriyatij. *Ekonomika i upravlenie,* № 12 (86). S. 66-71

Taburchak, P.P., Mikitas', M.A., 2012. Mekhanizm ustojchivogo razvitiya predpriyatiya s ispol'zovaniem ego organizacionnogo potenciala. *Upravlenie ekonomicheskimi sistemami: elektronnyj nauchnyj zhurnal,* № 4 (40). S. 84.

Berkutova, T.A., 2018. Resursnyj potencial predpriyatij oboronno-promyshlennogo kompleksa v usloviyah voenno-grazhdanskoj integracii. *Vestnik IzhGTU imeni M.T. Kalashnikova,* №4. S.51–59.

Berkutova, T.A., 2018. Pokazateli effektivnosti diversifikacii predpriyatij oboronno-promyshlennogo kompleksa. *Vestnik IzhGTU imeni M.T. Kalashnikova*. T. 21. № 3. S. 136-141.

Petrov, K.N., 2015. MVA dlya chajnikov: [perevod s anglijskogo]. 336 s.

Tret'yakova, E.P., Kuvshinov, M.S., 2017. Organizacionnyj potencial kak sredstvo upravleniya ustojchivym funkcionirovaniem proizvodstvennyh organizacij. *Vestnik YUUrGU. Seriya Ekonomika i Menedzhment*. Том 11. №3. S.126-134.

SHirokova, G.V., 2013. Podhody k provedeniyu organizacionnyh izmenenij v rossijskih kompaniyah. *Vestnik SPbU. Menedzhment*. № 3. S. 76

SHirokova, G.V., Bystrova, YU.E., 2014. Organizacionnye izmeneniya v molodyh rossijskih predprinimatel'skih firmah kak faktor uspeshnosti. *Vestnik SPbU. Menedzhment*. № 2. S. 60-99.

Korotkov, E.M., 2015. Izmeneniyami v organizacii mozhno i nuzhno upravlyat'. *ZHurnal issledovanij po upravleniyu,* T. 1. № 5. S. 1.

Pavlova, A.V., 2012. K voprosu ob institucional'nyh problemah upravleniya izmeneniyami v social'no-ekonomicheskih sistemah makro-, mezo- i mikro ekonomiki. *Regional'naya ekonomika: teoriya i praktika.* № 28(259). S. 30-39.

Okorokova, L.G., 2010. Resursnyj potencial predpriyatij. 293 s.

Sokolov, D.V., 2015. Bazisnaya sistema risk-menedzhmenta organizacij real'nogo sektora ekonomiki: monografiya.125 s.

Adizes, I.K., 2017. Upravlyaya izmeneniyami: kak effektivno upravlyat' izmeneniyami v obshchestve, biznese i lichnoj zhizni. Per. s angl. V. Kuzina. 368 s.

Glushakov, V.E., 2011. Upravlenie izmeneniyami v biznese. 212 s.

Kotler, F., 2018. Marketing menedzhment. 848 s.

Legal Regulation of the Process of Providing Telemedicine Services: World Experience, Trends and Development Prospects

Mikhail D. Dzhikiya[1]
Volgograd State University, Volgograd, Russian Federation
dzhickiamd@volsu.ru

Keywords: telemedicine, human rights, the right to health protection, the right to medical care, regulation, diagnosis, patient, personal data, recommendations, technologies, international experience.

Abstract: New technologies and breakthrough inventions at the first stages of their development cause mistrust in society, which is logical; often this mistrust interferes with the rapid development of one or another direction in science and technology. However, information technologies and artificial intelligence systems, despite the fears, concerns, and skepticism of many people, are already rapidly changing the daily life of mankind. The use of wireless networks, software and hardware complexes, databases and robots opens up new opportunities for medicine to find innovative treatment methods, effectively prevent diseases, provide remote medical care to patients, collect anamnesis and analyze it in order to make the right informed decisions. E-health care and telemedicine, thanks to the digital transformation of medical practice, make it possible to provide support to those citizens who cannot attend a face-to-face appointment due to their health condition or distance from a medical institution. Telemedicine today is multifaceted. It is not limited to teleconsultations, but also covers a system of remote patient support, remote collection of up-to-date information about their health status (blood pressure, sugar levels, etc.) and already includes mechanisms for software and intellectual support for doctors making decisions on treatment tactics. However, despite all the positive aspects, the development of telemedicine technologies raises the issue of ensuring the proper level of respect for human rights, in particular constitutional rights to health protection and medical care. Modern states should actively work to improve the legal regulation of this area, because new technological realities require adaptation of the mechanism for ensuring constitutional rights. The purpose of this study is to develop recommendations on overcoming barriers to the development of telemedicine technologies in Russia in the context of improving the system of ways and means to ensure the realization of everyone's right to health protection and medical care (Article 41 of the Constitution of the Russian Federation). The object of the study is social relations that develop in the process of providing telemedicine services to the population. The subject of the study is regulatory and technical requirements, as well as recommendations and standards governing the process of providing medical care and its documentation using information (telecommunication) technologies in Russia and foreign countries. The basic methodology of the study is general scientific methods of logical cognition, in particular, with the help of analysis and synthesis, data from a number of countries were obtained regarding general regulation, the possibility of making a remote diagnosis, technical and local regulation, technical support, authentication, identification and data security in telemedicine. The author offers a number of practical and legal recommendations on leveling the risks of transferring face-to-face medical appointments of patients to remote ones, and also develops ideas for improving Russian legal and technical regulation in the field of medical activity under consideration. The development of recommendations and proposals is based on the analysis of the experience of a number of countries (USA, China, Great Britain, India, Sweden, and Japan) in terms of legal and technical regulation of telemedicine.

[1] https://orcid.org/0000-0003-1633-9669

1 INTRODUCTION

In the current conditions of social development, debates continue among scientists and practitioners about the relevance, safety and economic feasibility of introducing telemedicine. The medical community demonstrates healthy conservatism and, based on the principle of "do no harm", is wary of remote diagnosis of diseases, the use of systems that replace paper documents and familiar equipment that has been tested for decades.

Nevertheless, the fact that information technologies are increasingly penetrating into various areas of human activity, including issues of maintaining health and providing medical care, is undeniable. Russia is not among the countries that can be considered flagships in the use of telemedicine services, however, telemedicine practice has also been actively developing here in recent years, and as a result, regional telemedicine centers are already being created in the country.

The works of A.V. Vladzimirskij (Vladzimirskij, Lebedev, SHadyorkin, Mironov, 2022), I.A. Shaderkin (SHaderkin, 2022), A.V. Gusev, S.P. Morozov, V.A. Kutichev and R.E. Novitsky (Gusev, Morozov, Kutichev, Novickij, 2021), etc. are devoted to theoretical understanding of the issues of telemedicine and the development of proposals for improving medical practice in this area. In turn, the studies of T.N. Garmanova and A.A. Tsoi examine the use of distancing technologies in working with certain categories of patients (pregnant women, minors, etc.) (Garmanova, SHaderkin, Coj, 2016). The problem of digitalization of healthcare in the context of the development of remote medical services is addressed in the works of N.A. Nazarova, N.I. Valueva (Nazarova, Valueva, 2022). Some problems of legal regulation are addressed in the works of E.A. Smirnova and A.A. Shishanova (Smirnova, SHishanova, 2018).

Research on the experience of the United States of America can be found in the article by I.Yu. Bogdanovskaya (Bogdanovskaya, 2007), which reveals the specifics of licensing, personal data protection and responsibility of participants in telemedicine relations.

Among foreign scientists whose works are devoted to general theoretical issues of information law, it is worth paying attention to L. Lessig (Loy, Chi, 2003), V. Cerf (Cerf, 2007), J. Dumortier (Dumortier, 2003), I. Lloyd (Lloyd, 2020), L. Bygrave (Bygrave, 2002), D. Schartum (Schartum, 2010). The studies of such authors as G. Carlisle, D. Whitehouse (Carlisle, Whitehouse, Duquenoy, 2013), N. Purtova, E. Kosta, B. Koops (Purtova, Kosta, Koops, 2015), S. Adams, R. Leenes (Adams, Purtova, Leenes, 2017), A. Gilroy, C. Spontani (Gilroy, Spontoni, Llewellyn, 2015.), S. Callens (Callens, 2003), A. Wernick, I. Klünker (Wernick, Klünker, 2019) are devoted to highly specialized aspects of telemedicine regulation, as well as electronic interaction. The issues of standardization and methodological aspects of the provision of telemedicine services by nurses are analyzed in the works of American researcher C.C. Bartz (Bartz, 2017).

The author of this article does not aim to characterize all possible aspects of legal regulation of telemedicine in Russia and in the world. In this case, the study contains conclusions and proposals regarding a small group of countries (USA, India, UK, Sweden, Japan and Russia) in which the following areas of regulation were analyzed:

1. General regulation (permissibility of use, mandatory conditions and licensing of telemedicine).
2. Possibilities of remote diagnosis.
3. Technical and local regulation (methodological principles, medical standards, clinical recommendations).
4. Technical support for the provision of telemedicine services (legal status of persons involved in it).
5. Authentication, identification, and data security.

2 MATERIALS AND METHODS

The basic methodology of the study is general scientific methods of logical cognition, in particular, with the help of analysis and synthesis, data from a number of countries were obtained regarding general regulation, the possibility of making a remote diagnosis, technical and local regulation, technical support, authentication, identification and data security in telemedicine. The systematic method made it possible to assess the possibility of using key tools for regulating the process of providing medical services using telecommunication technologies in foreign countries and in Russian legislation.

The formal legal method and the method of legal hermeneutics were used in the analysis of technical and local regulation (methodological principles, medical standards, clinical recommendations), the comparative legal method allowed to identify barriers to the implementation of effective tools for regulating the process of providing medical services using telecommunication technologies in Russian and foreign legislation.

3 RESULTS

When considering the specifics of regulating the provision of telemedicine services in the group of countries selected for analysis, it is worth dwelling in detail on the experience of the most economically developed countries - the USA and China.

USA.

Telemedicine technologies in the United States have been developing for a long time. At the same time, modern state legislation approaches the general regulation of telemedicine technologies in a rather piecemeal manner. Thus, the key issue regarding the possibility of diagnosing patients without a face-to-face appointment is being resolved differently in different regions of the country. In a number of states, the law prohibits the provision of telemedicine services using telephones and faxes. In 21 states, obtaining a special license for telemedicine practice is required, while in the rest, a general license is sufficient. Another distinctive feature of US legislation is that a license obtained in one state does not mean the possibility of conducting telemedicine practice in another state.

Despite the heterogeneity of legislation in the United States, there are a number of federal rules that all doctors providing telemedicine services must follow:

1. The relationship between the patient and the doctor must be “validly” established in advance.
2. The doctor must have the technological ability to receive information from the electronic medical record of the patient.
3. Drugs prescribed within the framework of a telemedicine appointment must take into account the specifics of federal and regional circulation of medicines.
4. Telemedicine diagnostics is possible only for a list of diagnoses for which authorities have established the identity of all forms (face-to-face and remote) of medical care.
5. The doctor and the patient must be in constant interaction during the treatment period.
6. Telemedicine in the USA necessarily implies constant internal (medical organization) and external (supervisory authorities) quality control (Vladzimirskij, Lebedev, SHadyorkin, Mironov, 2022).

The legal status of organizations providing communication and technical support for telemedicine services deserves special mention. The American state assumes that they have the status of a special entity. As a result, rules for the management of medical equipment, standards for the production of medical devices, recommendations for working with wireless medical equipment, a set of requirements for the quality and sale of medical equipment have been developed and are in effect for them (Bogdanovskaya, 2007). At the same time, the laws of individual states contain provisions that form an institution of liability of a telecom operator for criminal negligence in the process of its participation in the provision of telemedicine care. If technological equipment (medical product) stops working due to the fault of the operator, a lawsuit may be brought against it, both from the patient and from the medical organization.

It should be noted that the legislation of the Russian Federation on telemedicine also mentions an “information systems operator”, but its legal status still remains completely uncertain. According to the author of this article, the rights, obligations and responsibilities of legal entities indirectly involved in the provision of telemedicine services (whether they are authorities, telecom operators, manufacturers of medical equipment, persons ensuring the safety of digital data) should be regulated by law.

The US experience in terms of using teletriage in the process of providing remote medical care seems interesting. During teletriage, primary consultations are provided to patients via telephone (basically, simple questions are resolved by mid-level medical personnel over the phone). Teletriage as part of the e-health system is recognized by foreign researchers as one of the successful ways to reduce the number of “unnecessary and non-urgent consultations” (Frid, Ratti, Pedretti, Valinoti, Martínez, Sommer, Luna, Plazzotta, 2020).

In general, it should be noted that telemedicine in the United States has already become an integral part of the realization of the rights of the population to health care, as evidenced, for example, by budgetary financing of telemedicine consultations for a number of categories of terminal patients (Moncrief, 1998).

It should be noted in this regard that Russia also provides a segment of budget financing for the provision of teleconsultations for cancer patients, as well as telemedicine consultations with the participation of the country's leading medical organizations and regional hospitals. Funds for this are included in the national Healthcare project. However, unfortunately, consultations with patients with terminal stages of oncological diseases do not yet include the provision of assistance using telemedicine technologies, which, in the author's opinion, is a significant gap in public policy.

China.

Government regulation of telemedicine in China received a significant boost during the COVID-19 pandemic. The development of information technology allows a large number of medical institutions in the People's Republic of China to create their own remote platforms that allow real-time (24 hours a day) consultation of patients.

Mandatory legal requirements for telemedicine activities in China include:

1. Special license for telemedicine.

2. Work experience (professional experience) of a consulting doctor – at least 3 years.

3. The list of medications prescribed during telemedicine consultations is strictly limited.

4. Persons engaged in technical support of telemedicine (telecom operators, manufacturers of medical equipment) must also be certified and licensed.

As a promising area for the legal regulation of telemedicine services in the PRC, we can highlight the need to regulate the provision of remote medical care to people with chronic diseases, as well as the integration of all remote medical platforms, professional retraining of medical personnel in the field of telemedicine, the development of standards of medical care and increasing the investment attractiveness of the area under consideration for business (Wang, Li, Liu, 2020).

The main points of the analysis of foreign experience in regulating telemedicine technologies both in the above-described countries (USA and China), and in India, Great Britain, Sweden and Japan are presented by the author in a diagram created based on the results of comparing the goals of introducing telemedicine and the limitations of its use. In order to position the countries, the author considered such purposes of use as consultations, triage, examination, health monitoring, diagnostics, treatment prescription, prescription of over-the-counter and prescription medications. These goals were analyzed taking into account the existing restrictions on the types of examinations, diagnostics, observation without examination, electronic remote identification (Figure 1).

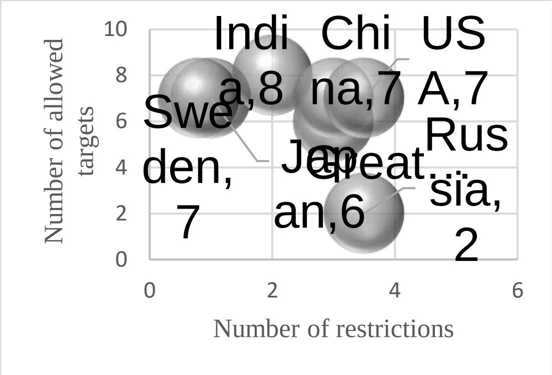


Figure 1: A diagram of countries based on the results of comparing the goals of telemedicine implementation and restrictions in its use.

Source: compiled by the author based on the analysis of foreign experience in implementing telemedicine technologies.

Taking into account the data obtained, the countries considered can be conditionally divided into 4 groups:

The 1st group of countries where telemedicine has not reached the level of systemic application is characterized by an insufficient number of goals established for telemedicine by the state and a practical absence of restrictions;

The 2nd group of countries where the development of telemedicine technologies is at the initial stage of its development are characterized by a small number of goals established for telemedicine by the state, but at the same time they have a large number of legal restrictions;

The 3rd group of countries where telemedicine is developing in the presence of a large number of goals established by the state, but also has many restrictions due to the peculiarities of the development of legal systems;

The 4th group of countries, the most progressive in terms of telemedicine regulation, has many goals for its development, but at the same time they have a minimum number of legal restrictions and direct prohibitions.

At this stage, the Russian Federation is assigned by the author to the 2nd group of countries. The further successful development of this type of activity in our country is hindered by a number of barriers, the main of which are:

- weak integration of telemedicine platforms;

- lack of economic incentives for medical equipment manufacturers;

- gaps in regulatory and technical regulation;

- the absence of an institution of tele-assistants, i.e. persons responsible for continuous technical support of telemedicine appointments;
- lack of a system for post-registration monitoring of medical computer programs;
- long periods of testing and examination of medical equipment;
- lack of a quality management system for telemedicine services;
- a small number of clinical standards and guidelines for telemedicine appointments with patients;
- excessive requirements for the doctor's workplace when providing telemedicine consultations (similar to the requirements for face-to-face patient consultations) (Gusev, Morozov, Kutichev, Novickij, 2021).

The main task of states regarding the development of e-health and telemedicine should be the inadmissibility of reducing the level of guarantees for patients and the quality of services provided to them when switching from personal (face-to-face) appointments to telemedicine (remote) ones. In this regard, the author, based on a summary of proposals previously made by scientists and practitioners, as well as taking into account his own developments, proposed a system of legal and organizational means aimed at leveling the risks of conducting telemedicine appointments in the "doctor-patient" mode.

The ways of eliminating risks proposed in Table 1 are based on an analysis of current Russian legislation, as well as on the identified gaps in existing legal provisions.

4 DISCUSSION

New technologies in medicine, along with the opening of horizons for more effective treatment, often carry risks for patients, whose rights should always be guarded by the state. In this regard, various aspects of the legal regulation of the use of telemedicine technologies will remain controversial for a long time.

The most acute discussions are about the possibility of allowing widespread diagnosis without a primary face-to-face appointment (Rockler Meurling, Adell, Wolff, 2023). Scientists and practitioners are also concerned about the economic feasibility of using telemedicine, as well as the mechanisms and ways to preserve personal data of patients and doctors.

Table 1: Risks of telemedicine medical appointments in Russia (in doctor-patient mode) and ways to eliminate them.

No.	Face-to-face appointment	Telemedicine appointment	Risks	Methods of elimination
1.	Identification through direct document verification.	Identification and authentication of appointment participants.	Patient substitution, data leakage.	Mandatory initial face-to-face appointment, use of reliable (protected) means of identification (Gosuslugi, banking systems, etc.).
2.	History taking, examination of the patient, diagnostics.	The impossibility of a personal examination of the patient, the absence of a medical record.	Lack of data	Methodological support of appointments, clinical recommendations, creation of a system of electronic medical records, limitation of the list of diseases permitted for diagnosis and treatment.
3.	Establishing a permanent information channel between the doctor and the patient through personal communication.	Establishing an audio-video communication session.	Interference, connection breaks, distortion of transmitted data.	Involvement of tele-assistants, unification of data exchange protocols, expansion of broadband high-speed communication networks.
4.	Personal informing of patients (their representatives) about the process and	Informing is provided only in digital (electronic) format.	Lack of proper legal regulation in terms of recognition of electronic medical	Elimination of legislative gaps, creation of an electronic health care system, support of state information systems in the field of medicine.

	consequences of treatment, medical intervention		documents, their verification, and distribution of legal responsibility for possible incidents.	
5.	Prescribing treatment and medications by issuing written recommendations and writing prescriptions on limited-issue forms.	Prescription of drugs only in the form of an electronic document.	Violation of requirements for circulation of medicines.	Elimination of gaps in the legal regulation of issuing electronic prescriptions.
6.	Mandatory control over the quality of medical appointments and treatment by: heads of medical organizations, supervisory authorities, insurance companies and the Federal Compulsory Medical Insurance Fund.	The control is fragmented and voluntary.	Risk of violation of patients' rights and non-compliance with state funding procedures due to the lack of mandatory requirements.	Development of mandatory standards for the provision of telemedicine services, broad inclusion of telemedicine in the sphere of compulsory medical insurance. Development of a legislatively enshrined system for monitoring the quality of telemedicine care.

However, despite the existing disagreements and differences in approaches, world experience suggests that telemedicine can solve a number of urgent problems and will soon be of a transboundary nature. Thus, in the opinion of the author of this study, the problems of mutual recognition of licenses, unification of requirements for the work experience of medical personnel, as well as supervision of compliance with the constitutional rights and freedoms of citizens in the process of using telemedicine technologies should come to the attention of scientists in the future.

5 CONCLUSION

Based on the results of the study, the author developed some practical and legal recommendations for overcoming barriers that hinder the development of telemedicine in the Russian Federation.

Based on an analysis of the current legislation in Russia, as well as the experience of regulating telemedicine services in a number of foreign countries, the author makes proposals to enshrine in laws the legal status of “non-obvious” participants in telemedicine sessions (telecom operators, manufacturers of medical equipment and tele-assistants). Moreover, the rights, duties and responsibilities for this category of persons should take into account their special role in the provision of telemedicine services, and therefore their potential impact on the proper implementation of the rights of everyone to health protection and medical care enshrined in Art. 41 of the Constitution of the Russian Federation

ACKNOWLEDGMENT

The study is financially supported by the Russian Science Foundation, project № 23-78-10175, https://rscf.ru/project/23-78-10175/.

REFERENCES

Adams, S., Purtova, N., Leenes, R., 2017. Under Observation: The Interplay Between eHealth and Surveillance. Springer, 210 p.

Bygrave, L. A., 2002. Data Protection Law, Approaching Its Rationale, Logic and Limits.

Callens, S.E-Health & the Law, 2003. Kluwer Law International. 2003.183 p.

Carlisle, G., Whitehouse, D., Duquenoy, P., 2013. eHealth: Legal, Ethical and Governance Challenges. Springer. 385 p.

Dumortier, J., 2003. E-government and digital preservation.

Lloyd, I.J., 2020. Information Technology Law.

Loy,U., Chi, L. J., 2003. Lawrence Lessig, *Law Regulating Code Regulating Law*, 35 1.

Vladzimirskij, A.V., Lebedev, G.S., SHadyorkin, I.A., Mironov, YU.G., 2022. Telemedicina «pacient — vrach»: upravlenie riskami. 94 s.

Cerf, V. G., 2007. Delay-Tolerant Networking Architecture.RFC 4838: 1-35.

Ana Maria, A., GRAJDEANU, I.V., SERBAN, B., Ana-Maria, C., 2019. STANESCU, etc. Telemedicine in Europe - Current Status and Future Perspectives.*Modern Medicine.* Vol. 26, No. 4 P. 165-168.

Frid, A. S., Ratti, M. F. G., Pedretti, A., Valinoti, M., Martínez, B., Sommer, J., Luna, D., Plazzotta, F., 2020. Teletriage Pilot Study (Strategy for Unscheduled Teleconsultations): Results, Patient Acceptance and Satisfaction. *Studies in health technology and informatics*, 270, 776–780.

Gilroy, A., Spontoni, C., Llewellyn, K., 2015.Undine von Diemar. Data protection challenges for telemedicine in the EU and US. *E-Health Law & Policy.* Vol. 2. Issue 8. R. 12-14.

Moncrief, J. W., 1998. Telemedicine in the care of the end-stage renal disease patient. *Advances in renal replacement therapy*, 5(4), 286–291.

Purtova, N., Kosta, E., Koops, B., 2015 Laws and Regulations for Digital Health. In: Fricker S., Thümmler C., Gavras A. (eds) Requirements Engineering for Digital Health. Springer, P. 47-74.

Rockler Meurling, C., Adell, E., Wolff, M., 2023. Telemedicine in Swedish primary health care - a web-based survey exploring patient satisfaction. BMC Health Serv Res 23, 129.

Schartum, D.W., 2010. Designing and Formulating Data Protection Laws. Int. J. Law Inf. Technol. 18:1-27.

Wang, Y., Li, B., Liu, L., 2020. Telemedicine Experience in China: Our Response to the Pandemic and Current Challenges. Front. Public Health 8:549669.

Wernick, A., Klünker, I., 2019. Prohibitions on long distance treatment: Historical roots and continuities in limiting the use of electronic telemedicine. In T. C. Bächle& A. Wernick (Eds.), The futures of eHealth. Social, ethicalandlegalchallenge, P. 169-177.

Garmanova, T.N., SHaderkin, I.A., Coj, A.A., 2016. Distancionnyj monitoring pacienta posle endoskopicheskoj korrekcii ust'ya mochetochnika. *Eksperimental'naya i klinicheskaya urologiya* (4):122-126

Gusev, A.V., Morozov, S.P., Kutichev, V.A., Novickij, R.E., 2021. Normativno-pravovoe regulirovanie programmnogo obespecheniya dlya zdravoohraneniya, sozdannogo s primeneniem tekhnologij iskusstvennogo intellekta, v Rossijskoj Federacii. *Medicinskie tekhnologii. Ocenka i vybor;*43(1):36–45.

Nazarova, N. A., Valueva, N.I., 2022. Problematika pravovogo regulirovaniya telemediciny v kontekste cifrovizacii zdravoohraneniya v Rossii. *Vestnik Sankt-Peterburgskogo universiteta. Pravo* 2: 360–377.

Smirnova, E.A., SHishanova, A.A., 2018. Telemedicina v novyh pravovyh realiyah. *Rossijskij zhurnal telemediciny i elektronnogo zdravoohraneniya.* Vypusk №3. S. 91-97.

SHaderkin, I. A., 2022. Bar'ery telemediciny i puti ih preodoleniya. *Rossijskij zhurnal telemediciny i elektronnogo zdravoohraneniya.* T. 8, № 2. S. 59-76.

Bartz, C.C., 2017. Standarty vedeniya telemedicinskoj praktiki: primer iz sestrinskogo dela. *ZHurnal telemediciny i elektronnogo zdravoohraneniya.* №1 (3).

General Controls for Medical Devices. An official website of the United States government. Food and Drug Administration. URL: https://www.fda.gov/medical-devices/regulatory-controls/general-controls-medical-devices

History of telemedicine in America. Stacker Media. URL: https://stackermedia.com/ (data obrashcheniya: 04.02.2024).

«Vtoroe mnenie»: kak nacproekt i telemedicina spasayut zhizni. IA Regnum. URL: https://regnum.ru/news/3425879 (data obrashcheniya 04.02.2024).

Bogdanovskaya, I.YU., 2007. Pravovoe regulirovanie telemediciny: opyt SSHA. *Vrach i informacionnye tekhnologii*. №3.

V Volgogradskoj oblasti zarabotal novyj telemedicinskij centr. Setevoe izdanie «Volga-Media.ru». URL: https://vlg-media.ru/2024/01/01/v-volgogradskoj-oblasti-zarabotal-novyj-telemediczinskij-czentr/ (data obrashcheniya: 04.02.2024).

Osnovnye vyvody po itogam analiza zarubezhnogo opyta vnedreniya telemedicinskih tekhnologij. URL: https://sk.ru/documents/238/5._itog_analiza_zarubezhnogo_opyta_telem_.docx (data obrashcheniya 04.02.2024).

Prikaz Ministerstva zdravoohraneniya RF ot 30 noyabrya 2017 g. № 965n "Ob utverzhdenii poryadka organizacii i okazaniya medicinskoj pomoshchi s primeneniem telemedicinskih tekhnologij". Dostup iz sprav.-pravovoj sistemy «Konsul'tantPlyus».

Economic Analysis of Research and Innovation Activities of Technical Higher Education Institutions in Zarafshan Region

Bobir Azimov Fattohevich[1] [1], Dilnoza Rakhimova Davronovna[2] [2]
[1]*Asia International University, Uzbekistan*
[2]*Bukhara engineering-technological institute, Bukhara, Uzbekistan*
bobirazimov1974@gmail.com, raximovadilnoza19832017@gmail.com

Keywords : Scientific and innovative activity, "System of Indicators for Evaluating the Scientific and Innovative Activity of HEIs" methodology, publication results, research work outcomes, innovative entrepreneurship results, potential of scientific and innovative activity, scientific and innovative efficiency of higher education institution.

Abstract: In the article, analyses based on the author's methodological approach to the scientific research and innovative activities of technical higher education institutions located in the Zarafshan economic region are provided. The main findings and proposals for enhancing the effectiveness of scientific research and innovative activities are also presented by the results of the analysis.

1 INTRODUCTION

The Zarafshan economic region is located within the administrative boundaries of the Bukhara, Navoi, and Samarqand regions of the Republic of Uzbekistan. In the Zarafshan economic region, there are a total of five higher education institutions specializing in various technology fields that have been actively operating over the last decade. These institutions include the Bukhara Engineering and Technology Institute (BETI), Bukhara Institute for Managing Natural Resources (BIMNR), Samarkand State University of Architecture and Construction (SSUAC), Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Samarqand Branch (TUITSamB), and Navoi State Mining and Technology University (NSMTU). Given the significant role played by these technical higher education institutions in the socio-economic development of the region, evaluating the effectiveness of their scientific research and innovative activities has become increasingly crucial in recent years.

2 METHODS

Methods for evaluating the scientific research and innovative activities of higher education institutions are not only described in the assessment areas but also the tools, indicators, and instruments used, with noticeable variations. Indeed, providing an accurate assessment of scientific and innovative activity requires creating favorable conditions for making well-founded decisions based on comprehensive, objectively assessed factors that influence it.

The history of interest in assessing the effectiveness of scientific research and innovation in global practice is quite extensive. However, the systematic emergence of these approaches began in the late 19th century with the quantification of productivity in scientific evaluation, and this should not be considered a mistake (Godin, 2009). In many cases, these efforts were initially linked to the monetization of research (Godin, 2009), and most of these activities were connected with the financial evaluation of research. Bibliometric indicators have been considered one of the main tools in evaluating

[1] https://orcid.org/0009-0007-1447-0600
[2] https://orcid.org/0009-0007-3078-6648

the scientific competence of individuals or institutions (Hicks, Wouters, Waltman, de Rijcke, 2015). The development of bibliometrics has brought with it the utilization of quantitative measures in assessing the effectiveness of scientific and innovative activities. Notably, the number of research publications, the impact factor of journals, and citations were used as criteria contributing to the assessment of productivity. Such conditions have shaped the focus of scientific articles toward a centralized factor. In 1926, Alfred J. Lotka introduced the concept of "Lotka's law," where he focused on the slowing down of the number of publications in his significant work (Lotka, 1926). Research productivity is a creative process in which the production of information involves human, material (scientific tools, materials, etc.), and non-material (accumulated knowledge, social relations, economic rents, etc.) resources, resulting in the product as new knowledge (Abramo, D'Angelo, 2014).

Currently, various international rankings and methods, such as the ARWU-Academic Ranking of World University (Shanghai Ranking Consultancy), QS World University Rankings (QS Quacquarelli Symonds Limited) , THE-World University Rankings, ARES-Higher Education Institutions Ranking (European Academy of Sciences and Arts), widely assess the effectiveness of the innovative activities of higher education institutions. These rankings utilize different methods and indicators. Among the indicators used to evaluate university activities, the quality of scientific research is given the highest weight, for example, 20% in QS/USNews, 40% in ARWU (Docampo, 2010), 70% in THE, and 100% in Leiden (Florian, 2007).

In Uzbekistan, the level and quality of the scientific and pedagogical activities of higher education institutions have been assessed based on a comprehensive ranking system since December 29, 2012. This evaluation system was established by the Cabinet of Ministers Resolution No. 371 and includes four main criteria and a total of 20 indicators (Fig 1).

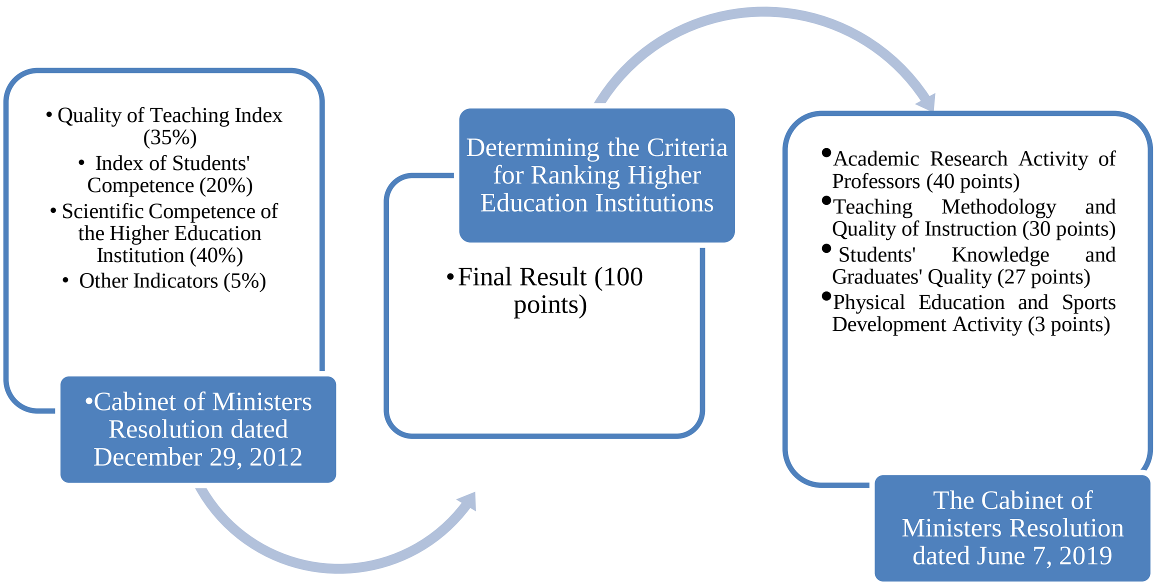


Figure 1: Structure of the Ranking System for Higher Education Institutions in Uzbekistan (Hazelkorn, 2011).

Later, on June 7, 2019, the Cabinet of Ministers issued Resolution No. 467, "On Measures to Improve the Procedure for Determining the Ranking of Higher Education Institutions," which marked the transition to the national ranking of higher education institutions. In the national ranking, within the category of the academic research activity of professor-instructors (40 points), the indicator of the impact of publications on international indicators carries the highest weighting coefficient (9 points).

In addition to numerous global or national rankings for assessing innovative activities, there are various proposed methodologies for evaluating the scientific and innovative activity of higher education institutions. The analysis of the essence of the concept proposed by K.S. Grishenko, I.I. Dyakov, N.A. Tretyak revealed the following functional components of the university's innovative environment: scientific component, personnel composition component, organizational component, and financial component.

According to the authors, each component is described using a system of indicators, based on which specific small indices are calculated. This, in turn, allows for a more detailed description of the overall development level of the innovative environment, revealing the share of each component, identifying the interdependence between indicators, and providing a systematic assessment of the overall development level (D'yakov, Tret'yak, Grishchenko, 2018). Author groups led by M. Vasilyeva, E. Reale, and D. Yu. Busigin have proposed specific mathematical expressions for evaluating scientific research and innovative activities (Table 1).

Table 1: Comparative Analysis of Authorship Methodologies for Evaluating the Efficiency of Scientific Research and Innovative Activities.

№	The authors	**Formula**	Conditional signs
1	M.Vasiljeva V.Ponkratov, T.Volkova, S.Khairova, N.Nikitina, O.Dudnik, M.Alimova, N.Kuznetsov, I.Elyakova (Vasiljeva, Ponkratov, Volkova, Khairova, Nikitina, Dudnik, Alimova, Kuznetsov, Elyakova, 2020)	$P_{ik} = \left[b_{ik} / \sum b_{ik}\right] \times \left[\sum e_k / (m-1)\right]$, $p_i = \sum p_{ik}$	***pi*** *– i-th factor - expert assessment of the significance coefficient;* ***bik*** *- assessment of k-expert regarding the importance of i-factor (b=1,10);* $\sum \boldsymbol{b_{ik}}$ *- Sum of k-expert scores for all factors;* ***t*** *– be a number of factors* $\sum \boldsymbol{e_k} / (\boldsymbol{m-1})$ *- k-expert qualification coefficient;* *∑ek – the sum of binary values (e = 0 ∩ 1, "0" — the expert considers the k-expert to be incompetent and considers it inappropriate to include him/her in the expert group; «1» — expert indicates that the k-th expert is needed in the group), taking into account the competence of the k-th expert of the given expert group (m - 1 expert);* ***m****- number of experts in the expert group.*
2	E.Reale, D.A.DeFilippo, I.Gómez, B.Lepori, B.Potì, E.Primeri, C.Probst,E.S. Casado (Reale, DeFilippo, Gómez, Lepori, Potì, Primeri, Probst, Casado, 2011)	$F_i = \sum k_{ji} \times X_{nj}$	$\boldsymbol{F_i}$ *- i-coefficient of the result of the scientific activity of a teacher;* $\boldsymbol{k_{ji}}$ *- coefficient of linear regression equations describes the relative importance of the j-th indicator within the i-th factor;* $\boldsymbol{X_{nj}}$*- normalised value of j-th indicator;* ***i****- factor number;* ***j****- serial number of the indicator;* ***n****- the number of indicators of the effectiveness of the teacher's scientific activity.*
3	D.Yu.Busigin (Busygin, 2020)	$\mathrm{Eki} = \frac{(\mathrm{VV} + \mathrm{VB} + \mathrm{RG})\mathrm{Kd}}{\mathrm{ID} + \mathrm{SV}}$	***Eki*** *- efficiency of the process of commercialization of university innovations;* ***VV*** *- the benefit of the university from the commercialization of university innovations;* ***VB*** *- business benefits from commercialization of university innovations;* ***RG*** *- the volume of state investments aimed at the commercialization of innovations created at the university;*

			Kdost *- coefficient of use of a specific form of commercialization of innovations created at the university;* ***ID*** *- transaction costs arising from the commercialization of university innovations;* ***CB*** *- costs of introducing university innovations.*

3 RESULTS

The study of scientific sources in the field of economics indicates that most research groups extensively utilize information collected from a wide range of sources for evaluating various aspects of scientific research and innovative activities, as well as assessing higher education institutions (HEIs). It has been highlighted that there is a necessity to extract valuable information from diverse sources, especially the data provided by higher education institutions themselves, the websites of state educational authorities and other organizations, national and international bibliometric materials, and the direct results obtained during the evaluation of HEIs through surveys. However, the results of the research on the use of such broad-spectrum information have not yet demonstrated an improvement in the quality of obtained results, particularly due to certain inconveniences. In addition to the challenges faced by companies developing such research and rankings, the evaluated universities also recognize the complexity of such approaches, acknowledging the significant amount of labor and information resources required. Moreover, it is essential to establish collaboration formats with ranked universities, choose methods for verifying obtained information, and simplify the process of collecting and reanalyzing remaining data, ensuring its reliability and integrity. These methodological issues, along with the need to ensure the practicality and reliability of the process, remain unresolved challenges in research and rankings.

In order to eliminate the shortcomings of methodical approaches used to evaluate the scientific and innovative activities of subjects, we propose a system called the "Indicators System for Evaluating Scientific and Innovative Activities of Subjects" on our part. By the rules, benchmarks for each indicator are determined by the average arithmetic mean of the three highest values of the indicator, aiming to liberate from the influence of the maximum indicators of individual subjects and giant indicators of HEIs. For this purpose, the average arithmetic mean of the three highest values of each indicator is identified, and the benchmark indicator is set equal to 100 points. It is determined with the following statements.

$$\frac{RES_{max} + RES_{max-1} + RES_{max-2}}{3} = RES_{etalon} \quad (1)$$

$$\frac{POT_{max} + POT_{max-1} + POT_{max-2}}{3} = POT_{etalon} \quad (2)$$

$$\frac{EFF_{max} + EFF_{max-1} + EFF_{max-2}}{3} = EFF_{etalon} \quad (3)$$

The system proposed by us, referred to as the "Indicators System for Evaluating Scientific and Innovative Activities of Organizations of Targeted Management (HEIs)," consists of three subsystems:

1. The first subsystem is named "Indicators of Scientific and Innovative Activity Results" and is dedicated to evaluating 20 indicators grouped into three conditional categories (RES_i) for a combined assessment.

I. PUBLICATION RESULTS CONDITIONAL GROUP:

- Number of scientific articles (published in foreign scientific journals selected by higher certification commission), RES_1.
- Number of scientific articles (published in Republic scientific journals selected by higher certification commission), RES_2.
- Number of articles indexed in Web of Science and Scopus, RES_3.
- Number of citations in Web of Science and Scopus journals over the last 5 years, RES_4.
- Number of published monographs, RES_5.
- Number of published textbooks, RES_6.
- Number of published teaching materials, RES_7.

II. SCIENTIFIC-RESEARCH RESULTS CONDITIONAL GROUP:

- Number of successfully defended dissertations (PhD, DSc), RES_8.
- Amount of funding from foreign and international scientific research grants, RES_9.
- Amount of funding from national sources, RES_{10}.
- Amount of funding from local sources, RES_{11}.

III. INNOVATIVE ENTREPRENEURSHIP RESULTS CONDITIONAL GROUP:

- Revenue from selling intellectual property objects under license agreements, RES_{12}.

- Number of patents obtained for inventions, utility models, industrial designs, and selection achievements, RES_{13}.

- Number of agreements and licenses for databases and electronic information systems protected by copyright, RES_{14}.

- Revenues from licensing agreements, RES_{15}.

- Number of startups created under innovative projects, RES_{16}.

- Number of innovation enterprises established under innovative projects, RES_{17}.

- Number of new jobs created as a result of innovative entrepreneurship, RES_{18}.

- Number of innovation startups, RES_{19}.

- Number of scientific, innovative, and technological projects implemented in collaboration with foreign organizations, RES_{20}.

The total score for each HEI`s scientific and innovative activity results is determined by the following formula:

$$SUMRES^n = \sum_{i=1}^{20} \frac{RES_i^n}{RES_{(i)etalon}} \cdot 100 \qquad (4)$$

Here,

$SUMRES^n$- *represents the total score for the indicators;*

RES_i^n- *denotes the performance indicator of the "i" result for the "n" subjects being evaluated;*

$RES_{(i)etalon}$- *stands for the benchmark indicator of the "i" result.*

The second subsystem is named "Indicators of Scientific and Innovative Competence," denoted as POT_j, and includes the following indicators:

- Number of professors and teachers, POT_1.
- Number of academic degree holders (PhD, DSc) (excluding the reporting year), POT_2.
- Number of doctoral students (PhD, DSc, independent researchers, intern-researchers), POT_3.
- Number of master's students, POT_4.
- Number of scientific staff, POT_5.
- Number of existing intellectual property objects (excluding the reporting year), POT_6.
- Number of scientific-research laboratories, POT_7.
- Number of innovation enterprises (excluding the reporting year), POT_8.
- Number of experimental-design-construction departments (enterprises), POT_9.

The total score for the indicators of scientific and innovative competence of each educational institution is determined by the following formula:

$$SUMPOT^n = \sum_{j=1}^{9} \frac{POT_j^n}{POT_{(j)etalon}} \cdot 100 \qquad (5)$$

Here,

$SUMPOT^n$- *the sum of system potential indicators;*

POT_j^n-*"j" indicator of the potential "n" of the subject whose activity is being studied;*

$POT_{(j)etalon}$- *"j" - standardised indicator of potential*

The indicators of the 3rd system are called "Performance indicators of research and innovation activity" and are found by dividing separately obtained indicators of the 1st system by individual indicators of the 2nd system (EFF_{ij}) and all performance indicators of HEIs by the sum of indicators are as follows:

$$\text{SUMEFF}= \sum_{i=1,j=1}^{i=20,j=9} \frac{RES_i^n}{EFF_j^n} \cdot 100 \qquad (6)$$

When implementing the proposed methodology, it is necessary to pay attention to the following features:

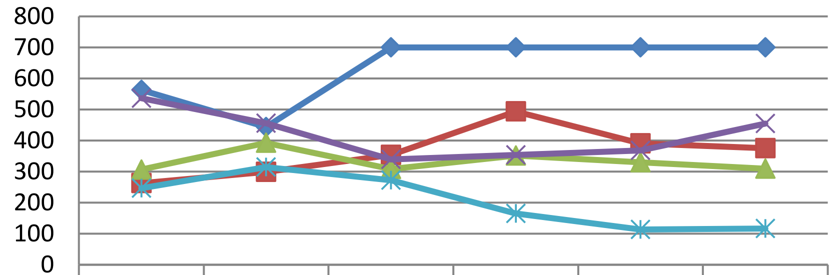
- it is determined to what extent the subject, whose activity is studied, is from the standard of the corresponding indicator (here it should be noted that even if the corresponding indicator of the subject involved in the calculation of the standard is higher than the standard, it is still accepted, as 100 points will be fulfilled);
- the sum of the indicators within each system determines the overall level of the subject;
- On which indicators the HEI has the lowest and highest scores among similar HEIs;
- measures will be developed to strengthen strengths and develop weak indicators among similar HEIs.

4 DISCUSSION

Based on the developed methodology, the indicators of results and potential indicators of research and innovation activity in technical universities of the Zarafshan region of the Republic of Uzbekistan (Bukhara, Samarkand, Navoi) for 2017-2022, scientific research and efficiency are analyzed indicators of innovation activity are determined.

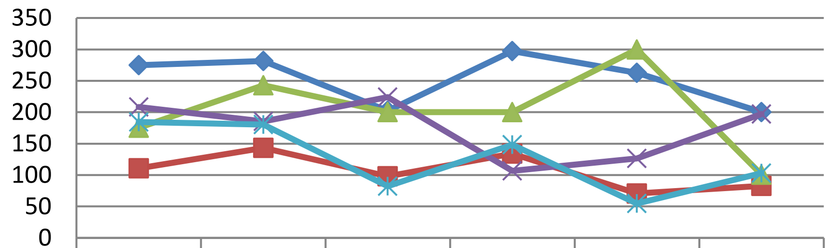
Calculations show by the dynamics of change of indicators of results of research and innovation activity of technical institutions of the region that BETI took the main place in the conditional group of publication results. For 2017-2022, BETI results were above the normative indicator in the conditional group of publication results in almost all cases, in 35 cases out of 42 it was above the normative indicator. SSUAC stands out in the next place, in 8 out of 42 opportunities it was above the benchmark. In NSMTU, there were 4 of 42 such results out of 42 possibilities. (Fig. 2).

NSMTU 2017-2022 on the conditional group of research results out of 15 opportunities (actually there should be 24 opportunities, but we stopped at 18 opportunities because no HEI has not utilized funds from local sources (RES_{11})) led to 12 of them. In particular, over the last 6 years, NSMTU has moved forward with PhD and DSc theses. The next place in this conditional group went to BETI, i.e. it advanced in 7 opportunities out of 18.



	2017	2018	2019	2020	2021	2022
BETI	563,4	443,8	700	700	700	700
BIMNR	262,75	299,16	353,7	493,75	390,69	375,78
NSMTU	306,72	392,44	308,09	351,4	329,64	309,38
SSUAC	536,51	455,31	339,3	353,24	367,7	455,01
TATUSamF	247	314,45	272,35	164,89	113,64	116,17

Figura 2: Dynamics of indicators of the conditional group of publication results in technical universities of the Zarafshan region.

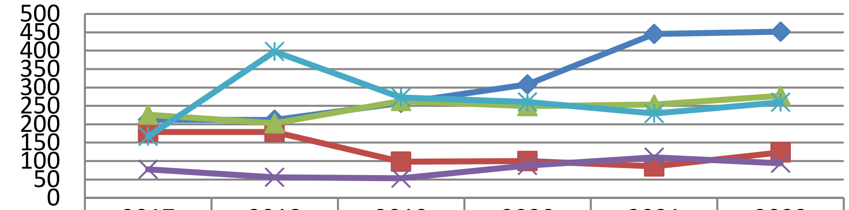


	2017	2018	2019	2020	2021	2022
BETI	275	281,42	202,21	297,27	262,47	200,19
BIMNR	110,46	143,18	97,85	133,84	70,73	82,66
NSMTU	175,16	242,77	200	200	300	100,75
SSUAC	208,19	185,41	224	106,71	126,29	196,85
TUITSamB	184,4	180,57	81,99	148,37	54,63	102,82

Figure 3: Dynamics of indicators of the conditional group of R&D results in technical universities of the Zarafshan region.

It is difficult to find a clearly advanced leader of the innovative entrepreneurship group according to the results of 2017-2022. Relatively BETI was leading in 15 opportunities out of 30 (actually there should have been 42 opportunities, but according to the indicators of sale of intellectual property based on license agreements (RES_{12}), (RES_{18}) no facts were observed in any HEI.). Samarkand branch of TUIT ranked next and was above the benchmark in 10 out of 30 opportunities. NSMTU was leading in 9 out of

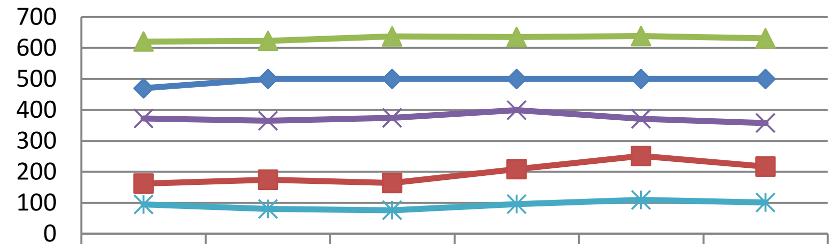
30 opportunities. It should also be noted that NSMTU has not lost its leadership for the last 6 years in terms of revenue from economic contracts (RES_{15}). As the highest example of integration of science, education, and production, NSMTU's ties with such industrial and production enterprises as Navoi Mining and Metallurgical Combine (Navoi Azot OJSC, Kizilkumsement OJSC) are commendable.



	2017	2018	2019	2020	2021	2022
BETI	212,03	211,89	258,34	308,69	445,29	451,7
BIMNR	178,73	179,02	98,08	100,38	85,63	123,09
NSMTU	226,26	202,8	262,96	248,99	253,62	277,32
SSUAC	77,88	55,42	53,2	87,81	110,05	94,15
TUITSamB	166,58	397,64	272,85	260,39	229,68	259,88

Figure 4: Dynamics of indicators of the conditional group of innovation entrepreneurship results in the universities of the technology sector of the Zarafshan region.

The number of professors and teachers (POT_1), the number of academic degrees (Ph.D., DSc) (except for the reporting year) (POT_2), the number of doctoral students (Ph.D., DSc, independent BETI researchers, research interns) (POT_3), the number of masters (POT_4) were leading in terms of numbers. In addition, in 2017-2022, NSMTU is a consistent leader in terms of the number of Master's students (POT_4), number of research staff (POT_5), number of active intellectual property (except for the reporting year) (POT_6). The number of research laboratories (POT_7) was in the same place. Of course, the significant growth of these indicators of research and innovation potential is related to the historical development of HEIs. According to the indicators of the number of innovative enterprises (except for the reporting year) (POT_8), the number of research and development departments (enterprises) (POT_9), the situation is almost the same in all HEIs, that is, in some HEIs there was only a slight positive shift in recent years of research.



	2017	2018	2019	2020	2021	2022
BETI	470,01	500	500	500	500	500
BIMNR	162	174,66	163,66	208,85	251,24	216,5
NSMTU	620,32	622,3	637,55	634,93	638,27	631,08
SSUAC	372,64	364,8	374,11	399,13	371,03	357,37
TUITSamB	94,21	79,96	75,73	96,04	109,31	100,67

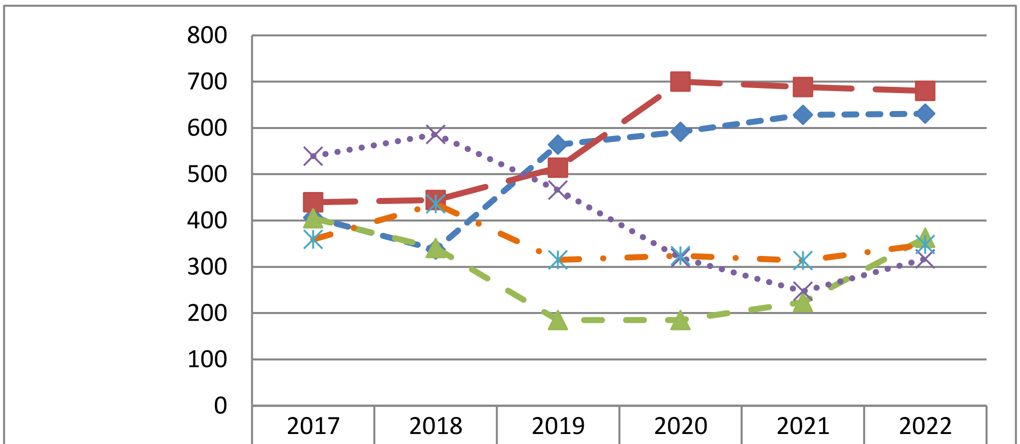
Figure 5: Dynamics of indicators of scientific-innovative potential in higher education institutions in the field of technology in the Zarafshan region.

BIMNR and Samarkand branch of TUIT are significantly inferior in terms of the indicators of the 2nd system, i.e. there was no leadership in any indicator in the years under study. SSUAC demonstrated higher potential compared to the benchmark only in 9 cases out of 54 opportunities.

To facilitate the calculation of the indicator of the efficiency of research and innovation activities of higher education institutions in the Zarafshan region, to give greater reliability to the results, as well as the presence of appropriate restrictions on the volume of publication of research results, all indicators of results (RES_i)) are the most important of higher education institutions, we limited ourselves to dividing by the number of professors and teachers (POT_1), which is considered an indicator of capacity. The results of calculating the efficiency of research and innovation activities in technical HEIs in the Zarafshan region are presented. We decided to choose only the number of professors (POT_1) from the competence indicators for analysis.

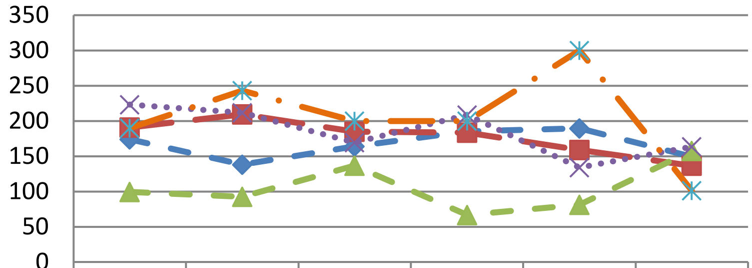
From the research, we see that the favorites have changed by groups of conditions of publication efficiency indicators. For example, BIMNR has strengthened its leadership in this conditional group over the years, and in recent years we can see from the BIMNR example that some indicators in this conditional group are not above the standard indicators, but very close to it. For example, the publication efficiency corresponding to the number of teaching professors at this university is very high. In addition, we can see that the indicators of such HEIs as BETI, and NSMTU, which are among the leaders in other systems in this conditional group of efficiency definition, have significantly decreased, for example, the above-mentioned HEIs are stable in the indicator every year facts of leadership are not distinguished.

As for the conditional group of research efficiency, no HEIs are demonstrating a sharp advantage by the indicators of the previous system. According to the ratio of the number of successfully defended dissertations (Ph.D., DSc) to the number of professors and teachers ($EFF_{8.1}$) and the ratio of the sum of grants received from national sources to the number of professors and teachers ($EFF_{10.1}$) NSMTU, almost all seem to be favorites by years, but this advantage shows relative leadership in this conditional group. It should be noted, however, that due to the lack of grants from local sources, it was not possible to calculate the effectiveness of this indicator.



	2017	2018	2019	2020	2021	2022
BETI	406,61	337,31	564,21	591,83	628,41	630,7
BIMNR	439,53	444,24	513,89	700	688,34	679,97
SSUAC	404,6	340,41	184,95	184,97	223,89	363,06
TUITSamB	539,34	586,08	465,89	319,19	247,18	317,35
NSMTU	359,61	435,68	314,78	323,71	313,44	348,21

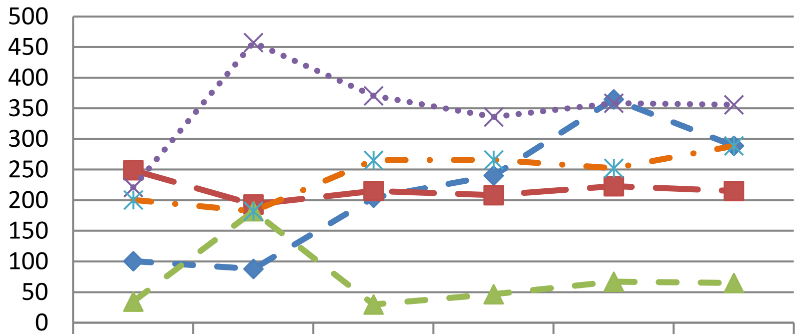
Figure 6: Dynamics of publication efficiency indicators in technical HEIs of the Zarafshan region.



	2017	2018	2019	2020	2021	2022
BETI	173,85	138,17	163,81	185,31	189,51	149,58
BIMNR	190,83	209,41	184,9	183,39	158,87	136,5
SSUAC	99,58	92,34	136,56	66,72	81,26	157,7
TUITSamB	223,23	211,88	169,42	208,49	133,94	163,57
NSMTU	189,85	243,17	200	200	300	101,21

.Figure 7: Dynamics of indicators of research efficiency in technical universities of Zarafshan region.

In the conditional group of innovative business efficiency, the Samarkand branch of TUIT has significantly advanced. Such a successful way was conditioned, firstly, by the correct utilization of HEI potential, and secondly, by the fact that the HEI activity profile was quite modern. According to this conditional group, NSMTU is in the 2nd place. According to the ratio of income from economic contracts to the number of teaching staff ($EFF_{15.1}$) in all years, except 2019, the number of patents for inventions, utility models, industrial designs, and selection achievements received was for professors and selection achievements. teachers and by the indicator ($EFF_{13.1}$) has been leading for the last 4 years.



	2017	2018	2019	2020	2021	2022
BETI	100,57	87,84	204,06	240,39	364,98	289,19
BIMNR	248,94	193,28	215,22	208,34	223,04	215,02
SSUAC	34,4	182,04	29,81	46,85	66,96	65,19
TUITSamB	220,82	457,47	370,46	336,03	358,54	355,94
NSMTU	200,68	182,06	265,54	265,81	252,27	288,73

Figure 8: Dynamics of innovation efficiency indicators in technical universities of Zarafshan region.

5 CONCLUSIONS

The conducted research has served as a basis to draw the following main conclusions about the efficiency of research and innovation activity of technical HEIs in the region:

- the efficiency of scientific research and innovation activity is not the result of the availability of potential, but the result of its rational use;
- the proposed methodology for assessing the innovation activity of HEIs is designed primarily for the management and staff of HEIs that make managerial decisions aimed at the development of innovation activity. Also, we believe that the proposed methodology will be useful for a wide range of researchers who use the results of the assessment to study the nature of innovation activity of local universities and patterns of development;
- another important feature of the methodology is the possibility of comparing individual universities in terms of the level of innovation environment development both in general and by its individual components, including the possibility of comparing specific evaluation criteria. We believe that this allows us to identify "weaknesses" and reserves for the development of innovation activity of HEIs, and also contributes to the improvement of their competitiveness and positions in national and world rankings;

One of the drawbacks of the methodology is that it is pointless to find a standard indicator until the relevant indicators of all subjects are determined. the proposed criteria, in our opinion, adequately describe the conditions for the effective development of innovation activity formed in HEIs, and we believe that their systematic application provides an adequate assessment of the innovation environment.

REFERENCES

Godin, B., 2009. The Making of Science, Technology and Innovation Policy: Conceptual Frameworks as Narratives; Centre Urbanisation Culture Société: Quebec, QC, Canada.

Hicks, D., Wouters, P., Waltman, L., de Rijcke, S., 2015. The Leiden Manifesto for research metrics. Nature, 520, 429–431. [CrossRef] [PubMed].

Académie Des Sciences. Du bon Usage de la Bibliométrie Pour L'évaluation Individuelle des Chercheurs. Available online: http://www.academie-sciences.fr/archivage_site/activite/rapport/avis170111_synthese.pdf (accessed on 10 December 2019).

Lotka, A.J., 1026. The frequency distribution of scientific productivity. J. Wash. Acad. Sci. 16, 317–324.

Abramo, G., D'Angelo, C.A., 2014. How do you define and measure research productivity? Scientometrics, 101, 1129–1144. [CrossRef]

ARW U Academic Ranking of World Universities 2017. ShanghaiRanking Consultancy. [Elektronnyj resurs]. URL: http://www.shanghairanking.com/ARWU2017.html

QS World University Rankings 2018. QS Quacquarelli Symonds Limited. [Elektronnyj resurs]. URL: https://www.topuniversities.com/university-rankings/world-universityrankings/2018

Times Higher Education World University Rankings 2018. [Elektronnyj resurs]. URL:
https://www.timeshighereducation.com/world-university-rankings/2018/world-ranking

Ranking of High Educational Instituitions-ARES – 2017. European Scientific-Industrial Chamber. [Elektronnyj resurs]. URL: http://www.eurochambres.org/ares-2017/russian-federation/

Docampo, D., 2010. On using the Shanghai ranking to assess the research performance of university systems. Scientometrics. T. 86. № 1. S. 77-92.

Florian, R.V., 2007. Irreproducibility of the results of the Shanghai academic ranking of world universities. Scientometrics. T. 72. № 1. S. 25-32

Hazelkorn, E., 2011. Do rankings promote trickle-down knowledge? University World News. No182.

https://lex.uz/uz/docs/-2111000,

https://lex.uz/uz/docs/4371479

Grishchenko, K.S., D'yakov, I.I., Tret'yak, N.A., 2017. Sushchnost' innovacionnoj sredy vuzov i metody eyo ocenki. Moskovskij ekonomicheskij zhurnal.. № 2.

D'yakov, I.I., Tret'yak, N.A., Grishchenko, K.S., 2018. Ocenka innovacionnoj sredy vuzov. Sovremennoe obrazovanie.. №1.

Vasiljeva, M., Ponkratov, V., Volkova, T., Khairova, S., Nikitina, N., Dudnik, O., Alimova, M., Kuznetsov, N., Elyakova, I., 2020. The Development of Scientific Activity in Russian Universities. Journal of Open Innovation: Technology, Market, and Complexity. 6. 110.

Reale, E., DeFilippo, D.A., Gómez, I., Lepori, B., Potì, B., Primeri, E., Probst, C., Casado, E.S., 2011. New uses of the institutional databases of universities: Indicators of research activity. Res. Eval. 20, 47–60.

Busygin, D.YU., 2020. Osobennosti ocenki intellektual'nogo kapitala v ekonomike znanij. Buhgalterskij uchet i analiz. № 1. S. 39-45.

Virtual Technological Line Simulator for the Production of Chocolate

M.A. Razakov[1,2][a], V.A. Nazarova[3][b] D.A. Derevyanko[3][c] and A.V. Kondrashov[3][d]
[1]*Moscow Power Engineering Institute (University), Krasnokazarmennaya Street. 14, Moscow, Russia*
[2]*Research Institute of Building Physics of Russian Academy of Architecture and Construction Sciences, Lokomotivniy Prospect, 21, Moscow, Russia*
[3]*Russian Biotechnological University,Volokolamskoe Highway, 11, Moscow, Russian Federation*
RazakovMA@mpei.ru; vlastelinak@list.ru; derevyanko_d@bk.ru; artyom.kond@gmail.com

Keywords: Virtual reality technologies, intelligent information system, production technology, training system, individual training, food industry, confectionery industry, chocolate.

Abstract: Authors have presented the designed simulation complex of chocolate production in this paper. There is an overview of researches which have modern programmes for training specialists in bachelor and masters degrees. Researchers have explored the information about modern tools for educational system of many industries engineers in actual databases: RSCI; Scopus; Web of Science; Ebsco; Agris and others. It has been presented the actual information solutions that can be used to train specialists in different sectors of the food industry in this work. There are advantages and disadvantages of the created software package in this article. Authors have used the tools of Blender 3D, Unity 3D, Autodesk Inventor software. Also researchers have used C# for setting the system. Article will be interested for lecturers in field of food production.

1 INTRODUCTION

In the modern world, all sectors of the national economies are developing dynamically. The food industry is not an exception. The industrial security of the country depends on its ability to meet new challenges and support human life. It is necessary to use current digital solutions for training the specialists in educational institutions. Also companiesmust introducethe high-level complexes in production.

There are3 main growth points for any industries: increasethe production efficiency by using automation and dispatching of technological processes at mostly production stages; reducing additional costs by redistributing production lines to improve the efficiency of each stage; training staff in modern technologies by using advanced didactic methods. All these points are possible through the transition from the «Industry 3.0» approach to «Industry 4.0». The main element of it is the digitalization and automation of control systems.

Automation systems of technological elements is necessary for each stage of food production. It could increases the accuracy of ingredients consumption, increases the reliability of production equipment, reduces raw materials and wear of the main mechanisms and also the risks of deviations from the manufacturing method (Fedosenkov, 2015). It is possible to use both existing software packages and create your own packages based on well-known program codes, for example, matlab simulink in these systems (Khvostov, 2018).

The developed programs can have a self-learning modular type, where each food production unit has its own independently configured, debugged mode and type of operation. There are the possibilies to change each element of the system, which expands the possibilities of using the complex for a large number production lines types (Wauters, 2012).

Almost every food production line include a mixing process. Moreover, it will be excellent for the production of, for example, coffee and viscous food products (Santos Cunnighan, 2019; Blagoveshchenskaya, 2020; Balykhin, 2018). The

[a] https://orcid.org/0000-0002-0419-4522
[b] https://orcid.org/0009-0009-3813-9984
[c] https://orcid.org/0009-0006-3699-5080
[d] https://orcid.org/0009-0006-6165-2333

main differences are the operating mode, the type of mixing elements and the power of the devices. There are other mechanical and nature (thermal, electromagnetic, etc.) processes which could be used as part of mixing with the main equipment and separately: centrifugation, vibration, heating, etc. (Ivanets, 2015; Krakhmalev, 2022; Vanderroost, 2017). They require an automation process with unique parameters according to technical requirements like other elements of the technological process. The production of food can also include the stage of finished productspackaging, where is necessary the automation of packaging lines (Mel'nikova, Ponomareva, Bogdanova, 2017).

Technologist must monitoring each stage in the process of food production. Each type of production line requires a unified approach to maintaining the necessary control conditions because of the wide availability of different food range types. Programs are also used to control the chemical and taste parameters of solid and liquid products (kefir, juices, confectionery) in the modern food industry (Petryakov, 2018; Aly, 2023; Muzyka, 2022). The work of Aly B. and other authors provides an overview of modern information technologies use in the meat processing industry, where special attention was to the automation of the primary cutting meat process and different problems of introducing modern devices and software into production (Al Balushi, 2019).There are newtechnical vision tools which become widespread (Blagoveshchenskiy, Petryakov, Sumerin, 2020; Vignali, 2017). These elements area new area in the «Industry 4.0», which is called digitalization. Today these things affects not only the control stage, but also to other components of the production technological line.

The key area of digitalization is the Virtual reality (VR). VR is a set of technologies which could be used to create and modernize the real world with augmented reality. The virtual space which was created by application software with the special controllers support, allows a person to experience all reality changes. An augmented reality complex refers to those devices that can simulate and reproduce virtual space, using all the connected data for the interaction of a person and the created augmented space. That reality systems are divided into several subtypes: virtual system, where all objects which have created in a certain environment are developed and realized into a single program with models; an augmented system, where the system allows person to view the familiar world with changes; a mixed system that combines the first two systems with reference to real objects. Domestic researches which are related to this topic is mainly focused at the industrial use of virtual reality, but an important common problem in that articles is not enough comple of published materials.

The main functions of complexes after the VR introduction in industry are: design and collection of information; modeling of structures; testing and use of a digital model on active structures; training in a virtual environment; use of simulators to train workers in industry for minimize costs on devices operations; control and quality management system using developed materials for presentation and informing in production; quick response in case of differnet systems breakdown at an industrial facility to minimize costs to achieve set production tasks. There are some systems which were developed to assist in the maintenance of existing equipment, for example, in the production of juices (Barricelli, Casiraghi, Fogli, 2019). These complexes are a virtual reality system with the characteristics of the used equipment.

The virtual and real objects binding and similarity is important for simulation modeling of technological processes (mixed system). The development of action scenarios is the main part. Therefore, today the main directions in creating models are digital twins and mathematical modeling. The creation is carried out in all sectors of the national economy (Rasheed, San, Kvamsdal, 2020; Jones, 2020; Kaychenov, 2022; Zheleznov, 2021). The practical results of these activities were the created models of buildings, engineering equipment, mechanisms and other equipmnet (Zheleznov, 2021; Johra, 2021; Volkov, 2018; Trenfield, 2022). These systems provide capabilities and increase reliability of assembly processes, diagnostics and different complexities testing. Introduction of information technologies in medicine and pharmaceuticals will help to improve the quality and speed of logistics services (accelerating the issuance of prescriptions, sending reports of medical tests, etc.) (Gao, 2022), and other medical operations. The medical operations include the determination of preliminary diagnoses, interpretation of the computed tomography and other analyzing machines results. Educational interactive medical simulators can improve the quality of specialists work and plan complex surgical operations in a virtual environment to minimize costs. It is planned that their use in practice and in training will reduce the duration of surgical operations and will make it possible to simulate the actions of a doctor with the elaboration of each stage of operations. Digital technologies are used to work out scenarios for different critical, non-standard situations and improve the qualifications of company employees in non-industrial sectors. These applications has made possible to increase website traffic and sales for many companies several times. There are programs that are used to present a company products sells or the organizations themselves. However, problems remain with all digital systems. The main types are: ensuring system performance and information security.

The objectives of this work are: find out real software systems which are using virtual reality technology for training specialists in the food industry and present the developed simulation environment for the manufacture of chocolate products.

2 MATERIALS AND METHODS

There is an analysis of publications from domestic and leading foreign databases. It includes the study of modern tools for training different specialists of industrial enterprises. It was carried out in following databases: RSCI, Scopus, Web of Science, Ebsco, Agris and others. The key search criterion was the use of virtual reality technology.

The use of digital augmented space in industry has increased several times because of the large-scale development of information technology and free platforms. They allow person to create for production fully constructed virtual models of the equipment operating processes and their individual parts (Wauters, 2012). The development of the food industry depends on many factors, for example, the modernization of law or the ability of consumer needs. New requirements for production processes and requirements for personnel safety, sanitary and hygienic standards in production appear every year. There is a need to change the recipe, rebrand the logo and packaging, and create new products. All these phenomena require manufacturers for quickly respond to changes. Therefore, the use of different simulators is need in production. Connected sensors that collect information about problems in the operation of equipment allow the simulator to make a prediction: how the production line will perform under certain tasks and conditions. As a result, introducing such digital models into food and beverage production provides companies with great benefits: optimizing production and costs at the design stage; analyze instruments and devices about the state of operation; test different scenarios in a virtual environment. Person can create a digital model of the product when using a simulator in the food industry. This opportunity will make it possible to make a forecast of the final product, check the product's compliance with the stated regulatory requirements and planned indicators (Muzyka, 2022; Blagoveshchenskiy, Petryakov, Sumerin, 2020). Digital simulators will allow person to quickly upgrade old recipes to new equipment. Another solvable problem which facing for food manufacturers is organizing production lines that could be installed in a small space and maintain the same performance as the original ones. Digital reality solutions also help to visualize belts, conveyors, machinery for possible optimal conditions.

Most studies on this topic are devoted to existing production modernization by using information systems. At the same time, less attention is paid to the educational process. Education is an integral part of the production process in other industrial fields. Educational virtual platforms are focused at training the skills of rolling stock and machines operators in the transport infrastructure and mining industry (Xie, Liu, Wang, 2022; Palmer, 2022). There are conducting seminars use systems for digital twins of existing laboratory equipment and programming languages in the basic sciences (Aliev, Ivanova, Borodzhieva, 2022; Razakov, 2023). Virtual laboratory complexes are most often used in engineering disciplines (including the food industry) which can completely replace real laboratory work and not complement them like other educational programs (Volkov, 2018; Yan, Jia, 2022). There are interdisciplinary researches that cover the fields of biology, psychology, sociology, medicine in the food industry. Virtual reality is focused at determining the effects of the food type on a person. Researches show the influence of the human senses (vision and hearing) on the uprise effect of the food products taste perception. It can be attributed to any type of food and have both positive and negative effects on taste (Stelick, 2018; Wang, 2020; Crofton, 2019;Padiotis, Mikropoulos, 2010).

Only a few studies were identified have virtual models of technological processes for educational purposes in the food industry during the search for works (Al Balushi, 2019; Yan, Jia, 2022). Main characteristics of them have been described previously. The last research, which is a completely educational product, can be used to train specialists in the food industry. It is a work that describes the use of the solo complex for a depth study of the milk pasteurization process. It describes the physical component of the process and the visualized elements of the technology. It can be concluded that existing simulator programs for food production lines do not fully describe the features of this industry. Therefore, it is necessary to develop simulator programs for training specialists in accordance with the field of training.

There is a presentation of the created simulator chocolate production line for training specialists in the confectionery industry. The simulator was implemented in 4 software environments. The creation of three-dimensional digital twins of all devices was done in the Autodesk Inventor environment. All models were loaded into the Blender 3D editor, where it was developed animation and simulated the mechanical elements actions of the devices after primary detailing. Direct settings of the system was carried out in C# in a special plugin. All developed components were loaded into the cross-platform Unity 3D environment after all the actions. It is usually used to create gaming applications on different platforms. In this project, this particular platform was chosen because of the fact that it has a modular system of components, which is necessary for the animated applications stable operation.

3 RESULTS AND DISCUSSION

The developed technological line for the production of chocolate has been implemented in the form of an animated simulator which is designed for employees at enterprises and for students who are receiving higher education. The main functional elements of the developed complex are presented in Figure 1. An engineer establishes all the main indicators of production data in order to determine their possible values and work out different situations. The main characteristics are calculated automatically and based on the collected data as a result of working process with the subtasks completed by students.

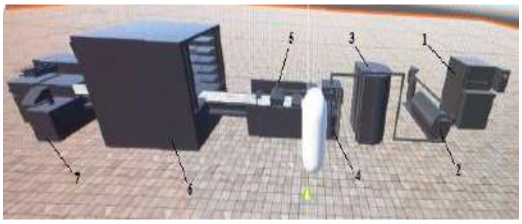


Figure 1: The main structural elements of a chocolate production line simulator: 1 – oven for melting cocoa beans; 2 – conching equipment; 3 – storage tank; 4 – machine for applying glaze; 5 – filling machine; 6 - refrigerator; 7 – packaging machine.

The process of technology operation in the virtual environment has been visualized in program. The routines are implemented that analyse and collect data which has been collected from the student in the simulator by system. Authors have developed the main points of the industrial lineinteraction in the complex which are necessary for setting up and performing the main tasks of operations that arise in production. There is the appearance of the equipment for chocolateheat treatment at the final productionstages in Figure 2.

Figure 2: Refrigerator equipment for cooling process of chocolate.

The key features of the current version are: visual remote inspection of an industrial line with the ability to customize it to increase (decrease) the quality of the work performed; research of all work processes; processing and storage of received information in different forms (creation of a specific database for all tests performed in the simulator); receiving a detailed analysis of the created product characteristics at each stage of the life cycle. One of the current version simulatordisadvantages is the inability of the program to work in automatic mode for the all-data complete transfer. Also, there is an imperfect detailing of theproduction line main elements because of the limited information about modern devices in the public domain. It is necessary to improve it in the field of data transmission and develop real, highly detailed main equipment digital twins from a certain company producing or information from an existing chocolate production. Current version of program can improve the quality of thecreated products, reduce the cost of components and get a new specialization (qualification profile) for employees at the enterprise. During the creation of the software package, the simulation of the main chocolate production line was included the real processwithout any deviation.A virtual production line will not be able to manufacture a product without an exact sequence of actions that are crated in the programmed technical specifications. This information corresponds to the ideal production process according to recipe and characteristic data.

Element of the developed chocolate production line simulator program code has presented below:

```
using System. Collections;
using System. Collections. Generic;
using System. UnityEngine;
public class LineTest :MonoBehaviour
{
private bool I = false;
public float scrollSpeed = 0.15f;
Renderer rend;
private float delay_start = 0.4f;
public GameObjectLight_Bulb_Line;
public GameObjectLine;
public Texture texture;
private float offset;
private float temp;
```

```
   void Start ()
   {
   rend =
Line.GetComponent<Renderer>();
   }
   void Update ()
   {
   if(i == false)
   Light_Bulb_Line.GetComponent<Rendere
r>().material.color=Color.red;
   }
   else if (i == true)
   {
   rend.material.mainTexture = texture;
   offset = Time.time * scrollSpeed;
   rend.material.SetTextureOffset("_Mai
nTex", new Vector2(offset,0));
   Light_Bulb_Line.GetComponent<Rendere
r>().material.color = Color.green;
   }
   }
   void OnMouseDown()
   {
   if(i == false)
   {
   i= true;
   }
   else
   {
   i = false
   }
   StartCoroutine(Delay_COR());
   }
   IEnumeratorDelay_COR()
   {
   transform.Translate(0,4,0);
   yield return new
WaitForSeconds(delay_start);
   transform.Translate(0,-4,0);
   }
   }
```

Inthe appendix article there is a video which was recordedin testing process of the software complex by a test operator. It imitates the work of a chocolate production line. If specialized equipment (virtual reality helmet, control panels, etc.)is available in educational institutions, this program could beused by it.

4 CONCLUSIONS

Food industry is a fairly independent industry which in recent years has demonstrated the technological growth and the potential for introducing digital solutions into production lines. The modern software solutions could be used at all stages of any production. The development and implementation of virtual simulators will minimize production losses, as well as train qualified personals on devices that are close to reality. Future researches in the field of food industry digitalization are associated with the modernization and detailing of existing models, the development of new algorithms and hardware components of systems and the creation of new scenarios for the operation of industrial lines.

Developed simulator of a chocolate production line can be implemented into existing educational programs for training specialists in the field of confectionery products in the food industry. Advantages of using the created a chocolate production line virtual simulator: flexible configuration of educational materials in accordance with the production line used; creation of automatic forecasting and assessment of students tasksperformance; generating reports and recommendations to the student during the operation of the industrial line; structuring the main visual indicators and collected information on production control and engineering skills during the use of the simulator.

ACKNOWLEDGEMENTS

Authors gratitude to the Russian Biotechnological University for the presented software, which was used in the development of a virtual technological line for chocolate production.

REFERENCES

Fedosenkov, D., et al., 2015. The computer-aided controlling of technical and technological plants in the wavelet medium. Food Processing: Techniques and Technology, 1(36), 127-135.

Khvostov, A., et al., 2018. Matrix dynamic models of elements of technological systems with perfect mixing and plug-flow hydrodynamics in Simulink. Foods and Raw Materials, 6(2): 483-492.

Wauters, T., et al., 2012. Real-world production scheduling for the food industry: An integrated approach. Engineering Applications of Artificial Intelligence, 25(2): 222-228.

Santos Cunnighan, M. el al., 2019. Improving the quality of ground coffee "Arabica" by using the SCADA system to automate the volumetric dosing process. Health, Food & Biotechnology, 2(1): 121-135.

Blagoveshchenskaya, M., et al., 2020. Development of a neural network model for controlling the process of dosing bulk food masses. Journal of Physics: Conference Series, 1705(1): 012027.

Balykhin, M., et al., 2018. Development of neural network model to control the dosing process of granular masses. Proceedings of higher education institutions. Textile industry technology, 6(378): 179-183.
Ivanets, V.N., et al., 2015. Intensification of bulk material mixing in new designs of drum, vibratory and centrifugal mixers. Foods and Raw Materials, 3(1): 62–69.
Krakhmalev, O., et al., 2022. Robotic Complex for Harvesting Apple Crops. Robotics, 11(4): 77. Balykhin, M., et al. (2019). Automation of vacuum sublimation drying of products using the combined management. Proceedings of higher education institutions. Textile industry technology, 2(380): 133-137.
Vanderroost, M., et al., 2017. The digitization of a food package’s life cycle: Existing and emerging computer systems in the pre-logistics phase. Computers in Industry, 87: 1-14.
Mel'nikova, E., Ponomareva, N., Bogdanova, E., 2017. Artificial neural networks for the assessment of quality indices of low-allergy fermented milk drinks. Food Processing: Techniques and Technology, 44(1): 152-158.
Petryakov, A., et al., 2018. Application of object-oriented programming method for monitoring quality indicators of confectionery products. Confectionery and bakery production, 5-6 (176): 21-23.
Aly, B., et al., 2023. Robotics and sensing technologies in red meat processing: A review. Trends in Food Science & Technology, 137: 142-155.
Muzyka, M., et al., 2022. Intelligent module-taster for prediction of the taste of kefir. Storage and processing of farm products, 1: 173-193.
Al Balushi, I., et al., 2019. Study of the impact of the use of technical vision on the quality indicators of Oman halva. Health, Food & Biotechnology, 4(1): 39-52.
Blagoveshchenskiy, V., Petryakov, A., Sumerin, V., 2020. Determination of the efficiency of the process of separating sunflower seeds in a stream using computer vision. Health, Food & Biotechnology, 3(2): 40-47.
Vignali, G., et al., 2017. Design and testing of an augmented reality solution to enhance operator safety in the food industry. International Journal of Food Engineering, 14(2): 20170122.
Barricelli, B., Casiraghi, E., Fogli, D. A., 2019. Survey on Digital Twin: Definitions, Characteristics, Applications, and Design Implications. In IEEE Access, 7: 167653-167671.
Rasheed, A., San, O., Kvamsdal, T., 2020. Digital Twin: Values, Challenges and Enablers arom a Modeling Perspective. In IEEE Access, 8: 21980-22012.
Jones, D., et al., 2020. Characterising the digital twin: a systematic literature review. CIRP Journal of manufacturing science and technology, 29(a): 26-52.
Kaychenov, A., et al., 2022. Mathematical modeling of thermal and humidity processes in the food drying chamber. Vestnik of Tver State Technical University. Series «Technical Science», 4(16): 76-87.
Zheleznov, M., et al., 2021. Analysis of building information modeling technologies for transport infrastructure objects at the stages of the life cycle. E3S Web of Conferences, 263: 05030.
Zheleznov, M., et al., 2021. Analysis of international experience in the field of building information modelling of transport infrastructure objects. E3S Web of Conferences, 263: 05029.
Johra, H., et al., 2021. Digital twins of building physics experimental laboratory setups for effective e-learning. Journal of Physics: Conference Series, 2069(1): 012190.
Volkov, A., 2018. Digital models in construction: classification paradigm. MATEC Web of Conferences, 251: 03066.
Trenfield, S., et al., 2022. Advancing pharmacy and healthcare with virtual digital technologies. Advanced Drug Delivery Reviews, 182: 114098.
Gao, D., at el., 2022. Research and design of virtual driving platform of simulated train based on python. Lecture Notes in Electrical Engineering. 2022; 867: 235-242.
Xie, J., Liu, S., Wang, X., 2022. Framework for a closed-loop cooperative human cyber-physical system for the mining industry driven by VR and AR: MHCPS. Computers and Industrial Engineering, 168: 108050.
Palmer, C., et al., 2022. Digital twinning remote laboratories for online practical learning. Production and Manufacturing Research, 10(1): 519-545.
Aliev, Y., Ivanova, G., Borodzhieva, A., 2022. Virtual laboratory for teaching coding theory. In ACM International Conference Proceeding Series, 142-148.
Razakov, M., 2023. The virtual laboratory complexes in education system of food technologies. Proceedings of SPIE, 12564: 125641B-1.
Yan, J., Jia, H., 2022. Construction of marine professional virtual simulation experiment platform based on internet-of-things technology. Security and Communication Networks, 2833741.
Ramos-de-la-Peña, A. M., Aguilar, O., González-Valdez, J., 2022. Virtual reality immersion: Taste and texture changes for identical samples of two common condiments. Chemosensory Perception, 15(2): 87-94.
Stelick, A., et al., 2018. Dynamic context sensory testing–A proof of concept study bringing virtual reality to the sensory booth. Journal of food science, 83(8): 2047-2051.
Wang, Q., et al., 2020. A dash of virtual milk: altering product colour in virtual reality influences flavour perception of cold-brew coffee. Frontiers in psychology, 11: 595788.
Crofton, E., et al., 2019. Potential applications for virtual and augmented reality technologies in sensory science. Innovative Food Science & Emerging Technologies, 56: 102178.
Padiotis, I., Mikropoulos, T., 2010. Using SOLO to Evaluate an Educational Virtual Environment in a Technology Education Setting. Journal of Educational Technology & Society, 13(3): 233-245.

APPENDIX

Link to video of developed chocolate production line simulator working in Google Drive: https://drive.google.com/file/d/1P5xVcFZRuMhJoUtaQ3l1KfwkIKCs1R9x/view?usp=sharing.

Application of Blockchain Technologies in the Digital Economy: Challenges and Prospects

Saitkamolov Mukhammadkhoja Sabirkhoja ugli[1]
Tashkent University of Information Technologies, Dean of the Faculty of Economics and Management in the Field of ICT, Doctor of Economic Sciences
mukhammadkhujasaitkamolov@gmail.com

Key words: blockchain technologies, blockchain, transformation of the digital economy, digital economy, effective implementation, economic processes.

Annotation: This article discusses the current topic of the use of blockchain technologies in the digital economy. The study is based on an analysis of existing research and publications, as well as on the consideration of examples of the use of blockchain in various business areas. The main purpose of the work is to identify the challenges and prospects of using blockchain, as well as to assess its impact on economic processes. The advantages and disadvantages of using blockchain are discussed in detail, as well as recommendations for its effective implementation. In conclusion, the conclusions about the potential of blockchain technologies for the transformation of the digital economy and identifies possible areas for further research. The digital economy encompasses a wide range of sectors, including finance, supply chain management, healthcare, voting systems, intellectual property rights, and more. Blockchain technology offers several advantages in these domains. Its decentralized and immutable nature enables transparent and secure transactions, enhances data integrity, and eliminates the need for intermediaries. However, the application of blockchain in the digital economy comes with its fair share of challenges. Scalability remains a major concern, as the current blockchain infrastructure faces limitations in terms of transaction speed and network capacity. Additionally, ensuring privacy and data protection within a public blockchain can be challenging, especially when dealing with sensitive information. Interoperability between different blockchain platforms is another challenge that needs to be addressed.

1 INTRODUCTION

Most countries today show great interest in the development of the digital economy, and blockchain technology, in particular, is advancing in all sectors of the economy, creating infrastructure for the development of the digital economy. Blockchain technology is developing in various sectors, including economics and public administration. This article examines the nature of the blockchain, the mechanisms of its operation and the main economic aspects. In particular, modern directions of using blockchain in society and business, its disadvantages and advantages, as well as problems of its implementation are considered. The directions for introducing the technology in many sectors of the economy are being researched. The object of the study is the national and international experience of individual states in the use of blockchain in socially significant areas of public life. The subject of the study. Applications of blockchain in business and society. The scientific novelty of the research lies in the review of the directions of application of blockchain technology. Scope of application of the results: it is advisable to use the obtained results in projects to implement blockchain technology.

[1] https://orcid.org/0000-0002-1246-5257

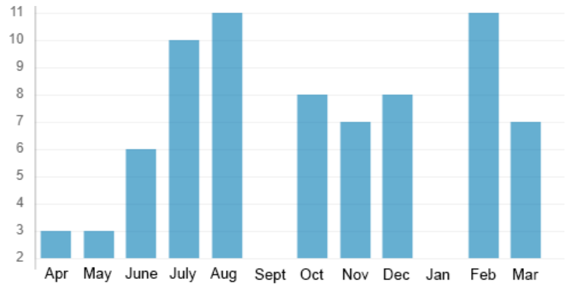


Figure 1: The number of downloads of blockchain technologies from 04.2023 to 03.2024.

Hypothesis. The use of blockchain technologies in the digital economy can solve the problems of centralization, lack of trust and complexity of interaction between participants, as well as increase transparency, efficiency and security in various areas of economic activity.

This hypothesis suggests that blockchain technologies may be a key tool to overcome the challenges faced by participants in the digital economy. It suggests that blockchain can provide decentralization, stability and reliability of systems, as well as increase automation and efficiency of processes. To confirm or refute this hypothesis, research and practical testing of blockchain technologies in various sectors of the digital economy is required. This may include an analysis of the advantages, disadvantages, cost of implementation, as well as examination of security and regulatory issues.

2 RESEARCH METHODS

The study of blockchain technologies in the digital economy of Uzbekistan can be carried out using the following methods:

Analysis of documents and legislation: The study of official documents such as laws, regulatory acts and strategies related to blockchain technologies in Uzbekistan. This will help understand the official position of the state and its plans for the development of the blockchain.

Research on the use of blockchain in government projects: Analysis and study of publicly available information about projects where blockchain technologies are already being used or are planned to be used in the public sector of Uzbekistan. This may include projects in the field of electronic voting, digital identification, public services, etc.

Expert Interviews: Conducting interviews with government representatives, academic experts, entrepreneurs and other stakeholders to get their opinions and understand the current state and prospects of blockchain application in the digital economy of Uzbekistan.

Analysis of projects and startups: A study of blockchain projects and startups in Uzbekistan to assess their success, challenges, prospects and impact on the digital economy. This may include an analysis of business models, technical solutions, and project results.

Comparative analysis with other countries: A study of the experience of other countries, especially those that are actively developing blockchain technologies in their digital economies. A comparative analysis will help to identify advantages, disadvantages and lessons that can be applied in the context of Uzbekistan.

The results of the study of blockchain technologies in the digital economy of Uzbekistan:

1. Government support:

The "Uzbekistan – 2030" Strategy aims to introduce blockchain technologies into various sectors of the economy, such as public services, healthcare, education, logistics, etc. The Digital Economy Development Center has been created, which is engaged in the development and implementation of blockchain solutions. The law "On Crypto Assets" has been adopted, which legalizes the turnover of cryptocurrencies and the activities of crypto exchanges.

2. Examples of the use of blockchain technologies:

Public services: Electronic document management system: blockchain is used to ensure the security and transparency of document management. Real Estate Title Registration System: Blockchain is used to create a decentralized real estate title registry. State Procurement System: Blockchain is used to ensure transparency and efficiency of procurement.

Healthcare: Medical Record Storage System: Blockchain is used to ensure the security and confidentiality of medical records.

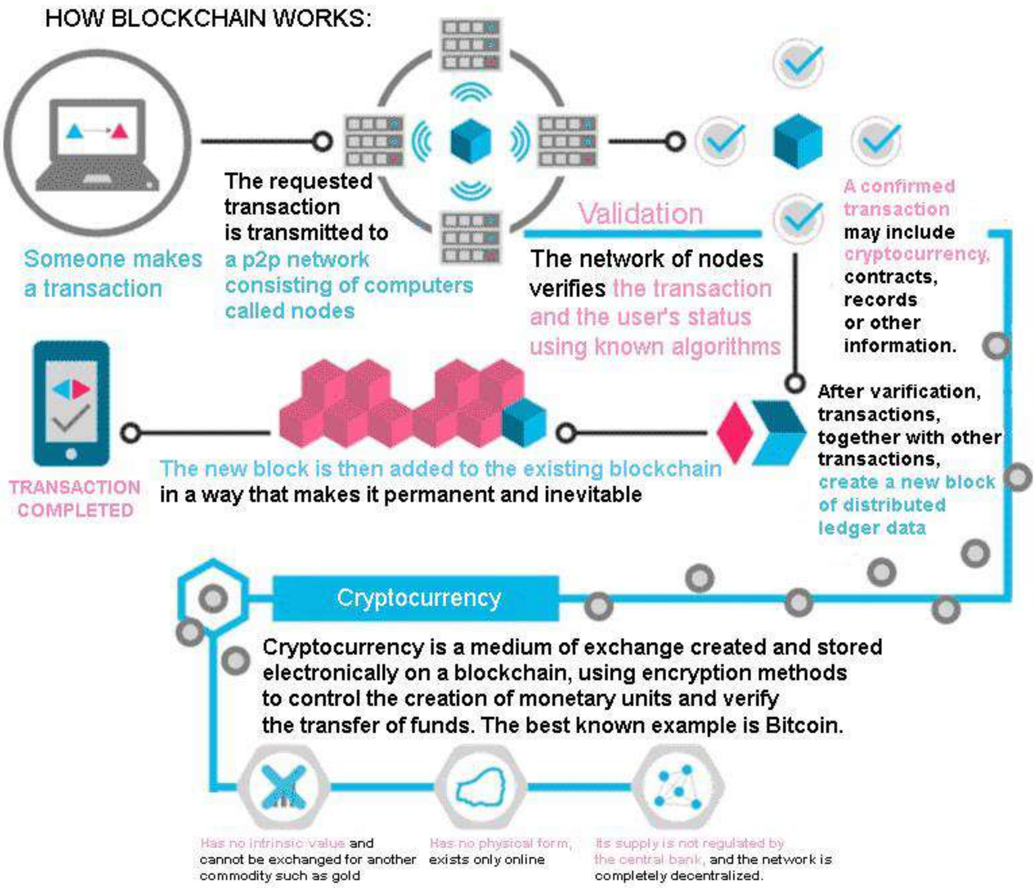


Figure 2: The process of explaining the system of operation of blockchain technologies.

Drug Traceability System: Blockchain is used to track the origin and quality of drugs.

Education: Diploma system: Blockchain is used to create secure digital diplomas. Document Authentication System: Blockchain is used to verify the authenticity of diplomas and other documents.

Logistics: Cargo Tracking System: Blockchain is used to track the movement of cargo throughout the supply chain. Customs Clearance System: Blockchain is used to simplify customs procedures.

3. Advantages of using blockchain technologies: Increased security: blockchain provides a high degree of data protection from unauthorized access. Increased transparency: all transactions in the blockchain are recorded in an immutable log, which ensures transparency of all processes. Cost reduction: blockchain allows to optimize business processes and reduce costs. Efficiency improvement: blockchain allows to speed up transactions and increase work efficiency.

4. Challenges and Obstacles: Lack of awareness: Many people and organizations are unaware of the benefits of blockchain technologies. Insufficient infrastructure: the development of blockchain technologies requires a well-developed IT infrastructure.

Regulation: it is necessary to develop a regulatory framework that will regulate the turnover of cryptocurrencies and the activities of crypto exchanges.

In the last decade, the concept of the "digital economy" has become widespread in the scientific community and practice in many countries.

The rapid development of digital technologies in the context of economic globalization has served as the basis for the digital revolution and the transformation of the role of information from an auxiliary one into a main resource for market participants. The transition to the digital economy has manifested itself in the following aspects: digitization of business processes and the introduction of digital technologies into the activities of industrial enterprises, service organizations, government agencies and financial institutions. The development of digital technologies brings obvious benefits to economic entities in the form of increasing the efficiency of economic processes, increasing competitiveness, and synergetic effect through networking between market participants and expanding opportunities for market participants. Interaction between market participants and expansion of business opportunities through the use of digital payment systems and digital financial institutions. They also include expanding business opportunities through the use of digital payment systems and digital money. Despite the active development of digital technologies in all areas of economic activity, their capabilities, advantages and disadvantages have not yet been fully studied. Both theorists and practitioners continue to argue about the prospects of digitalization and the possible risks associated with the transition to digital technologies. Risks that may be associated with the transition to digital technologies in strategically important sectors of the economy, in particular in the following areas: Blockchain technology is used in strategically important sectors of the economy, in particular in financial and banking activities.

Blockchain technology has a wide range of applications in various business areas. Let's look at some examples of the use of blockchain in various industries:

Financial industry: Blockchain is used to create secure and transparent financial systems. For example, blockchain can be used to ensure secure and fast transactions, eliminate intermediaries in international payments, and create digital currencies such as bitcoin.

Supply and Logistics: Blockchain can be used to track the supply chain, verify the authenticity and control the quality of goods. This improves efficiency and trust in the supply chain and prevents counterfeiting of goods.

Healthcare: In the medical field, blockchain can be used to store and exchange medical data, ensuring the safety and privacy of patients. Blockchain can also help track and verify medical research and clinical trials.

Real estate: Blockchain can be used to simplify the process of buying and selling real estate, registering property titles and verifying property history. This can reduce the risks of fraud and increase transparency in real estate transactions.

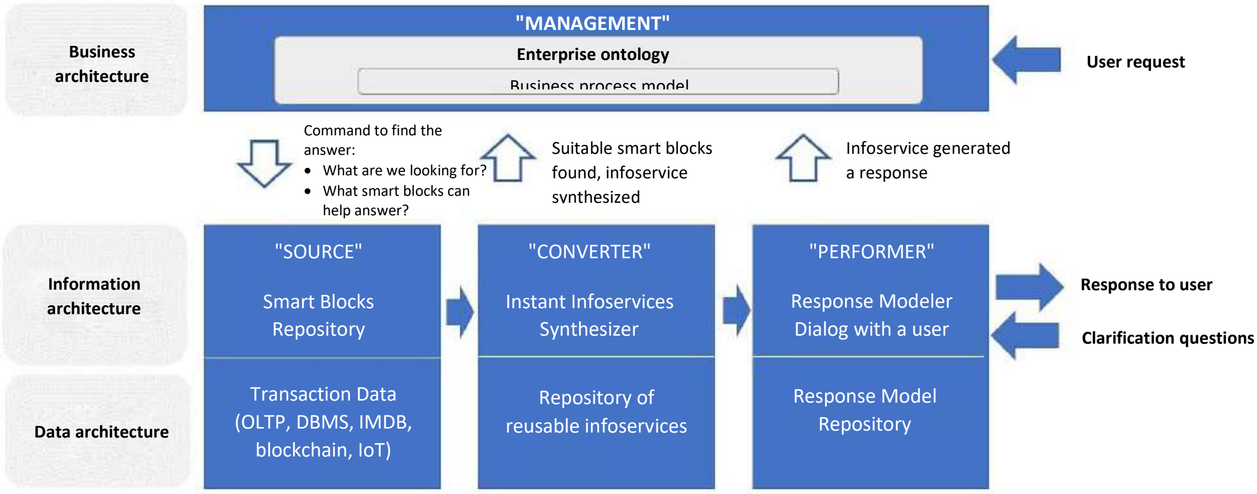


Figure 3: Example of creating a model using blockchain technology.

Intellectual Property: Blockchain can be used to register and protect intellectual property such as patents, copyrights or trademarks. This helps establish provable authorship and prevent intellectual property theft.

Voting: Blockchain can be used to organize electronic voting, ensuring transparency, security and the impossibility of substitution of results. This can increase confidence in the electoral system and prevent possible manipulation.

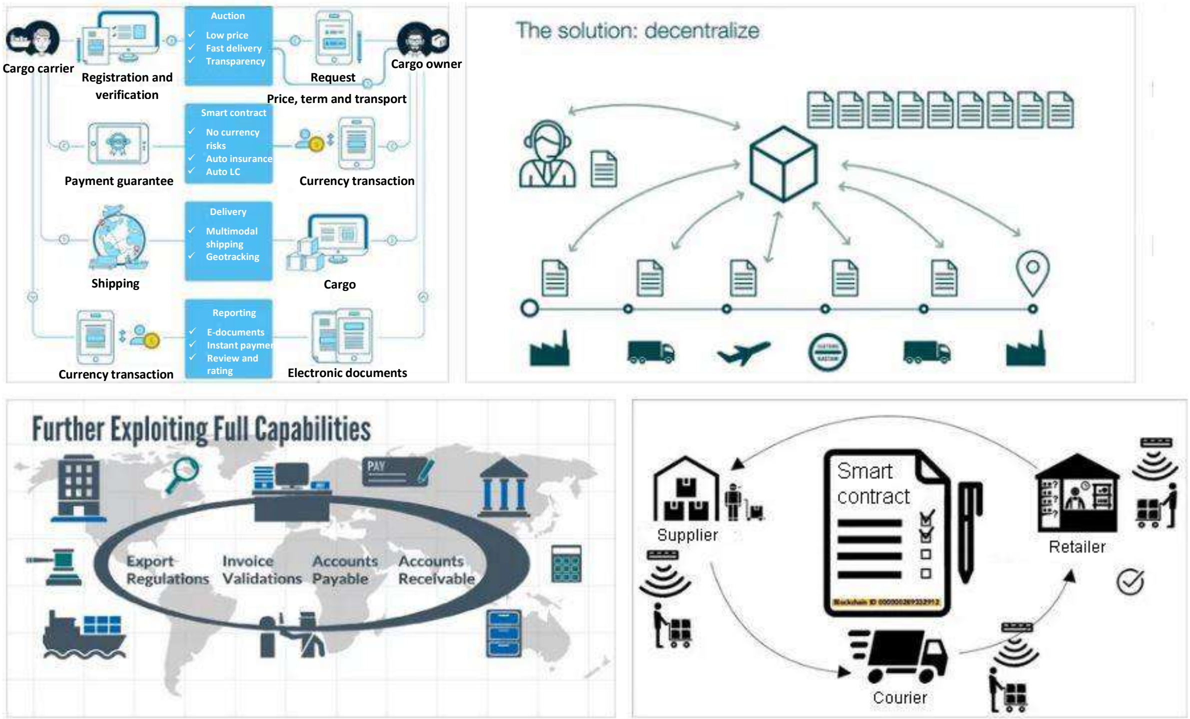


Figure 4: Use of blockchain technology in logistics.

The purpose of using blockchain technology may depend on the specific application case, but in a general sense, blockchain is used to create decentralized, transparent and reliable systems. Here are some of the main purposes of using blockchain:

Decentralization: Blockchain allows to create systems without central management, where control is distributed among network participants. This can improve the security and stability of the system, as there is no single point of failure.

Transparency: Blockchain provides transparency, as all transactions and data changes are recorded in a public blockchain. This allows network participants to verify and confirm the actions of other participants, which promotes trust and reduces fraud.

Reliability and Security: Blockchain uses cryptography to ensure the security of data and transactions. Each transaction must be confirmed by the network and recorded in a block, which is then linked to the previous blocks. This makes it much more difficult to change or falsify data.

Efficiency Improvement: Some blockchain systems can improve efficiency and reduce costs by automating processes, removing intermediaries and increasing the speed of transaction processing.

Despite its advantages, blockchain technology also has some disadvantages:

Scalability: Blockchain may face scalability issues when processing a large number of transactions. This is due to the need for each transaction to be confirmed by the network and each transaction to be recorded in a block, which can slow down the process.

Energy consumption: Some blockchains, especially those that use the Proof-of-Work mechanism, require significant computing resources and energy to confirm transactions. This can cause problems with energy efficiency and the environment.

Lack of regulation: Blockchain technology often operates in a decentralized environment, which can make it difficult to apply legal norms and regulation. This can cause problems regarding consumer protection, crime control, and regulatory compliance.

The possibility of errors in smart contracts: Smart contracts that run on the blockchain may contain errors or vulnerabilities that can be exploited by attackers. Incorrect implementation of smart contracts can lead to loss of funds or system shutdown.

3 CONCLUSION

Blockchain technologies have a huge potential for transforming the digital economy. They offer new opportunities to create secure, transparent and decentralized systems that can increase efficiency, reliability and trust in various business areas.

However, despite the progress and achievements in the field of blockchain, there remain some technical, legal and regulatory challenges that need to be addressed. Blockchain scalability, ensuring data privacy, establishing standards and regulatory frameworks, and interoperability with traditional systems are some of the key aspects that require further research and development.

Possible directions for further research are:

Scalability and performance: Further research should focus on the development of scalable and efficient blockchain protocols that can handle a large number of transactions without compromising performance.

- Privacy and security: Blockchain must provide data reliability and privacy to protect users' confidential information. Research can be aimed at developing new protocols and algorithms that guarantee security and privacy while maintaining the transparency of the system.
- Integration and interaction: Research should focus on developing standards and protocols that will allow blockchain to interoperate with traditional systems and networks. This will help ensure interoperability and security when implementing blockchain in various industries.
- Legal and regulatory aspects: Future research should address legal and regulatory issues related to blockchain, including aspects such as identification, consumer protection, data management and dispute resolution.
- Exploring new applications: Blockchain technologies are still relatively new, and research should be focused on finding new applications where blockchain can bring significant benefits, as well as on developing innovative business models based on blockchain.

In general, blockchain technologies have a huge potential for transforming various business areas. Further research and development will help overcome current limitations and unlock the full potential of blockchain in the digital economy.

4 RECOMMENDATIONS

The development of blockchain technology in Uzbekistan can be stimulated through the following strategies and recommendations:

Creating a favorable regulatory environment: Uzbekistan can develop and implement a favorable regulatory framework that will provide legal protection and clarity for the development of blockchain technology. This includes establishing transparent rules and regulations governing the use of blockchain in various industries, including the financial system, public services, procurement, healthcare and others.

Support for innovations and startups: Uzbekistan can create programs and initiatives aimed at supporting and developing blockchain startups and innovative projects. This may include providing financial support, incubation programs, access to experts and mentors, as well as organizing hackathons and contests to stimulate the development of new blockchain solutions.

Education and awareness-raising: Uzbekistan can invest in education and awareness-raising about blockchain technology. This may include incorporating blockchain into university and technical school curricula, organizing seminars, trainings and conferences, and creating online courses and educational resources for a wider audience.

Partnership with the private sector: Uzbekistan can actively seek partnerships with the private sector, including large companies and industrial giants, to jointly develop and implement blockchain solutions. This may include joint research and development, pilot projects, as well as the exchange of experience and knowledge transfer.

Blockchain integration into public services: Uzbekistan can use blockchain to improve the efficiency and transparency of public services. This may include the creation of a single digital platform for registration and authentication of documents, improvement of the voting system, digitalization of real estate registration processes and other state procedures.

International cooperation: Uzbekistan can actively cooperate with other countries and international organizations to share experiences, transfer best practices and create international standards in the field of blockchain. This can help strengthen Uzbekistan's position in the global blockchain community and attract foreign investment and expertise.

These strategies and recommendations can help Uzbekistan develop blockchain technology and take advantage of its potential to facilitate digital transformation in the country. However, it is important to note that the implementation of these strategies will require broad support and cooperation between government agencies, the private sector, academic institutions and international partners.

REFERENCES

http://kras-science.ru/jour/index.php/nk/article/view/71

The State Committee of the Republic of Uzbekistan for Investments (2020). "Uzbekistan Blockchain Roadmap 2019-2021", https://invest.gov.uz/storage/files/Blockchain_Roadmap_ENG.pdf

https://uzbekistan.gov.uz/en/o-uzbekistane/natsionalnye-strategii-i-programmy/strategiya-tsifrovoy-transformatsii-2030/

Strategy "Uzbekistan 2030"" https://www.gazeta.uz/ru/2023/09/12/stratery/

https://www.gazeta.uz/ru/2022/08/26/blockchain/

https://uzdta.uz/

https://www.comindware.ru/blog/digital-economy/

https://cssrzd.ru/news/blockchein-v-logistike.php

Cultural Heritage in the Economy of a Modern City

Olga Saginova[1][a], Dmitry Zavyalov[1][b] and Nadezhda Zavyalova[1][c]
[1]*Plekhanov Russian University of Economics, Stremyanny lane, 36, Moscow, Russian Federation*
Saginova.ov@rea.ru, Zavyalov.dv@rea.ru, Zavyalova.nb@rea.ru

Keywords: cultural heritage sites, customer empowerment, digital technologies, citizens, India, Iran, China, comparative analysis

Abstract: Modern smart cities are not only newly built modern buildings, smart transport systems and digital services. It is also city history and architecture, beautiful landscapes and comfortable public spaces. Tourists are attracted to cities with rich heritage of history and culture, which is easy to access, and interesting to see. Cultural heritage objects should be integrated into urban economy to be both safely preserved for the future generations and to be effectively used in the life of the current city dwellers. Based on the comparison of best practices in managing cultural heritage in the capital cities of China, Iran, and India, obtained from open sources, scientific publications and expert opinions, a mechanism to manage cultural heritage is developed, including objectives, key processes and implementation tools.

1 INTRODUCTION

The preservation of historical and cultural heritage is an important task of modern cities. Objects of historical and cultural heritage contribute to the understanding of people's history and national identity, support the development of comfortable urban environment, form an important part of the tourist brand of the city and the country, which positively affect the economy of cities and territories, in line with the UN sustainable development goals.

An important element of cultural heritage protection is the involvement of citizens and civil society. Their participation in the decision-making process for the preservation, use and promotion of cultural heritage sites allows them to develop a sense of belonging and co-ownership. This, in turn, enables not only to harmonize efforts to effectively manage heritage sites in accordance with the expectations and needs of the local population, but also stimulate citizens and public organizations to take a more active part in the preservation and use of heritage sites.

The purpose of this paper is to identify effective models of interaction between the state and society to preserve historical and cultural heritage and develop citizens' sense of belonging and responsibility for the protection of cultural heritage, its use in the economic life of the city and the country.

2 RESEARCH METHODS

A comparative analysis of modern practices of managing citizens' participation in the processes of preserving cultural heritage was carried out based on the analysis of regulatory and legislative documents, scientific publications and other open sources, and experts' opinions in the People's Republic of China, the Islamic Republic of Iran, and the Republic of India. The choice of countries for comparative analysis was determined by the presence in these countries of a significant number of cultural heritage sites relating to different eras and being used in the capital cities economic and social life.

This paper presents results of the second wave of research of cultural heritage management in the world capital cities, the first being related to five European capitals (Naslediye, 2021). The second wave of research was contracted to the research team of the Plekhanov Russian University of Economics and was conducted in 2023. An integrated approach was used by the research team to select and assess the interaction mechanisms between the state and society

[a] http://orcid.org/0000-0002-7342-095X
[b] https://orcid.org/0000-0003-1963-0021
[c] https://orcid.org/0000-0003-2939-4974

and their impact on the cultural heritage sites management.

3 RESEARCH RESULTS

3.1 Cultural Heritage as an Economic and Social Asset

At the beginning of the XXI century, more than 100 international legal documents were related to the regulation of identification, conservation, protection, classification, and promotion of cultural heritage sites. National laws are largely based on international conventions, with the basic document being the Convention on the Protection of the World Cultural and Natural Heritage, adopted by the General Conference of the United Nations Educational, Scientific and Cultural Organization UNESCO in 1972 (Convention, 1972). In the Convention, the term "cultural heritage" is used to mean: (1) monuments: works of architecture, monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, caves and groups of elements that have outstanding universal value from the point of view of history, art or science; (2) places of interest: human works or joint creations of man and nature, as well as zones, including archaeological sites of outstanding universal value from the point of view of history, aesthetics, ethnology or anthropology.

All country-parties to the convention comply with the rules established by the UNESCO and use the cultural heritage management system contained in UNESCO documents and recommendations. For sites included in the World Heritage List, the participating country regularly submits reports to the World Heritage Committee and receives UNESCO representatives to monitor and verify the condition of the sites in a particular country and actions taken to protect them.

The system of managing the interaction of the state, business and civil society does not have a single universal pattern. The basis of interaction is legislation and regulations explaining the role of participants in the process of preserving historical and cultural heritage when identifying cultural heritage sites, adding them to lists of protected values, planning restoration and archaeological excavations.

The guiding document on the preservation of cultural heritage sites in all the countries under consideration is the Constitution, which obliges the state to provide conditions for the preservation of cultural heritage monuments, and every citizen to appreciate and cherish the historical and cultural heritage of the country. In China, the law "On the Protection of Cultural Relics" (Cultural Relics Protection Law) contains a definition of the concept of "cultural relic"; it presents the principles of management and distribution of powers of authorities when working with cultural relics; formulates the main approaches to financing the protection and management of cultural property, defines the ownership rights and responsibilities of the owners. In India, the "Ancient Monuments, Archaeological Sites and Remains Act of 1958" (The Ancient Monuments, 2010) defines the principles of classification of cultural heritage sites and distribution of powers of authorities, the rights and obligations of owners. In Iran, the "Law on the Preservation of National Cultural Heritage" (Iran, 1930) defines the national heritage, the registration process, the responsibility of the state and owners, the rules for the import and export of cultural heritage objects, the responsibility of organizations and citizens for damage to such objects.

Basing on the legislation, a management system is formed from the federal to the regional and municipal levels. The State, acting jointly with public organizations, plays the leading role in the process of preserving and managing cultural heritage and acts as a guarantor of its protection. The state level, in the form of a specialized department, Ministry of Culture, Tourism or Education, defines the basic rules and regulations, transferring practical responsibilities for the preservation of cultural heritage to local authorities. They are responsible for the protection of cultural heritage sites in all the countries studied, they involve businesses, public and non-profit organizations, and individual citizens assist in cultural heritage sites protection. Some cultural centres and research organizations collect information about the cultural monuments (for example, the project of the Indira Gandhi National Centre for the Arts in India or the participation of volunteers in the Chinese national census of Cultural Heritage). Some projects are short term (for example, repair and restoration of sections of the Great Wall of China) and some are long-term (like the program for the historical and cultural monuments adoption in India).

The management processes of cultural heritage sites include several stages (table 1).

In India and Iran, after an expert opinion on the value of an object is presented, a public notification is issued, and within a specified period, the owner of the object (and in India, anyone) can express their disagreement if they consider their property rights infringed by the object registration as cultural heritage. During registration, not only the level of protection of the object (world, national or local) can be determined, but also its class. Registration of the object is executed by a document (certificate, passport), which specifies the basic data on the object (name, location, characteristics of value).

Table 1: Key processes for cultural heritage management.

Stages	Participants	Explanation
Initiation	owner of the object (physical person or legal entity), or cultural heritage management bodies	Information about the site is initially collected by local cultural heritage management authorities
Examination	commission of experts in accordance with the criteria defined by the law	criteria include the age of the object, its historical or architectural value, originality and degree of preservation
Registration	supervising authority/ministry at the state or local level	Cultural heritage object is registered depending on its value as local/national/world heritage
Protection	authorized bodies	conservation plan restoration, if necessary, protection and use.

The main coordinating role at all stages is played by authorized state bodies, but gradually the role of public initiative in the field of protection and promotion of national heritage is increasing in all the countries studied. That is why, it is so important to identify effective mechanisms to involve and manage non-government bodies and individual citizens in the processes of preserving cultural heritage.

The preservation of the historical function of a cultural heritage object also includes its profitable usage. As a rule, this model includes elements of adaptation (redevelopment) of individual parts of the object to achieve profitable usage. For example, the Trans-Iranian Railway, included in the World Heritage List, has preserved the authenticity of its main elements in terms of location, shape, design, materials, use and functions. Since its creation in 1927-1938, the railway has been used and continues to play a key role in the life of the region, connecting the Persian Gulf with the Caspian Sea.

Museumification model includes the transformation of historical, cultural, or natural objects into museum displays to maximize the preservation and identification of their historical, cultural, scientific, and artistic value. Modern museumification process includes not only the cultural object itself, but also its environment and landscape, which undergo certain changes during the restoration process. One example of redevelopment and adaptation of cultural heritage sites to the needs of a modern city is creation of the Shougan Industrial Park on the territory of the former metallurgical plant in Beijing, creation of a museum of wildlife and nature on the territory of the former Beryanak sock factory in Tehran.

One of the most painful factors reducing the effectiveness of cultural heritage management is the lack of coordination and integration of actions between various stakeholders – government agencies, businesses, public and local civic organizations.

3.2 The Concept of Customer Empowerment as the Basis for the Activation of Citizens' Initiative

The concept of "customer empowerment", which has become popular during the past 20 years, can be interpreted as increasing customers' individual freedom of choice, expanding control over resources and decisions that affect the quality of citizens' lives (Stegareva, Saginova 2022). The traditional view of customer empowerment involves a transfer of power from producers to consumers (Lincoln, Travers, Ackers, & Wilkinson, 2002). In the marketing publications, the concept of customer empowerment is used to justify new opportunities and tools for consumers to collect and use information and to provide legal and practical remedies for the market failures (Nardo, Loi, Rosati & Manca, 2011). Some authors expand the concept of customer power to the active participation of consumers in production processes to show what consumers really want from products and services (Fuller, Muhlbacher, Matzler, & Jawecki, 2009).

The concept of customer empowerment is used in the economic literature to denote both a subjective aspect or experience associated with an increase in consumer capabilities (Hunter, Garnefeld, 2014) and an objective aspect associated with the expansion of consumer knowledge or understanding (Stegareva, Saginova, 2022). Within this concept, a wider range of choices, easier access to information and a higher level of consumer education is a prerequisite for their empowerment, which leads to greater engagement and a better quality of life (Leary, Vann & Mittelstaedt, 2017). Based on previous studies (Hwang, Wang & Kim, 2014), customer empowerment can be characterized as consumer's ability for the personally conscious and socially sustainable consumption behaviour.

The concept of customer empowerment has found practical application not only in the marketing activities of businesses, but also in social life of modern society, in the field of healthcare and digital medicine, for example. Patients armed with their rights and new technologies access their medical records and can share their health data with other participants within the healthcare system and have control of the process. To empower patients, health policies are being developed aimed at providing citizens with the necessary information and decision-making instruments.

The concept of customer empowerment provides for the interaction of four main elements: (1) free access to information, (2) inclusion and participation, (3) transparency and accountability, (4) self-organization and initiative (Stegareva, Saginova, 2022).

Information exchange between government bodies and citizens is equally important for the implementation of an active responsible civic position of the people and responsible, accountable to citizens, managerial efforts of the authorities. Well-informed citizens have access to services, exercise their rights, defend their interests, and can monitor the proper performance of their functions by government and non-government organizations.

Inclusion is the answer to the question "who should participate?", and participation is the answer to the question "how should their participation be organized?". Transparency and accountability means being able to hold public officials, employers, or service providers accountable for their policies, actions, and use of funds. Various groups and communities are organized to work together, mobilize resources to solve problems of common interest. Various types of public organization are possible: voluntary groups, professional communities, associations and joint projects.

In the research papers on management of cultural heritage, we have not found examples of the use of the concept of customer empowerment, although international agreements, regional and national programs for the preservation of cultural heritage indicate the need to actively involve citizens into this work. A comparative analysis of the involvement of citizens in projects to preserve cultural heritage in China, India and Iran confirmed the relevance of the above conditions for the customer empowerment.

Free access to information about cultural heritage sites in the form of public information portal (as in Delhi), updated information on the website of the governing body in Beijing, public notifications on registration of objects in India – all these provide citizens with information about existing heritage objects, their current condition, ongoing or necessary restoration work, organizations, and individuals responsible for their protection. Based on this information, public awareness of the cultural heritage of a city, region or country is being formed.

However, just access to information does not activate citizens to actively exercise their customer power, they must understand how they can influence the state of cultural heritage, where they should forward their proposals or complaints, whom to contact for direct participation in projects. In some countries, there are special websites and portals for registering the position of citizens, public discussions are held, statements and proposals are posted, citizens can receive feedback (for example, "Active citizen" portal in Moscow). In China, the website of the Beijing Cultural Heritage Administration provides an opportunity for feedback, through which citizens can inform about the improper condition of an object, complain about the actions of the authorities or specific persons, but there is no opportunity to participate in the decision-making process on this issue. In India and Iran, the issue of public announcements on the registration of cultural heritage sites is more likely to concern owners who may declare their rights or disagree with the planned actions regarding a particular object. There is also no public channel for citizens' initiative in Iran or India.

The practices of self-organization of citizens' initiatives usually depend on the activity and role of non-government organizations (NGOs) in the country, and their independence. However, even in conditions of limited independence of NGOs in China, free access to information about their activities at cultural heritage sites attracts large numbers of volunteers to work to preserve cultural heritage (for example, the "Friends of the Great Wall of China" movement).

Insufficient and limited access to information, passive position of government bodies responsible for the preservation of cultural heritage, do not allow the development of residents' initiative, prevent the formation of awareness and participation. This is the way it is in Iran, where the perception of some cultural heritage sites as alien if these objects or artifacts have been identified, registered, and preserved by experts from foreign countries or under their supervision. This attitude is characteristic for other developing countries, and as a result, the people's sense of "ownership" of such cultural items is not developed, and they consider them valuable only to outsiders and foreigners. To revive this sense of belonging among the population, preference should be given to those objects that will attract or stimulate the greatest interest among the local community.

Government agencies responsible for the preservation of cultural heritage at the ministerial level often combine tourism development in their functions (Ministry of Cultural Heritage and Tourism in Iran, for example). However, information about cultural attractions to develop domestic or international tourism is not enough to activate citizens' enthusiasm to preserve cultural heritage. It is also important to have clear and accessible communication channels, involve citizens in various projects and works, and have clear organizational schemes. Analysis of the best practices for attracting citizens to projects in the field of cultural heritage preservation using the concept of customer empowerment allowed us to formulate the main components of a mechanism to manage citizens' participation.

4 DISCUSSION

4.1 Mechanism to Manage Citizens' Participation in Protecting Cultural Heritage

The concept of customer empowerment has become the basis for reviewing best practices and identifying mechanisms for activating citizens to preserve cultural heritage. According to the concept, four elements are needed to empower consumers (in our case, citizens) with customer power: free access to information; inclusion and participation; transparency and accountability; self-organization and initiative. In the case of cultural heritage, since most of work is organized and implemented by the state or municipality, the element of transparency and accountability should be combined with the availability of information, access is provided to information about heritage objects, their condition, work carried out and expected results. Free access to this information means meeting the transparency/accountability requirement (Fig.1).

The comparative analysis of cultural heritage management systems in China, India and Iran has shown that access to information is available in all

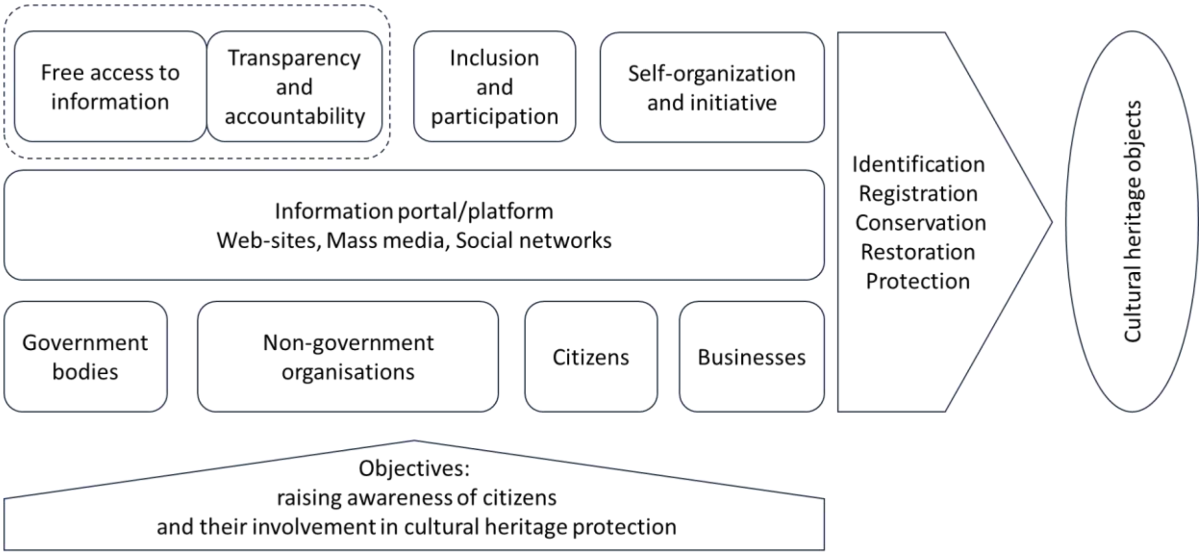


Figure 1: Mechanism of cultural heritage management.

countries. However, the channels used, and their capacity are different. In China, information is available on the Cultural Heritage Management Department website and is distributed through the organization of the annual Cultural Heritage Day on the second Saturday of June. In India, there is limited information on the site of the Archaeological Survey of India (ASI), but with the help of public organizations, certification of heritage objects has been carried out by the Indira Gandhi National centre for Arts, and public notifications are issued to inform about the intentions of registering heritage objects. In Iran, as well as in India, public notifications on registration of heritage objects are being issued. However, lack of digital tools for the dissemination of information significantly limits its accessibility.

Inclusion is stated as the guiding principle in all countries studied, but organizationally, the possibility of participation needs specific tools. In India, since 2017, there has been a government program for the "adoption" of cultural heritage objects, under which an organization or citizen can undertake a certain amount of work to preserve an "adopted" cultural heritage object.

As part of this program, businesses and citizens were invited to take care of more than 3,000 protected monuments throughout the country to improve their tourist accessibility and attractiveness by organizing various additional services and developing their territory. Since 2020, an updated version of the program has been implemented through a special web portal (Adopt a heritage, 2020) containing detailed information about the monuments that are supposed to be adopted, as well as the analysis of gaps in their maintenance and a financial assessment of the necessary tourist amenities around the site.

In Iran, in the post-revolutionary period of 1979-1988, Iranian cultural heritage activists promoted the rejection of anything pre-Islamic, and therefore the protection of pre-Islamic cultural relics became a problem of that time. A more active manifestation of activism in the field of cultural heritage began in 1997. While maintaining a focus on Islamic principles, interest in pre-Islamic culture related to Iran's historical monuments and the formation of Iranian identity has been revived. Citizens' and NGOs' activities in the field of cultural heritage generally include organizing cultural tourism to historical sites, working as guides, organizing thematic events and discussions about the role of cultural heritage sites in the development of the Iranian society.

The self-organization and initiative of citizens are unevenly represented in the open sources of the studied countries, which makes it difficult to make comparisons. In China and India, associations and public movements are mainly implemented within the framework of government programs. In India, individual citizens can participate in the government program of adopting cultural heritage objects. In China, proactive citizens hold thematic events in schools, youth hostels and other institutions to promote cultural relics and protect cultural heritage. Examples are projects to protect the old city of Beijing - "Friends of Old Beijing" movement, "Walking around Old Beijing for Children", training programs for repairing the traditional Beijing courtyards, etc.

The mechanism for activating citizens to preserve cultural heritage, based on the concept of customer empowerment, thus includes objectives (raising awareness of citizens and their involvement in cultural heritage protection), participants (authorized state bodies, NGOs, associations and individual citizens), objects (cultural heritage sites and various additional services on their territory), communication tools (information portals, websites, social networks, mass media).

4.2 Digitalization as a Tool of Customer Empowerment

Digital technologies are effectively used to preserve and promote cultural heritage. Digital duplicates are used to show how well a new building fits into the historical urban landscape, to plan transport accessibility, and assess the dynamics of the historical sites.

In all countries studied digital instruments are used to promote heritage sites and inform citizens. In India a mobile application (Indian Heritage) demonstrates the sites of historical and cultural heritage. The application provides a detailed information about the historical monuments, gives their photos, and lists the tourist services available.

In China a digital platform for monitoring World Cultural Heritage sites has been created. The information collected from the monitoring is used to plan the restoration, preservation, and promotion of the cultural heritage. Together with the charitable foundation of the Tencent investment holding, the project "Cloud Tour of the Great Wall of China" has been developed (Virtual tour), within which users can take a virtual tour of the Great Wall of China using their smartphones and see the restoration in progress.

Digital technologies are widely used for research and restoration work, to collect and store data on cultural heritage sites, for the interaction between participants in the process of its preservation. The analysis of the practices of citizens' participation in the preservation of cultural heritage in the countries studied showed that the more widely digital technologies are used to inform and self-organize citizens, the more widespread are public programs, volunteer projects, the more tangible is the perception of citizens' "ownership" of cultural monuments, concern for their preservation and profitable use.

In China the creation of the Great Wall digital platform and government program for the Great Wall National Park in China to attracted thousands of volunteers in a short time to clean up the territory, do the restoration work, and increased the awareness of the entire population about this symbol of the Chinese culture.

The lack of digital support for projects of the Ministry of Cultural Heritage and Tourism of Iran limits the availability of information about the country's unique cultural heritage sites – such as the Trans-Iranian Railway or the Persian Caravanserai system - to popularize this work and attract potential corporate investors and active citizens.

5 CONCLUSION

Approaches to the historical and cultural heritage management are diverse and reflect countries' national characteristics, historical, economic and political structure, specifics features of the cultural heritage sites, public and government interest in preserving and usage of the national heritage for the living and future generations.

The world experience has clearly shown that addressing the historical roots of one's nation makes it possible to solve the complex tasks of modern development. The society's understanding of the importance of protecting cultural heritage contributes to the improvement of legislation in this area, the creation of effective management and financing models, processes for identifying, preserving, protecting, studying, and popularizing cultural values and cultural heritage sites.

The analysis of cultural heritage management systems and practices for activating the initiative of the population in China, Iran and India based on the concept of customer empowerment resulted in identifying the main elements of the mechanism for managing citizens' participation in the preservation of cultural heritage. The most important factors in raising awareness and forming a sense of "ownership" of cultural heritage objects is to widely inform citizens about the existing cultural heritage objects, their condition, ongoing and necessary work, and the potential of their use in economic life of the capital city and the country; the availability of accessible and understandable channels for citizens' participation in this work; organizational and information support for citizens' initiatives and their direct participation in projects.

The widespread use of modern digital technologies significantly contributes to popularize cultural heritage, allows not only to effectively manage heritage sites in accordance with the expectations and needs of the local population, but also involve citizens and public organizations in the preservation and effective use of heritage sites.

REFERENCES

Adopt a Heritage" Project for Development of Tourist Friendly Destinations, March 2020 URL: https://tourism.gov.in/sites/default/files/2020-08/adopt%20a%20Heritage%20Project%20Guidelines.pdf (Avccessed 12.10.2023).

Brennan, C., Ritters, K., 2004. Consumer education in the UK; new development in policy, strategy, and implementation, International *Journal of Consumer Studies.* 28(2); 97–107.

Convention on the Protection of the World Cultural and Natural Heritage URL: https://www.un.org/ru/documents/decl_conv/conventions/heritage.shtml (Accessed 20.11.2023).

Cultural Relics Protection Law of the People's Republic of China URL:https://www.beijing.gov.cn/zhengce/zhengcefagui/qtwj/200210/t20021028_780536.html (Accessed 16.09.2023).

Fuller, J., Muhlbacher, H., Matzler, K., Jawecki, G. 2009. Consumer empowerment through internet-based co-creation. *Journal of Management Information Systems.* 26(3);71–102.

Hunter, G.L., Garnefeld, I., 2008. When does consumer empowerment lead to satisfied customers? Some mediating and moderating effects of the empowerment-satisfaction link. *Journal of Research for Consumers*. 15; 1–14.

Hwang, H., Wang, Y., Kim, K.-O., 2014. Comparison of consumer empowerment index between Korean and Chinese young adult consumers. *Consumer Policy and Education Review.* 10(4);1–29.

Indian Heritage. URL https://www.indianheritage.gov.in Accessed: 12.01.2024

Iran national cultural heritage protection act. URL: https://en.unesco.org/sites/default/files/iran_national_heritage_protection_act_engtof.pdf (Accessed 23.11.2023).

Leary, R.B., Vann, R.J., Mittelstaedt, J.D., 2017. Leading the way; motivation environmental action through

perceived marketplace influence. *Journal of Business Research.* 79; 79–89.
Lincoln, N. D., Travers, C., Ackers, P., Wilkinson, A., 2002. The meaning of empowerment: the interdisciplinary etymology of a new management concept. *International Journal of Management Reviews*, Vol 4 No 3, pp. 271-290.
Nardo, M., Loi, M., Rosati, R., Manca, A.R., 2011. The Consumer Empowerment Index: A Measure of Skills, Awareness and Engagement of European Consumers. Luxembourg: Publication Office of the European Union.
Naslediye v bolshom gorode (Heritage in a big city) Comparative analysis of activities in the field of cultural and historical heritage protection in 5 European capitals over the past 5 years, PWC, 2021
Stegareva, E.V., Saginova, O.V., 2022. Koncepcii potrebitel'skogo mogushchestva v kontekste cifrovizacii zdravoohraneniya. Ekonomika, predprinimatel'stvo i parvo (Economics, Entrepreneurship and Law). Tom 12. № 3. pages 1159-1172.
The Ancient Monuments And Archaeological Sites and Remains (Amendment and Validation) Act, 2010 URL: https://nma.gov.in/showfile.php?lang=1&level=2&ls_id=67&lid=59&nma_type=0 (Accessed 12.10.2023).
Vitrual Tour of the Great Wall of China, URL: https://artsandculture.google.com/story/igVxCi6iJJ6CrA Accessed 12.01.2024.

The Role of Digitalization in the Process of Learning a Foreign Language

Fomina Olga A.[1], Potanina Olga Yu.[2]
Don State Technical University, Gagarina sq.1, Rostov-on-Don, Russia
lelik8181@list.ru

Keywords: digitalization, multimedia technologies, online communication, competencies, teaching foreign languages.

Annotation: The article is devoted to the problem of teaching foreign languages in the context of digitalization of education. The use of multimedia technologies and online communication are particularly relevant nowadays. The purpose of this work is to draw the attention of teachers and professors of high school to the reasonable use of Internet technologies in their professional activities. The analysis of the literature on this issue has shown the presence of both positive (accessibility, cost-effectiveness, openness, mobility, wide coverage, etc.) and negative aspects (unreliability of sources, lack of live communication, weak socialization of children and youth, dependence on the Internet, harm to health, etc.). As a result of the study, the authors concluded that modern teaching tools cannot replace the live communication with a teacher and should be used in an appropriate manner.

1 INTRODUCTION

The realities of modern days are such that, no matter what social and political changes take place in the world, learning foreign languages is an obligatory part of education, from preschool to higher professional education. Currently, various approaches to teaching foreign languages and a wide variety of materials are used. In the modern world learning any foreign language is impossible to imagine without the use of various digital and multimedia technologies, especially when conducting classes not only in the classroom, but also by means of online communication (Kuzmina, Popova, 2019). The methodological basis of this study is the fundamental works of Russian scientists.

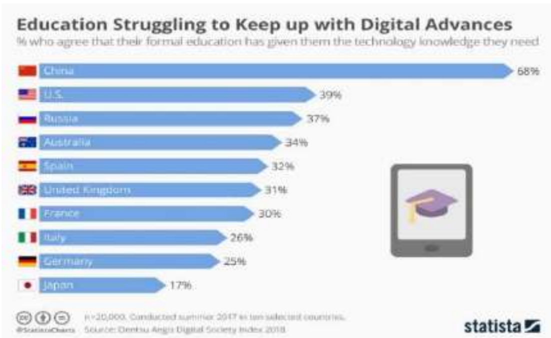


Figure 1: Education Struggling to keep up with digital advances.

2 MATERIALS AND METHODS

The solution of the tasks required the complex use of methods and techniques of analysis and synthesis characteristic of modern linguistics: analytical method of observation and generalization of linguistic facts, method of component analysis; method of conceptual analysis; method of linguistic description, method of correlation of linguistic facts; multi-stage definitional analysis.

[1] https://orcid.org/0000-0003-1796-0713
[2] https://orcid.org/0009-0003-1336-4444

3 RESULTS

Digitalization covers more and more spheres of our lives. It is even impossible to imagine today's education without modern technologies. However, it is fundamentally wrong to say that digitalization can replace a teacher. It is necessary to highlight the advantages and disadvantages of the participation of modern technologies in the learning process, especially when learning foreign languages.

Digitalization of education primarily overcomes geographical and social barriers, allowing students to receive education regardless of their location. Virtual classes and online courses make knowledge accessible to everyone, even for those who previously had no opportunity to receive a high-quality education.

Secondly, digital technologies allow us to create what pedagogy has been saying for many years: personalized, individualized educational programs that take into account the needs and specific characteristics of each student. Young people can independently plan their studies, choose subjects of interest to them and study materials in a format that is convenient for them. Thus, it is possible to implement a personal approach to each student.

Thirdly, students can communicate with teachers and students from different regions, share experiences and interact in the global educational community. It promotes intercultural understanding, broadens horizons and helps students develop interpersonal skills (Kipnes, Vasilyeva, Vinogradova, 2022).

Another important aspect is saving money. Digitalization of education frees parents from the annual purchase of notebooks, textbooks, diaries and other stationery. The student receives all educational materials and manuals from the Internet. Of course, for successful work you will need constant access to the world wide web, a laptop or tablet of good quality, and this is another expense item.

Also, the transition to online learning assumes that the student will study independently most of the time. This is certainly a big plus in the development of a young person who consciously receives an education. Independence is one of the important skills that will be very useful in the future.

However, in addition to the obvious advantages, there are also big disadvantages that are likely to be even more significant for the upbringing of future generations. First of all, this is a low degree of socialization. Children, being at home, constantly sitting at computer and tablet screens, stop communicating with their peers, and meeting in real life, they cannot find common topics for conversation. The child is becoming addicted to Internet resources. Moreover, constant use of the computer significantly reduces the physical activity of the child, disrupts his posture, spoils his eyesight. Therefore, it is necessary to find a "golden mean" in the issue of using modern technologies.

4 DISCUSSION

The modern educational process requires an increasing participation of various multimedia tools in teaching, especially when learning foreign languages. And the task of a foreign language teacher is to provide pupils and students with such conditions that will allow them to build the most effective learning trajectory.

Today, digital technologies make it possible to use various feedback techniques to train grammar, pronunciation, and word learning. The most striking examples are various speech simulators for the development of students' communicative competence. Speech cards voiced by native speakers are used to learn new words. There are also programs that allow you to record a student's speech and compare his pronunciation with that of a native speaker. And this is an undoubted advantage of new media technologies.

Figure 2.

Currently, there are a huge number of applications for smartphones and tablets, which can also help when learning a foreign language. However, it should be noted that, unlike the recommended certified digital training products, not all applications contain correct information. Various unverified sources mislead people learning a foreign language. This should be taken into account when choosing an information training tool (Karakozov, Ryzhova, Koroleva, 2020).

Figure 3.

The modern economic development of Russia has had a significant impact on the process of informatization of the entire education system. The didactic potential of the introduction of information and communication technologies is great: the implementation of a personality-oriented approach to learning, multilevel, creating conditions for the formation of all components of foreign language communicative competence, maximum consideration of the interests and needs of students.

The advantage of introducing Internet technologies into the process of learning a foreign language is undeniable. The additional possibility of creating an information-subject learning environment contributes to increasing the level of socio-cultural competence of students. The Internet creates unique conditions for students to familiarize themselves with the cultural diversity of the communities of the countries of the studied language.

Currently, the Internet supports the following tasks:

1) ensuring the operation of e-mail;

2) search for information resources;

3) real-time user communication;

4) organization of teleconferences and exchange of newsgroups;

5) file sharing;

6) video conferencing.

As it was noted, the main purpose of learning a foreign language is the formation of communicative competence. By connecting to the Internet, the student finds himself in a real language environment. Using the Internet in the classroom allows you to more effectively solve a number of didactic tasks:

1) improve listening skills based on the use of authentic audio texts;

2) to develop reading skills and abilities using authentic texts of varying degrees of complexity;

3) to improve the skills of monological and dialogical utterance based on the discussion of the materials of the network;

4) to improve writing skills;

5) to replenish your vocabulary;

6) to form a stable motivation for foreign language activities based on Internet materials.

It is known that in didactic terms, the Internet includes two main components: forms of telecommunications and information resources. Forms of telecommunications include e-mail, chat, forum, video, and web conferences. Initially, they were created for real communication between people who are at a distance from each other, and only then began to be used for educational purposes in teaching a foreign language (Nikiforova, 2021).

Internet information resources contain text and audio-visual material on various topics in different languages. At the moment, there are many specially designed materials created exclusively for educational purposes. They must meet the following criteria:

1. Authenticity of the language: the sites themselves can be both authentic and educational.

2. Compliance with the subject set by the standard.

3. Acceptable styles of texts used: journalistic, artistic, popular science, colloquial, absence of overly expressive and profanity.

4. The modernity of the material, its reliability.

The use of both forms of telecommunications and Internet resources in the educational process contributes to the development of cognitive activity of students and the achievement of the main goals of teaching a foreign language.

The following types of educational materials are distinguished in English-language literature:

1. Hotlist.
2. Multimedia Scrapbook.
3. Treasure Hunt.
4. Subject Sampler.
5. Webquest.

The hotlist is a list of sites on the topic under study. It is quite simple to create and it does not take time to search for the necessary information, just enter the keyword into the search engine.

Multimedia Scrapbook is a kind of collection of multimedia resources. It contains links to text sites, photos, audio files and video clips, graphic information and animated tours. Students can download files and use them as informational and illustrative material when studying a specific topic.

Treasure Hunt resembles a Hotlist in many ways: it contains links to various sites on the topic under study. The difference is that in each of the links there are questions about the content of the site, with the help of which the teacher directs the search activity of students.

Subject Sampler is at the next level of complexity compared to Treasure Hunt. It also contains links to text and multimedia materials. After studying each aspect of the topic, students need to answer a question. The peculiarity of the Subject Sampler is that students do not just get acquainted with the material, but express and argue their point of view on the issue under study. It is noted that the activity of students in performing this task increases significantly. It is possible to discuss opinions with other students of the group.

Webquest is the most complex type of educational materials, which includes all the components of the four mentioned above. It involves the preparation of a project with the participation of all students. Before dividing into groups, they get acquainted with general information on the topic under study, thereby immersing themselves in the problem of the upcoming project. The teacher selects Internet resources and classifies them so that each group gets acquainted with only one problematic aspect of the topic. After studying, discussing and fully understanding the specific problem in each primary group, students are regrouped so that the newly formed groups have one representative from each primary group. During the discussion, all students learn from each other all aspects of the problem under discussion, express their own opinions, draw conclusions, and predict the further possible development of the action. In the course of solving the webquest through studying the material and discussing it, students must answer one general question of a debatable nature.

Thus, Webquest is a scenario for organizing students' project activities on any topic, which is based on a constructivist approach to learning, where the teacher acts as a consultant, organizer and coordinator of problem–oriented research educational and cognitive activities of students. The teacher creates conditions for independent mental activity of students and supports their initiative in every possible way. And they, in turn, become full-fledged "co-authors" of the learning process, sharing responsibility for the learning process and results with the teacher (Kotova, Nuzhnova, 2019).

Obviously, each of the five types of online educational materials follows from the previous one and gradually becomes more complicated: Hotlist and Multimedia Scrapbook are aimed at searching, selecting, classifying information, and Treasure Hunt, Subject Sampler and Webquest already contain elements of problem-based learning.

Online educational resources allow you to:

1) select text, graphic, photo, audio and video materials on the topics being studied;

2) organize a discussion of cultural and social issues in groups and the whole class;

3) carry out a linguistic analysis of the speech of native speakers (representatives of various social troupes, speakers of dialects);

4) create favorable conditions for the development of the intellectual potential of students.

New goals and objectives in education require new approaches from teachers: not just to transfer knowledge, but to teach them to think, stimulate the creative activity of students, and teach them the basic techniques of independent work. At the same time, each teacher uses his own professional methods and best practices.

At the present stage, it is more realistic to talk about the use of online educational materials along with traditional printed educational publications.

5 CONCLUSIONS

However, access to Internet resources alone is not a guarantee of fast and high-quality language education. Methodically illiterate work of students with Internet resources can lead to the formation of false stereotypes and generalizations about the culture of the country of the studied language.

The complexity of the material, its volume and frequency of use should vary and correspond to the level of development of students.

Thus, the considered didactic possibilities of the Internet in teaching a foreign language indicate that its resources, with reasonable and purposeful use, can become another effective means of teaching.

REFERENCES

Akhmetova, D. Z., Artyukhina, T. S., Bikbaeva, M. R., Sakhnova, I. A., Suchkov, M. A., Zaitseva, E. A., 2019. Digitalization and Inclusive Education: points of contact. *Vysshee obrazovanie v Rossii.* Vol. 29. No. 2, pp. 141–150.

Esina, L. S., 2019. Improving the efficiency of teaching monologue speech in English using digital technologies. *Modern Pedagogical Education.* No. 7. P. 42–46.

Karakozov, S. D., Ryzhova, N. I., Koroleva, N. Yu., 2020. Virtualnaya realnost: genezis ponyatiya i tendentsii ispolzovaniya v obrazovanii. *Informatika i Obrazovanie.* No. 10 (319), pp. 6–16.

Koroleva, N. Yu., Ryzhova, N. I., 2009. Virtualnaya sreda obucheniya predmetu kak interpretatsiya metodicheskoy sistemy obucheniya v usloviyakh IKT-nasyshchennoy obrazovatelnoy sredy. *Mir nauki, kultury, obrazovaniya.* No. 2, pp. 196–199.

Kipnes, L. V., Vasilyeva, I. V., Vinogradova, M. V.,2022. Aktualnye sredstva formirovaniya kommunikativnoy kompetentsii inostrannykh studentov-filologov. *Mir nauki, kultury, obrazovaniya.* No. 2 (93), pp. 167–171.

Kotova, S. A., Nuzhnova, N. M., 2019. Challenges of the time and new prospects for the development of additional education. *Herzen Readings. Art education of the child: strategies for the future.* Vol. 5. Issue. 1. P. 278–289.

Kovalchuk, N.V., Timashova, M.V., Shcherbakova, I.V., 2023. Application of the project method using modern IT technologies. XVI International Scientific and Practical Conference "State and Prospects for The Development of Agribusiness – INTERAGROMASH 2023". 413.

Kuzmina, A. V., Popova, N. V., 2019. Problematics of Pedagogical Research on the Use of Video Materials on a Foreign Language in the University. In Nauchno-tekhnicheskie vedomosti SPbGU. *Gumanitarnye i obshchestvennye nauki.* Vol. 10. No. 2, pp. 74–86.

Nikiforova, I.N., 2022. Positive and negative trends in the use of digital technologies in teaching a foreign language. *Science and school*, № 6, pp. 232-240.

Nikiforova, I. N., 2021. Teaching English using online educational platforms. *Modern education: traditions and innovations.* No. 4. P. 151–154.

Zemskova, A. N., 2022. Ispolzovanie resursov tsifrovoy sredy v ramkakh obucheniya distsipline "Inostrannyy yazyk" v neyazykovom vuze. *Obshchestvo: sotsiologiya, psikhologiya, pedagogika.* No. 5 (97), pp. 157–162.

Innovations in Digitalization of Customs Procedures: Current State and Development Prospects

G.D. Alybaeva[1] , S.T. Alybaev[2] , A.N. Tadzhibaev[3] , D.Ch. Imanberdiev[4]

[1] *Diplomatic Academy of the Ministry of Foreign Affairs of the Kyrgyz Republic, 36 Erkindik Boulevard, Bishkek, Kyrgyzstan.*

[2] *Kyrgyz Economic University, 58 Togolok Moldo str., Bishkek, Kyrgyzstan*

[3] *Diplomatic Academy of the Ministry of Foreign Affairs of the Kyrgyz Republic, 36 Erkindik Boulevard, Bishkek, Kyrgyzstan*

[4] *Kyrgyz National University, 547 M.Frunze str., Bishkek, Kyrgyzstan*

alybaeva61@mail.ru, salybaev@gmail.com , adylbek.tadzhibayev@mail.ru, imandos01@gmail.com

Keywords: customs, digitalization, risk management, e-customs, innovative technologies, customs policy, customs control, electronic declaration, customs procedures, customs clearance.

Abstract: ` The article reveals the features and current state of digitalization of customs procedures for the movement of goods and vehicles crossing the state border and subject to customs declaration. In particular, there is a need to introduce modern digital technologies to serve citizens and enterprises, which will significantly change the attitude of entities engaged in foreign economic activities to assessing the activities of the customs system of Kyrgyzstan. The state of implementation of modern electronic services for automation of customs control is analyzed and the directions of its improvement are determined. In particular, the analysis of tasks to improve the efficiency of customs authorities in the field of process automation by concentrating all efforts on creating favorable conditions for all entities engaged in foreign economic activities, the development of e-customs and testing positive foreign experience in the introduction of innovative information systems and technologies in the management of customs relations, was carried out. It was noted that today an important step in global trade is the automation of all processes of declaring goods during customs clearance of export, import, transit operations and the transition to full electronic document management. The priority of digitalization of customs clearance mechanisms, simplification of customs control mechanisms, the formation of an effective system of analysis and management of customs risks and the introduction of a higher level of responsibility for violations of customs and tax legislation by both entities engaged in foreign economic activities and employees (officials) of customs authorities themselves was noted. Also, the article notes that the role of government authorities in the decision-making process on the passage of goods and vehicles across the customs border should be minimized, which will minimize corruption risks in the work of public administration bodies and impartially identify violations of customs legislation by entities engaged in foreign economic activities.

1 INTRODUCTION

Customs procedures for goods and vehicles crossing the border play an important role in the system of foreign economic policy instruments of the state. It is quite obvious that speeding up and simplifying customs procedures is impossible if old paper-based technologies are used. The introduction of electronic document management can significantly reduce the time for receiving, processing and making a decision on the movement of goods across the customs border of Kyrgyzstan, the release of goods into free

[1] https://orcid.org/0009-0006-2214-9326
[2] https://orcid.org/0009-0000-6345-7815
[3] https://orcid.org/0009-0001-7538-0250
[4] https://orcid.org/0000-0002-7009-8782

circulation, reduce the risks associated with customs offenses and smuggling, which in turn will ensure an increase in trade turnover, and hence an increase in revenues to the state budget.

Analysis of the latest research and publications. Important issues on the problems of automation and digitalization in the process of implementing state management activities have been considered in many works of foreign and domestic scientists, in particular J. Davletbaev (Davletbaev, 2012), A.Sh. Sharsheeva (SHarsheeva, 2021), K.T. Kamytov (Kamytov, 2015), A.M. Kojchiev (Kojchiev, 2019), etc.

However, the authors do not pay attention to the issues of digitalization of customs procedures in relation to citizens crossing the customs border and transporting goods and vehicles that are subject to declaration. In particular, the problems of automating all processes of declaring goods and their customs clearance and the transition to full electronic document management. Therefore, this article examines the problems of digitalization in the field of customs on a broader scale.

The purpose of this article is to study the current state and prospects for the development of digitalization of customs procedures in the context of strengthening international economic cooperation in Kyrgyzstan.

2 MATERIALS AND METHODS

The article analyzes the scientific literature, uses reports from international organizations (the World Customs Organization, the Supreme Eurasian Economic Council, etc.), as well as interviews with experts in the field of customs procedures and digital technologies of the Customs Service of the Kyrgyz Republic. Statistical data on the processes of mutual trade and the introduction of digital technologies in the EAEU are analyzed.

3 RESULTS AND DISCUSSION

In the scientific literature, the category “digitalization” is considered by researchers from different perspectives. Some interpret it as ways of bringing any type of information into digital form using digital technologies (Kuprina, 2016), others as a process of modernizing production, making it more flexible, adapted to the realities of the present day and competitive in the “digital” world,” or the transition of activities from the real world into the virtual one (online) (Antonov, 2023). A number of other authors understand digitalization as a unique phenomenon of our time, which is due to the development of productive forces, and at the same time as a process of large-scale changes in the relations between actors (government, business and society, representing its individuals), covering all spheres of public activity and and occurring under the influence of the integration of digital technologies, data and the Internet (Tull, 2019). Digitalization is also defined as a means of achieving the desired result, namely flexible production, which gives customers excellent results and owners higher profits. Digital transformation is the process of transferring an enterprise to a "flexible" state from the current one (Alekseev, 2019). In a broad sense, digitalization means the transformation of information into digital form, where the digitization of data represents the first stage in the automation of public services.

So, the process of digitizing data is a component of the automation process, contributing to the optimization of the workflow, reducing operating costs, providing high-quality customer service, as well as increasing the demand for qualified specialists capable of working at customs using modern digital technologies.

Also, the role of the latest information technologies in customs is reflected in the International Convention on the Simplification and Harmonization of Customs Procedures (Kyoto Convention), which provides for the maximum practical use of information technologies; considers information technologies as one of the principles of customs clearance, the implementation of which will contribute to the simplification and harmonization of customs procedures; establishes a standard rule for the use of information technologies and means of electronic communication to improve customs control. In order to bring customs procedures in line with international standards, it is envisaged to establish a simplified customs control regime for goods transported by individuals at the customs border checkpoints of Kyrgyzstan.

It should be noted that in recent years, the digitization of international trade has mainly focused on the development of electronic declaration. The Automated Customs Clearance System and the Automated Risk Analysis and Management System work and demonstrate high results in the context of the priority tasks facing the customs service, including, in particular, reducing the human factor and digitalizing the processes of customs clearance and tax administration.

A striking example of the successful use of automated customs clearance and control systems is the functioning of customs regimes in the United States. In particular, the United States has created a high-quality legal framework for electronic declaration of goods, that is, the issue of equal responsibility for declaration has been legally resolved, in whatever form it is organized, electronic or paper (1-2% of goods are registered on paper). The system of customs clearance of goods in the United States is based on the principles of creating a complete electronic description of goods, i.e. computerization of information about the product during its transportation from the point of loading abroad to the point of unloading and release in the United States.

One of the best technological developments of American specialists is the BRASS (Border Release Screening and Selectivity) system, which allows clearance and customs control of imported shipments to be carried out within 5–10 seconds. This is one of the latest achievements of the American customs, which was invented specifically to simplify the formalities of a relatively large number of goods. The main achievement of the technology using the BRASS system is the use of a special bar code and operational decision making at the checkpoint by local US Customs units. The bar code is usually generated by a customs broker and repeats the main characteristics of the shipment (Boyko, 2017).

Thus, in the United States, the main factor in accelerating customs clearance and customs control is the complete computerization and informatization of the entire customs process, as well as the accumulation and use of customs history of previous years to identify goods and participants in foreign economic activity that pose a potential threat to the security of foreign economic activity.

The European experience of using the electronic system "Single Window for International Trade" provides for interaction with four main Web blocks, through which enterprises-entities engaged in foreign economic activities provide information on the export or import of goods, and they are provided with the necessary permits, namely: Web interface of state control over compliance with legislation on food and feed; Web interface of veterinary and sanitary control; Web interface of government agencies issuing permits; Web interface of phytosanitary control. Document flow and certain types of control again occur in a contactless form through this electronic system, informing the relevant regulatory authority about the receipt of documents by posting the relevant information in the web block (Motorygina, 2022).

The experience of the EAEU member states shows that, in general, the volume of mutual trade is growing. There is an increase of 13% in the first half of 2023. However, the volume of foreign trade with countries outside the EAEU in the total volume of foreign trade in goods among all members of the Eurasian Union is predominant, for example, for Kyrgyzstan it is 73.9%, Kazakhstan - 73.9%, Armenia - 64.7%, Russia - 91.1 %, only in Belarus this ratio is 50% to 50%. In general, for all the EAEU countries, this ratio is on average 70% to 30%. These data demonstrate, first of all, a weak synchronization in the digitalization of the movement of goods and services between the member states of the union.

In the context of the rapid development of the global economy based on informatization, it is important for the State Customs Service under the Ministry of Finance of the Kyrgyz Republic (SCS KR) to modernize and use the latest information technologies and support customs control, effective automation and analytical processing of information on violations of current legislation. In particular, the effectiveness of the functioning of the SCS of the Kyrgyz Republic depends on the customs information structure, existing and future information and communication means for processing large flows of different types of information, presentation of the results of their analytical processing and management decisions based on them. A high level of organization of information support facilitates the exchange of data between customs authorities and their departments; provides the opportunity to timely obtain information about entities engaged in foreign economic activities, persons violating customs legislation, and also ensures monitoring of customs clearance and customs control.

Thus, the creation of a transparent border due to the openness of procedures, speed and security, reduction of the human factor and digitalization of customs procedures represents the digitalization of customs procedures in the context of simplifying customs control of modern electronic services for automating customs procedures in the Kyrgyz Republic.

During the period of its formation, the customs service of the Kyrgyz Republic, as a modern, multifunctional system, occupied a special place in the economic structure of the Kyrgyz Republic, playing an important role in the system of state regulation of foreign economic relations, the formation of the revenue side of the republic's budget, and ensuring the economic security of the country.

Many activities and actions in the field of foreign economic policy of the country are not only vital for the customs service in terms of implementing general reform and modernization, for example, the "Digital Customs Project", but are also largely interrelated with issues of facilitating foreign trade, implementing the national agenda and achieving its comprehensive goals. In the 12 months of 2023, the State Customs Service of the Kyrgyz Republic provided the collection of customs payments in the amount of 111 billion 503 million soms. The plan was fulfilled by 103.6 percent, or an excess of 3 billion 904.4 million soms was collected. Such an indicator of the receipt of customs payments is observed for the first time in the history of the customs service. Compared to 2022, the growth rate was 150 percent, or 37.2 billion soms more were collected.

A significant step towards liberalizing and simplifying foreign trade was the expansion of the practice of electronic declaration, the introduction of the practice of mandatory advance notification, the reduction of the period of release of goods, the determination of the minimum list of documents required for submission for customs purposes, the introduction of the institution of an authorized economic operator, the possibility of releasing goods before submitting a customs declaration, the use of new technologies for customs payments.

Within the framework of the National Development Program of the Kyrgyz Republic until 2026, the Concept of digital Transformation "Digital Kyrgyzstan 2019-2023", the most important task arises for the customs service in building a modern customs authority through the application of innovative projects to simplify trade, provide high-quality service to citizens and the business community as part of optimizing customs processes, ensuring sustainable digital interaction between other state regulatory authorities authorities, business community and citizens.

An important role in the process of informatization of customs procedures in Kyrgyzstan is played by the development of new approaches in the customs sphere, which is due to taking into account the main directions of implementation of the digital agenda of the Eurasian Economic Union until 2025, approved by the decision of the Supreme Eurasian Economic Council No. 12 dated October 11, 2017, the National Development Program of the Kyrgyz Republic until 2026, approved by Decree of the President of the Kyrgyz Republic No. 435 dated October 12, 2021 (Motorygina, Kuskov, 2022), the Concept of Digital Transformation "Digital Kyrgyzstan 2019-2023", approved by the decision of the Security Council of the Kyrgyz Republic No. 2 dated December 14, 2018, the provisions of international treaties and acts that form the legal basis of the Eurasian Economic Union (hereinafter – the EAEU).

One of the important modern activities of the EAEU is the simplification and improvement of the effectiveness of customs procedures through their informatization. In this aspect, the Strategic Directions for the Development of Eurasian Economic Integration until 2025 identified the task of improving customs regulation in the Union, which means simplifying customs formalities without compromising the effectiveness of customs control.

The main directions of such improvement are:

- expanding the use of digital technologies that ensure the automatic execution of customs operations;
- ensuring a single standard for customs operations and customs control;
- further unification of electronic document management between customs authorities and foreign trade participants;
- settlement of e-commerce issues;
- development of a unified system for the transit of goods in the Union;
- definition of general principles and approaches to the establishment of liability for non-compliance with the requirements of the law of the Union in the field of customs regulation.

In addition, measures are envisaged for effective cooperation between customs administrations and other relevant authorities in the field of trade facilitation and compliance with customs regulations.

It is interesting to use the EGAIS program (electronic control system for the movement of individual goods) in Russia, the experience of which could be widely implemented for all EAEU member states. Currently, this program is designed for two types of goods: alcohol (other alcohol-containing goods) and wood (wood materials)

Monitoring is carried out by applying special codes or chips to the product at the stage of its release from production. All further movements of each unit of production should be reflected in the unified state database. The chain is interrupted only when the product has been purchased by the end user for their own consumption.

As we can see, having gone through a relatively long path of transformation, today our country is in an active phase of the digitalization of customs control processes, covering comprehensive monitoring of the continuous flow of information from entities engaged in foreign economic activities, the main goals of which, first of all, are the elimination of paper documents, the fight against fraud, organized crime and terrorism, improving the quality of goods and trade security, standardization of customs operations, protection of intellectual property rights and national cultural heritage.

The issue of digitalization of customs procedures remains important in order to minimize the corruption component at customs. In particular, the Customs Code of the Kyrgyz Republic defines what a risk assessment is – "a systematic determination of the probability of risk and the consequences of a violation of customs legislation in the event of its occurrence", however, the risk criteria themselves are not provided, which leads to the fact that the Kyrgyz customs authorities in the field must determine these risk criteria at their discretion.

In this regard, the positive experience of China deserves attention and determination of the possibilities of introducing into national legislation and legal practice. The customs there is maximally computerized, the latest technologies are used. All risk algorithms are written out, and the computer automatically selects which container and which cargo should be put under control. The human factor has been removed. But if this risk is highlighted, no one has the right to ignore the check. Therefore, given that we have several key importing countries for Kyrgyzstan, it would be appropriate to do only 30-40 API integrations (Application Programming Interface) and receive the necessary customs information automatically at the time of shipment of goods from the sending customs office. Therefore, it is only necessary to write out clear risk algorithms, where the computer itself would determine the implementation of baggage control and its expediency, while eliminating the human factor and minimizing the corruption component.

4 CONCLUSIONS

In summary, it should be noted that the introduction of modern digital technologies to serve citizens and enterprises into the practice of the customs authorities of Kyrgyzstan will significantly change the attitude of citizens to the assessment of the customs system of Kyrgyzstan and create favorable conditions for all entities engaged in foreign economic activities, the development of national e-customs and the testing of positive foreign experience in the introduction of information systems and technologies in customs.

REFERENCES

Davletbaev, Z.H., 2012. Neeffektivnost' gosudarstvennogo upravleniya po vnedreniyu Elektronnogo Pravitel'stva.

SHarsheeva, A.SH., 2021. Transformaciya sistemy gosudarstvennogo upravleniya v Kyrgyzskoj Respublike. Dissertaciya na soiskanie uchenoj stepeni kandidata politicheskih nauk.

Kamytov, K.T., 2015. Elektronnoe pravitel'stvo kak koncepciya effektivnogo gosudarstvennogo upravleniya. *Izvestiya Vuzov*. №5.

Kojchiev, A.M., 2019. Elektronnyj pasport uprostit Kyrgyzstanu vizovyj rezhim.

Kuprina, K.A., 2016. Cifrovizaciya: ponyatie, predposylki vozniknoveniya i sfery primeneniya. *Vestnik nauchnyh konferencij*. №5-5(9). S. 259-262.

Antonov, I.S., Rodionova, V.N., 2023. Cifrovaya transformaciya predpriyatiya kak uslovie obespecheniya ego konkurentosposobnosti. *Organizator proizvodstva*. №1.

Tul, S.I., 2019. Transformaciya mirovogo rynka trudy v usloviyah cifrovizacii: avtoref. dis. ... kand. ekon. nauk: 08.00.02. V., 20.s.

Alekseev, A.A., 2019. Cifrovizaciya proizvodstva. *Academy*. №1 (40).

Kuprina, K.A., 2016. Cifrovizaciya: ponyatie, predposylki vozniknoveniya i sfery primeneniya Vestnik nauchnyh konferencij. Kachestvo informacionnyh uslug: po materialam mezhdunarodnoj nauchno-prakticheskoj konferencii 31 maya 2016 g. Tambov. No 5-5(9). S. 259-262.

URl: https://www.elibrary.ru/item.asp?id=26383210.

Mezhdunarodnaya konvenciya ob uproshchenii i garmonizacii tamozhennyh procedur (Kiotskaya konvenciya) ot 18.05.1973. http://www.singlewindow.org/docspravo/12/218.

Bojkova, M.V., 2017. Zarubezhnyj opyt tamozhennogo administrirovaniya: monografiya / pod obshch. red. V.V. Makruseva. Moskva: RIO Rossijskoj tamozhennoj akademii, 130 s.

https://xn--80aeiti0ahp.xn--p1ai/wp-content/uploads/2018/03/%D0%97%D0%9E%D0%A2%D0%90_% D0%91%D0%BE%D0%B9%D0%BA%D0%BE%D0%B2%D0%B0_%D1%82%D0%B5%D0%BA%D1%81%D1%82.pdf

Motorygina, A.A., Kuskov, A.N., 2022. Effektivnost' ispol'zovaniya mekhanizma «edinogo okna» v EAES. Ekonomika i biznes: teoriya i praktika. №12-2.

Osnovnye napravleniya realizacii cifrovoj povestki Evrazijskogo ekonomicheskogo soyuza do 2025 goda, utverzhdennoj resheniem Vysshego Evrazijskogo ekonomicheskogo soveta ot 11 oktyabrya 2017 goda №12 https://fci.eabr.org/upload/napravleniya.pdf

Nacional'naya programma razvitiya Kyrgyzskoj Respubliki do 2026 goda, utverzhdennoj Ukazom Prezidenta Kyrgyzskoj Respubliki ot 12 oktyabrya 2021 goda №435 https://mkk.gov.kg/ru/wp-content/uploads/2023UKAZ-PREZIDENTA-

KYRGYZSKOJ-RESPUBLIKI-ot-12.10.2021-g-UP-№-435.pdf (mkk.gov.kg)
Koncepciya cifrovoj transformacii "Cifrovoj Kyrgyzstan 2019-2023", odobrennoj resheniem Soveta bezopasnosti Kyrgyzskoj Respubliki ot 14 dekabrya 2018 goda №2 https://www.gov.kg/ru/programs/12
Strategicheskie napravleniya razvitiya evrazijskoj ekonomicheskoj integracii do 2025 goda https://eec.eaeunion.org/comission/department/dep_razv_integr/strategicheskie-napravleniya-razvitiya.php
EGAIS – chto eto takoe i kak rabotaet. https://spmag.ru/articles/egais-chto-eto-takoe-i-kak-rabotaet
Postanovlenie Kabineta ministrov Kyrgyzskoj Respubliki ot 8 aprelya 2022 goda №202 Ob utverzhdenii Koncepcii razvitiya tamozhennoj sluzhby Kyrgyzskoj Respubliki na 2022-2024 gody (V redakcii Postanovlenij Kabineta Ministrov Kyrgyzskoj Respubliki ot 12.07.2022 g. №378, 29.05.2023 g. №285 https://www.gov.kg/ru/npa/s/4444)
Tamozhennyj kodeks Kyrgyzskoj Respubliki ot 12 iyulya 2004 goda № 87
https://invest.gov.kg/wp-content/uploads/2019/07/14-Customs-code-of-KR.pdf
Interv'yu s glavoj GTS KR Samatom Isabekov, 20.02.2024 g.
Po itogam pervogo polugodiya ob"em vzaimnoj torgovli mezhdu gosudarstvami EAES uvelichilsya na 13%. https://www.finmarket.ru/news/6031372
Vneshnyaya i vzaimnaya torgovlya tovarami Evrazijskogo ekonomicheskogo soyuza.EEK.2022 https://eec.eaeunion.org/upload/files/dep_stat/tradestat/infoblock/Infoblock_trade.pdf

The Regression Model of the Pay Back Period of Expenditures for a Cafeteria Opening

E. I. Shagiakhmetova[1] [1], E. R. Mukharramova[2] [2], E. I. Biktemirova[1] [3]

[1]*Kazan State University of Architecture and Engineering, Kazan, Russian Federation*

2Financial University under the Government of the Russian Federation, Moscow, Russian Federation

bikti77@yahoo.com

Keywords: economic efficiency, payback period, public catering enterprise, regression analysis.

Abstract: The sphere of services is actively developing in the modern world the level of which affects the quality of life of the population and the attractiveness of the place among the tourists. Catering companies make up an important part of the service sector. The aim of the study: a regression model development for calculating the cost recovery for opening a cafeteria in Kazan (Russia). Research methods: one-parameter and multi-factor regression analysis, calculation of the discounted payback period, internal rate of return, net present cost of the project. The results of the study: the equation of regression dependence of the discounted payback period (Y) on the value of the average sales price in the cafeteria menu (X1), construction and installation costs and equipment purchase (X2), discount rates (X3) is obtained. The multiple correlation coefficient of 0,954 indicates high accuracy of calculation. The suggested model will allow to make the payback period estimation for any public catering enterprise on the base of selected initial factors. The results obtained can be useful for investors and developers.

1 INTRODUCTION

The population quality of life directly depends on the level of the service sector development , with the catering as an important constituent part. Historical analysis carried out by Nadyrova D.A., shows that places for public catering were already in the middle of the XIX century as part of multifunctional leisure complexes built. They included also trading areas and areas for cultural and entertainment leisure (Nadyrova, 2017).

A present world pays attention to the formation of unnecessary food waste in public catering . Ch. Malefors, I.Strid and M. Eriksson write that the global goal of public catering is to halve food waste by 2030 (Malefors, Strid, Eriksson, 2022). N. Sundin, Ch. Malefors , M. Danielsson, M. Hardiyanti, Ch. Persson Osowski and M. Eriksson draw attention to the fact that 260 million state-funded school lunches, which are served annually in Sweden, form 21,000 tons of food waste (Sundin, Malefors, Danielsson, Hardiyanti, Persson Osowski, Eriksson, 2023). P. Kaur, Sh.Talwar, A. Madanaguli, Sh. Srivastava and A. Dhir write of corporate social responsibility rising in the hospitality industry (Kaur, Talwar, Madanaguli, Srivastava, Dhir, 2022). V. Filimonau, Ch.-Ch. Chiang, L.-en Wang, B. J. Muhialdin and V. A. Ermolaev consider the need to reduce food waste in gourmet restaurants with the participation of cooks (Filimonau, Chiang, Wang, Muhialdin, Ermolaev, 2023). C. Malefors, I. Strid, Per-A. Hansson and M. Eriksson have created forecasting models of the number of necessary meals on purpose of food waste minimization at public catering facilities based on traditional methods and using neural networks (Malefors, Strid, Hansson, Eriksson, 2021). The creation of a system for tracking plate waste and forecasting the number of guests as well as the use of tasting spoons and information campaigns are found to be effective tools for reducing plate waste in school canteens in Sweden (Malefors, Sundin, Tromp, 2022). In addition to excessive portions, food waste occurs in the catering industry when food is spoiled. C. Willis, Mclauchlin,

[1] https://orcid.org/0000-0002-0475-4374
[2] https://orcid.org/0000-0002-5228-7088
[3] https://orcid.org/0000-0002-4165-3134

C. Amar, L. Sadler-Reeves, N. Elviss, H. Aird, A. Fox and M. Kaye conducted a study of pre-sliced fruits in catering and retail establishments in the United Kingdom in order to assess their microbiological safety (Willis, Mclauchlin, Amar, Sadler-Reeves, Elviss, Aird, Fox, 2016). The crisis caused by the COVID-19 pandemic has affected the restaurant business, while new delivery and takeaway services become helpful to achieve financial stability (Neise, Verfürth, Franz, 2021). According to Julia C. Carrillo Ocampo, Matilda Marshall, Lotte Wellton and Inger M. Jonsson, one of the ways to achieve sustainable development of restaurants in the post-crisis period is to buy local products with a minimum delivery distance (Carrillo Ocampo, Marshall, Wellton, Jonsson, 2021). N. Messabia, , Paul-R. Fame and C. Kooli in their study analyze the experience of owners of small and medium-sized enterprises in the catering sector during the COVID-19 crisis. Several problems were identified: employee shortages, financial losses, the problems of liquidity and difficulties in adapting to changes (Messabia, Fomi, Kooli, 2022). Strategic response in the field of pricing, maintaining customer loyalty in restaurants in Turkey become the object of research in the works of F. Semerciöz, Ç. Pehlivan, A. Sözüer A. Meruntat and G. Altş (Semerciöz, Pehlivan, Sözüer, Mert, 2015; Altuntaş, Semerciöz, Mert, Pehlivan, 2014).

The national cuisine of the regions are important in connection with the development of tourism in the context of the search for the uniqueness of the proposed tourist product (Mengual-Recuerda, Tur-Viñes, Juárez-Varón, Alarcón-Valero, 2021). Catering enterprises are an important part of tourism centers (Pokka, Gafiyatullina 2020). For successful further tourism development a well-developed infrastructure is needed, including a variety of catering enterprises from a canteen to a restaurant not only in communities but also within the clusters of roadside services (Khusnudinova, Zabruskova, 2018). The economic aspects of the public catering enterprises functioning concern the organization of electronic accounting, the selection of optimal packaging (Sularto, Wardoyo, 2015; Ronzonia, Accorsia, Guidania, Manzinia,. 2022). The work of D. Eravia, Tri Handayani and Julia examines the effectiveness of business in the food and restaurant industries. It is negatively affected by: limited access to capital and raw materials, information technologies restriction , lack of qualified human resources and a high bank interest rate (Eravia, Tri Handayani, 2015). The relationship between various indicators of catering enterprises activities was also reflected in the works of foreign authors. A. Qa show and Ya. Saleh performed a regression analysis based on sixteen factors and revealed the degree of their influence on the effectiveness of marketing in small and medium-sized restaurants in Palestine (Qashou, Saleh, 2018). Based on the analysis of variance M. A. A. Majid, M. A. M. Alias, A. Samsudin and Ch. T. Chik calculated the strength of the brand in three different family restaurants and were able to identify the best of them (Majid, Alias, Samsudin, Chik, 2016). Y. Sha, X. Song, J. Zhan, L. Lu, Q. Zhang and Y. Lu found in their study that large restaurants are at higher risk of food safety than small restaurants which was confirmed by negative binomial regression (Sha, Song, Zhan, Lu, Zhang, Lu, 2020). The study of public catering enterprises is of importance according to the analysis of key literature references . Mathematical models allow one to perform analysis and prediction and make recommendations based on analitic data set. The results gained from the simulation are distinguished by their accuracy and measurability. The purpose of this study is to perform economic calculations to create a regression model of the payback period for a catering company using the example of a cafeteria in Kazan (Russia).

2 METHODS

The following calculation methods were used:

– the method of graphic construction;

–the net present value of the project evaluating:

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+d)^t} - \sum_{t=1}^{T} \frac{I_t}{(1+d)^t} - I_0,$$

where d – is a discounting rate;

Ct – serving dish proceeds in the studied catering company in the period t;

I_t – current expenses in the period t;

I_0 – initial investment in the project;

– the calculation method of the discounted payback period (PbP);

– the calculation method of the internal rate of return (IRR);

– the calculation method of the investment index return (PI)

– one-parameter modeling method: impact analysis of the selected factor influence on the result indicator at the same values of other selected factors;

– regression analysis: identification of the relationship between the outcome and the selected group of factors;

– a linear normalization method for moving from different units of measure to normalized (comparable) results:

$$X_{in} = \frac{X_{ik} - X_{min}}{X_{max} - X_{min}},$$

where

X_{in} – normalized value;

X_{ik} – sample variable value;

X_{min} – minimum value from sample;

X_{max} – maximum value from sample.

3 RESULTS AND DISCUSSION

Recently, the administration of Kazan city has been paying great attention to the organization of recreation areas, landscaping and restoration of the city's attractions and, in general, to the convenience of the population in different parts of the city.

Public catering improves people's lives, absolve from low-productivity work, allows more time for active recreation. Let's consider the construction of a cafeteria in «Square of the 100th anniversary of the formation of the construction industry in the Republic of Tatarstan » in Kazan. There are fountains on the territory of the square operating during the summer period. Large remote control cars are also rent out by entrepreneurs and are in demand among children. The entire area of the fountain is filled with ice in winter. A large district Christmas tree is erected there and there is a skate rental shop nearby. It is necessary to locate the cafeteria pavilion in close proximity to them.

Calculations have shown that the cafeteria will be able to serve about 10-159 visitors per day with an average bill of 700 - 1000 rubles.

Costs and final performance indicators for an estimated period of 5 years are presented in Table 1

Table 1: Basic indicators.

Order number	Name	Numerical value	Measurement unit
1.	Construction and installation work costs and the purchase of equipment	3 078 000	rub.
2.	Pavilion purchase	4 398 000	rub.
3.	Preparation costs	671 000	rub.
4.	Costs for utility charges, salary payment , social security contributions, advertising and land rental per month	846 728	rub.
5.	Raw materials costs per month	673 364	rub.
6.	Net present value of the project (NPV)	2 105 013	rub.
7.	Simple payback period	3.42	yrs
8.	Discounted payback period (PbP)	4.52	yrs
9.	Discount rate	30	%
10.	Internal rate of return (IRR)	38	%
11.	The investment index return (PI)	1.17	разы

(Source: calculated by the authors)

Let us take a look at the payback period of the project (Y) will change with an increase in the sales price (X1), the costs of construction and installation work and the purchase of equipment (X2), and the discount rate (X3). Such single-parameter modeling shows a change in the payback period only with an increase in one factor and constant values of others (Table 2).

Table 2: Changing the payback period with an increase in selected initial factors.

Order num-ber	Factor growth in percentage	Change in discounted payback period (U) with:		
		an increase in selling price (X1)	an increase in costs for construction and installation work and the purchase of equipment (X2)	an increase in the discount rate (X3)
1.	100%	4.52	4.52	4.52
2.	110%	3.88	4.57	4.68

3.	120%	3.45	4.63	4.87
4.	130%	3.15	4.68	5.07
5.	140%	2.93	4.74	5.30
6.	150%	2.76	4.79	5.56
7.	160%	2.63	4.85	5.87
8.	170%	2.52	4.90	6.23
9.	180%	2.43	4.95	6.67
10	190%	2.35	5.01	7.23

(Source: calculated by the authors)

Each of the selected factors affects the value of the discounted payback period: an increase in the selling price leads to its decrease, an increase in the other two indicators leads to an increase (Fig. 1).

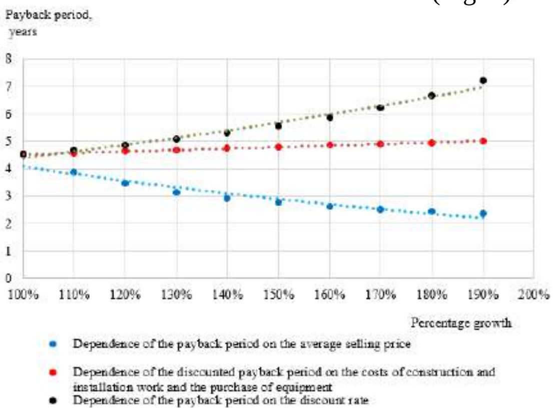


Figure 1: Change in discounted payback period in one-parameter modeling. (Source: proposed by the authors)

The dependence of the discounted payback period on the selected factors can be expressed by equations, the significance of which is confirmed by the high values of the approximation reliability indicators - R2 (Table 3).

Table 3: Univariate linear regression.

Model	Name	Equation	R2
Univariate linear regression	Plot of Y against X1	$y = 8.1126e^{-0.687x}$	0.933
	Plot of Y against X2	$y = 4.0341e^{0.1143x}$	0.999
	Plot of Y against X3	$y = 2.641e^{0.5107x}$	0.983

(Source: calculated by the authors)

Let us consider how the value of PbP (Y) will change with a simultaneous change in all initial factors: the price of selling (X1), the construction and installation work costs and the purchase of equipment (X2), the discount rate (X3). The minimum sample size was determined based on the number of initial factors (X1, X2, X3) and free terms of the equation (1 piece) - 20 options (Nizamova, Borovskikh, Shagiakhmetova, 2022). To increase the accuracy of calculations, 32 options for the development of the situation were analyzed (Table 4).

Table 4: Basic data for calculating regression dependen

Percentage growth

Order num-ber	X1, average selling price, rub.	X2 the construction and installation work costs and the purchase of equipment, rub.	X3, the discount rate, %	Y, payback period, yrs
1	239	3 078 000	30	4.52
2	239	3 385 800	33	4.79
3	239	3 693 600	20	4.33
4	239	4 001 400	10	4.14
5	239	2 770 200	12	3.78
6	239	2 462 400	15	3.86
7	239	2 616 300	25	4.32

8	239	2 154 600	18	3.90
9	271	2 154 600	20	3.46
10	306	2 462 400	15	3.07
11	324	2 770 200	16	3.00
12	343	3 385 800	23	3.05
13	208	3 359 700	17	4.76
14	223	3 693 600	14	4.22
15	271	3 785 940	25	3.80
16	423	4 309 200	28	2.82
17	271	3 078 000	28	3.83
18	306	3 078 000	20	3.25
19	343	3 078 000	25	3.09
20	324	3 078 000	28	3.26
21	208	3 078 000	13	4.51
22	208	3 078 000	10	4.40
23	179	3 078 000	2	4.95
24	193	3 078 000	11	4.87
25	271	3 385 800	30	3.95
26	288	3 539 700	30	3.73
27	288	3 693 600	30	3.76
28	271	3 847 500	30	4.07
29	288	3 938 450	30	3.79
30	362	4 281 200	30	3.16
31	382	4 281 200	30	3.07
32	423	3567700	30	2.82

(Source: calculated by the authors)

The selected factors (X1, X2, X3) have different units of measurement so they need to be normalized. To accomplish this the linear normalization method was used (Borovskikh, Shagiakhmetova, Nizamova, Kazymova, 2021).

The resulting multiple regression equation shows the dependence of the discounted payback period (Y) of the project on all factors simultaneously (X1, X2, X3):

$$Y= 0.726-1.283X_1+0,265X_2+0.195X_3,$$

где Y- discounted payback period of the project (PbP), years,

X_1 – selling price, rub.,

X_2 – the construction and installation work costs and the purchase of equipment, rub.

X_3– the discount rate, %.

The equation is characterized by the following results of regression statistics (Table 4).

Table 4:Regression statistics.

Order number	Name	Values
1.	Multiple R	0.954
2.	R-square	0.910
3.	Normalized R-square	0.900
4.	Standard error	0.094

5.	Observations	32

The multiple correlation coefficient shows the accuracy of the model and the relationship between the selected factors and the final indicator. The value of 0.954 indicates high accuracy of calculations. An R-square of 0.910 shows that 91% of changes in the discounted payback period are due to the selected factors and only 9% are due to factors not selected for modeling. The resulting model shows that the payback period of a public catering enterprise depends to a greater extent on the selling price and to a lesser extent on the construction and installation work costs and the purchase of equipment, the discount rate.

4 CONCLUSIONS

The calculations made by the authors allow to obtain the relationship between the discounted payback period (PbP) and the selling price, the construction and installation work costs and the purchase of equipment, and the discount rate. As an example the authors proposed the construction and operating of a public catering enterprise for 5 years.

The regression dependence was calculated on the basis of 32 observations. The R2 of the multiple regression equation is 0.91, which indicates that the calculations were performed correctly. The model proposed in the work will make it possible to predict the payback period for any public catering enterprise based on selected initial factors.

REFERENCES

Nadyrova, D. A., 2017. Multifunctional leisure complexes of Kazan mid-XXth-early 20th century. *The news of the Kazan State University of Architecture and Engineering* . № 4(42). C. 32-40. EDN ZTSUCZ.

Malefors, Ch., Strid , I., Eriksson, M., 2022. Food waste changes in the Swedish public catering sector in relation to global reduction targets. *Resources, Conservation & Recycling* 185,106463.

Sundin, N., Malefors, Ch., Danielsson, M., Hardiyanti, M., Persson Osowski, Ch., Eriksson, M., 2023. Investigating goal conflicts in menu planning in Swedish school catering on the pathway to sustainable development. *Resources, Conservation & Recycling* 190,106822.

Kaur, P., Talwar, Sh., Madanaguli, A., Srivastava, Sh., Dhir, A., 2022. Corporate social responsibility (CSR) and hospitality sector: Charting new frontiers for restaurant businesses. *Journal of Business Research* 144.1234–1248.

Filimonau, V., Chiang, Ch.-Ch., Wang, L.-en., Muhialdin, B. J., Ermolaev, V. A., 2023. Resourcefulness of chefs and food waste prevention in fine dining restaurants. *International Journal of Hospitality Management* 108.103368.

Malefors, C., Strid, I., Hansson, Per-A., Eriksson, M., 2021. Potential for using guest attendance forecasting in Swedish public catering to reduce overcatering. *Sustainable Production and Consumption* 25. 162–172.

Malefors, C., Sundin, N., Tromp, M., 2022. M. Eriksson. Testing interventions to reduce food waste in school catering. Resources, Conservation & Recycling 177 105997.

Willis, C., Mclauchlin, C., Amar, L., Sadler-Reeves, N., Elviss, H., Aird, A., Fox, M., 2016. Assessment of the Microbiological Safety of Precut Fruit from Retail and Catering Premises in the United Kingdom. *Journal of Food Protection*, Vol. 79, No. 4, Pages 598–604.

Neise, T., Verfürth, Ph., Franz, M., 2021. Rapid responding to the COVID-19 crisis: Assessing the resilience in the German restaurant and bar industry. *International Journal of Hospitality Management* 96. 102960.

Carrillo Ocampo, J.C., Marshall, M., Wellton, L., Jonsson, I.M., 2021. When sustainable cuisine imaginaries become unsustainable: Storage and preservation practices in Swedish restaurants. *International Journal of Gastronomy and Food Science* 24,100353.

Messabia, N., Fomi, Paul-R., Kooli, C., 2022. Managing restaurants during the COVID-19 crisis: Innovating to survive and prosper. *Journal of Innovation & Knowledge* 7. 100234.

Semerciöz, F., Pehlivan, Ç., Sözüer, A., Mert, A., 2015. Crisis management practices and strategic responses through customer loyalty and price strategy in hard times: Evidence from fine-dining restaurants. *Procedia - Social and Behavioral Sciences* 207,149 – 156.

Altuntaş, G., Semerciöz, F., Mert, A., Pehlivan, Ç., 2014. Industry forces, competitive and functional strategies and organizational performance: Evidence from restaurants in Istanbul, Turkey. Procedia - Social and Behavioral Sciences 150. 300 – 309.

Mengual-Recuerda, A., Tur-Viñes, V., Juárez-Varón, D., Alarcón-Valero, F., 2021. Emotional Impact of Dishes versus Wines on Restaurant Diners: From Haute Cuisine Open Innovation. *J. Open Innov. Technol. Mark. Complex.* 7, 96.

Pokka, E. V., Gafiyatullina A. F., 2020. Modern trends in the formation of tourism centers in the context of the development of tourist centers. *The news of the Kazan*

State University of Architecture and Engineering . № 2(52). C. 145-159.

Khusnudinova, A. F., Zabruskova, M. Y., 2018. Principles of formation of roadside service clusters in the structure of the region. *The news of the Kazan State University of Architecture and Engineering* . № 4(46). C. 152-158.

Sularto, L., Wardoyo, T., 2015. User Requirements Analysis for Restaurant POS and Accounting Application Using Quality Function Deployment. Procedia - Social and Behavioral Sciences 169.266 – 280.

Ronzonia, M., Accorsia, R., Guidania, B., Manzinia,. R., 2022. Economic and environmental optimization of packaging containers choice in Food Catering Supply Chain. Transportation Research Procedia 67. 163–171.

Eravia, D., Tri Handayani, J., 2015.. The Opportunities and Threats of Small and Medium Enterprises in Pekanbaru: Comparison between SMEs in Food and Restaurant Industries. Procedia - Social and Behavioral Sciences 169, 88 – 97.

Qashou, A., Saleh, Ya., 2018. E-marketing implementation in small and medium-sized restaurants in Palestine. A r a b e c o n o m i c a n d b u s i n e s s j o u r n a l .

Majid, M. A. A., Alias, M. A. M., Samsudin, A., Chik, Ch. T., 2016. Assessing Customer-Based Brand Equity Ratings in Family Restaurant. *rocedia Economics and Finance* 37. 183 – 189.

Sha, Y., Song, X., Zhan, J., Lu, L., Zhang, Q., Lu, Y., 2020. Regional Character, Restaurant Size, and Food Safety Risk: Evidence from Food Safety Violation Data in Gansu Province, China. *Journal of Food Protection*, Vol. 83, No. 4, Pages 677–685.

Nizamova, A. Sh., Borovskikh, O. N., Shagiakhmetova, E. I., 2022. Mathematical modeling of the parameters influencing the mortgage lending availability. *Housing strategies.* T. 9, № 2. C. 147-166.

Borovskikh, O., Shagiakhmetova, E., Nizamova, A., Kazymova, T., 2021. Cost Modeling of a Land Plot for Private Housing Construction. Lecture Notes in Civil Engineering : Proceedings of STCCE 2021.Selected Papers, Switzerland, Vol. 169. Switzerland: SPRINGER INTERNATIONAL PUBLISHING AG, GEWERBESTRASSE 11, CHAM, SWITZERLAND, CH-6330, 2021. – P. 47-57.

Improving the Methodology for Determining Injury Rates in Road Accidents using Machine Learning - The Random Tree Method

Pugachev Igor Nikolaevich[1][a], Grigorov Denis Yevgenyevich[2][b], Skripko Pavel Borisovich[3][c], Sheshera Nikolay Gennadyevich[3][d]

[1]*Khabarovsk Federal Research Center of the Far Eastern Branch of the Russian Academy of Sciences (HFRC FEB RAS), Dzerzhinsky street, Khabarovsk, Russia*

[2] *Khabarovsk Institute of Infocommunications SibGUTI, Lenin street, Khabarovsk, Russia*

[3]*Far Eastern Law Institute of the Ministry of Internal Affairs of Russia named after I.F. Shilova, lane Barracks, Khabarovsk, Russia*

Keywords: Injury rates, machine learning method – random forest, data analysis, characteristic curve, forecasting, correlation analysis.

Abstract: Every year in Russia there are a large number of road traffic accidents (RTA), in which more than 100 thousand people are injured and over 10 thousand die. (https://rg.ru/2023/11/18/ezhegodno-v-avtomobilnyh-avariiah-gibnet-bolee-milliona-chelovek-chto-mozhet-izmenit-pechalnuiu-statistiku.html, 2023). This has an impact on the demographic and economic situation of the country. The aggravated problem forces the Government to develop various programs and strategies to improve road safety. They are primarily aimed at preventing accidents with the help of sanctions policy. But the practice of holding drivers accountable is not always objective and leads away from the truth of the origin of accidents, especially with victims (Pugachev, I., Furman, B., Umanets, I., 2023).

The article proposes a comprehensive approach to identifying accident blackspots with a high risk of injury. The study includes an analysis of the dependencies of all elements of the Driver-Vehicle-Road-Environment (DVRE) system. Regression analysis and machine learning libraries of the random forest method in the Python programming language are used.

1 INTRODUCTION

The event – a traffic accident – is not random and is accompanied by a certain set of characteristics of the street and road network (SRN). The driver is the final element of the DVRE system and has a certain psychophysical potential that allows them to interact to a certain extent with the environment, the road and the car (Pugachev, I., Kulikov, Y., Markelov, G., Ostapenko, A., 2021). Research by Professor V.F. Babkov explains the influence of accompanying transport, road and natural characteristics on a person through their capabilities or peculiarities of perception of the surrounding environment. Nevertheless, there are negative combinations of factors of the DVRE system, with the simultaneous influence of which the average driver will not be able to ensure safety when driving their vehicle due, for example, to a large number of irritating factors and high speed. Information overload will distract their attention from dangerous elements, and high speed will not leave them the opportunity to stop or make a safe maneuver (V.F.Babkov, 1991).

To determine the causes of road accidents with injuries, it is necessary to investigate each case, to describe the surrounding situation, and then compare the accident with and without victims (Pugachev, I.N., Lopashuk, V.V., Kulikov, Y.I., Vasilev, A.Y., Barsukova, N.V., 2021). In the 60s, Professor V.F. Babkov developed the “Methodology of Accident Rates”, thanks to which, by generalizing the road

[a] https://orcid.org/0000-0003-0345-4350
[b] https://orcid.org/0009-0005-4049-9488
[c] https://orcid.org/0009-0006-0923-7081
[d] https://orcid.org/0009-0006-3302-5572

transport characteristics of each individual case of an accident, it became possible to predict accident rates using coefficients (Babkov V.F., 1991). Based on the works of the author, his explanation of the causes and consequences of the interaction of the subsystems of the DVRE system, it was decided to continue research in this direction to determine injury rates in road accidents using regression analysis and machine learning in order to generalize characteristics, determine their dependencies and build a model.

The research took place on the SRN of the city of Khabarovsk, Russia.

2 DEVELOPMENT OF A METHOD FOR DETERMINING INJURY RATES IN ROAD ACCIDENTS USING LOGISTIC REGRESSION

In order to collect statistical data, more than 400 km of roads were surveyed. The studies of the characteristics of the SRN took place at the scene of accidents, for which a tabulated template was prepared in advance. The following indicators were analyzed: intensity, number of lanes, width of the road, roadside, slopes (longitudinal, transverse), radius of the curve, visibility in plan and profile, as well as crossings at the same level, type of crossing, regulation of crossroads and crosswalks, type of a crosswalk, marking, dividing strips, additional and main lanes, distance from the road to buildings, pavement, fences, heaviness, sidewalks, bus stops, curbs, poles, time of day, advertising banners, trees along the road, etc.

The data were grouped into specified intervals and binarized according to the principle: 1 - if the factor was present and 0 - if it was absent. This is necessary for regression analysis in the Statistica program (Pugachev I.N., Kamenchukov A.V., Kapsky D.V., Kot E.N., Burtyl Yu.V., Shcheglov, 2022).

Using correlation analysis, as well as the Pearson criterion, features not exceeding the correlation coefficient of 0.7 and the probability of error according to the Pearson criterion of 0.05 I were selected. (I. Pugachev, Y. Kulikov, G. Markelov, N. Sheshera, 2017).

In the Statistica 6.0 program, as a result of experimental studies, a prognostic scale was developed; the best predictive model was selected using the variable selection method, which consists of 9 SRN factors: 2 traffic lanes, roadway width is 18-18.9 m, presence of a 3 m wide roadside, visibility limitation in plan ≥ 200 m, rough (new) coating, tire-to-surface friction coefficient is 0.75, presence of a sidewalk ≥ 4 m wide, average speed is 60 km/h, crosswalk, curve radius in plan is 200-349.9 m.

Each factor is characterized by a rate (severity rate Sr1,Sr2…Sr9).

The logistic regression method is based on the equation:

$$Y= b_0+b_1X_1+ b_2X_2+\ldots+ b_iX_i \qquad (1)$$

where Y is a dependent feature, X1, X2,...,X9 are independent features, b1,b2...,bi are coefficients, b_0 is a constant.

Taking into account the logical transformation, the final injury rate will be calculated using the formula:

$$SrTOTAL= Sr_1+Sr_2+Sr_3+\ldots+Sr_9 \qquad (2)$$

where – Sr1 – 2 lanes (-0.34556), Sr2 – the width of the road of 18-18 m. (1.44674), Sr3 – the presence of a roadside with a width of 3 m (2.9149), Sr4 – limitation of visibility in plan of 200≤ m (1.312754), Sr5 – rough coating (new), tire-to-surface friction coefficient of 0.75 (0.937902), Sr6 – the presence of a sidewalk with a width of ≤ 4 m (1.262661), Sr7 – average speed of 60 km/h (-0.04846), Sr8 – crosswalk (1.59205), Sr9 – curve radius in plan of 200-349.9 m (2.09848).

The quality of the model was confirmed by the characteristic ROC curve (Figure 1). The area under the curve was 0.82, which confirms the high quality of the prognostic scale.

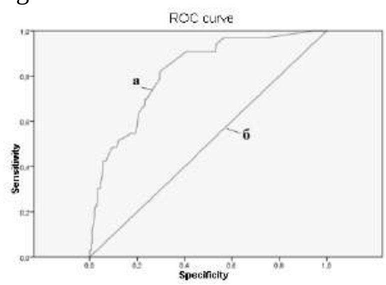


Figure 1: Characteristic curve (a – ROC curve (characteristic curve); b – null hypothesis).

Sensitivity and specificity studies have allowed us to develop a threshold value exceeding which increases the risk of injury in an accident by up to 70%. It was 2.09.

The obtained results were tested on the accident blackspot in Khabarovsk, Suvorova Street, from

Pavla Morozova Street to Malinovskogo Street. Similar to the Methodology of Accident Rates of Professor V.F. Babkov, the analysis involves calculating the injury rate in road accidents using a linear graph and the derived formula 2 (Figure 2).

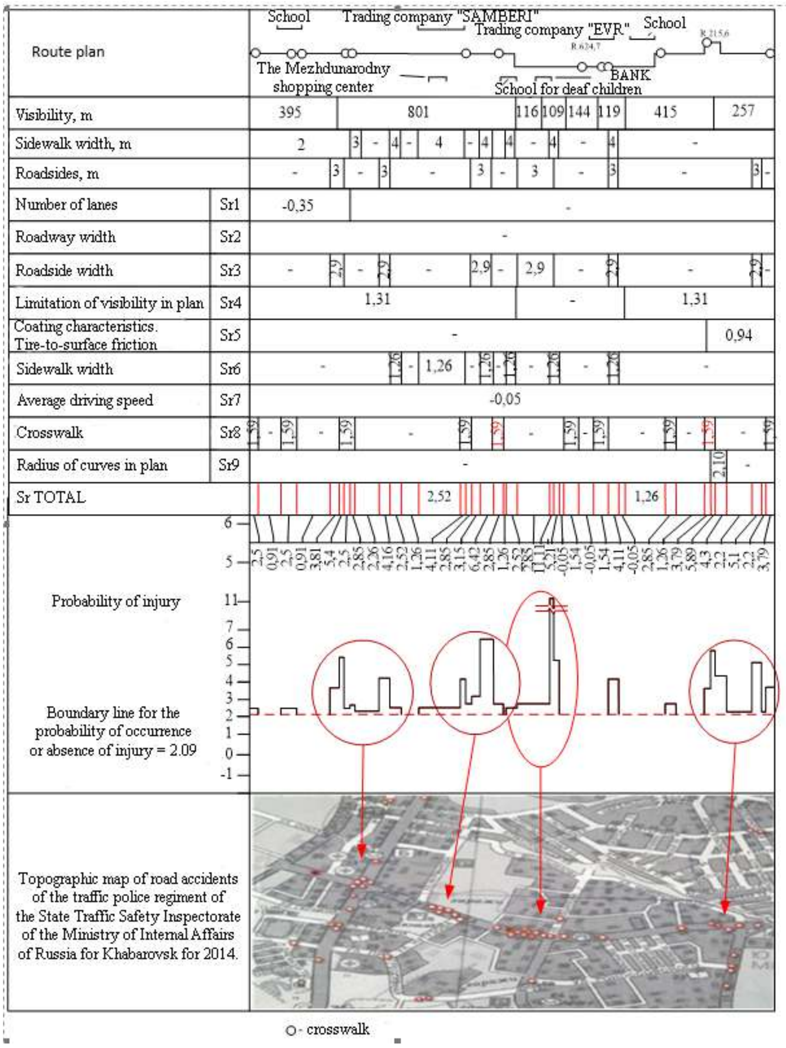


Figure 2: Linear graph of injury rates on Suvorova Street, from Pavla Morozova Street to Malinovskogo Street.

3 ANALYSIS OF INJURIES IN ROAD ACCIDENTS USING MACHINE LEARNING

Despite the efficiency of the prognostic scale created using logistic regression, a large number of features were not significant. However, Professor V.F. Babkov, when studying the psychophysical properties of a driver, considered it natural that all characteristics manifest themselves to varying degrees. Moreover, he spoke about the need for additional research of new ones on a par with the old ones, taking into account the changing transport situation (I.N. Pugachev, A.V. Kamenchukov, N.S. Nesterova, 2022).

The difficult task of studying the degree of influence of various combinations of DVRE subsystems has been solved using machine learning – the Random Forest Method.

3.1 Data collection and preparation

In order to increase the representativeness of the data, most of it was collected by software and hardware systems. For example, the intensity of traffic flow was formed using the INTEGRA KDD traffic flow registration, accounting and analysis system, data on accidents were taken from the open portals of the State Road Safety Inspectorate of the Russian Federation (http://stat.gibdd.ru/), geometric elements of roads were measured in-situ or using modern geoinformation systems, etc. (Pugachev I.N., Skripko P.B., Sheshera N.G., 2023). Additionally, information on weather and climatic conditions provided by the Khabarovsk Center for Hydrometeorology and Environmental Monitoring with the functions of the regional specialized meteorological center of the World Weather Service (Khabarovsk station No. 4853511) was added to the features under consideration.

When collecting data, special attention was paid to an underestimated indicator – speed. In the first part of the study, only the maximum permitted speed in the territory of Khabarovsk, established by state and local authorities, was taken into account. It was assumed that drivers observe it when driving, and accordingly, the value was taken as a constant (Rudenko N.V., 2022). Further observations forced us to doubt this. In the territory of the Russian Federation, in order to be held administratively liable for exceeding the maximum permissible speed, for example 60 km/h, the driver must drive at a speed of 81 km/h. This is necessary to level out various equipment errors and, accordingly, to increase confidence in the commission of an administrative violation. Knowing this, drivers increase their speed to the maximum permissible level, and in places where there are no means of recording violations, the speed is limited only by road conditions and the driver's personal confidence in safety. At the same time, on uncovered main streets in places where people are attracted, there is a high concentration of cars parked along the road. In conditions of insufficient parking spaces, people park on the roadway, violating the rules. This leads to difficulties in traffic flow (Batishcheva O.M., Ganichev A.I., Starikova A.G., 2023). In Khabarovsk there are areas where this happens systematically. The speed rate there is below the permissible limit.

Taking into account the above, it was decided to collect data on the maximum speed allowed in the areas where accidents occurred during the relevant time period. For this purpose, a GPS tracker was used, which recorded data as the vehicle moved along the studied road sections over a period of 2 years. They were processed and each accident was assigned the maximum speed provided in accordance with the place and time. It is worth noting that the research vehicle with a GPS tracker was moving at the maximum speed that the road conditions allowed.

The collected data amounted to over 75 thousand. Road accidents that occurred in the city of Khabarovsk (from 2016 to 2021). They included features that hypothetically influence the injury rates or are secondary, but necessary to prepare the data: Date, Time, Type of accident, Place (administrative districts of the city), Street, House, People died, Children died, People wounded, Children wounded, Grouped by injuries (0 - no victims, 1 - injured, 2 - died), Lane where the accident occurred, Width of the sidewalk, Width of the dividing strip, Type of pavement, Vehicle type (1 - bicycles; 2 - motorcycles; 3 - cars; 4 - buses; 5 - special equipment; 6 - trucks), Vehicle color, Purpose of use, Transportation, Transportation type, Damage, Technical problems, Category, Gender, Severity of consequences, Social characteristics of a driver (place of work), Direct traffic violations, Associated traffic violations, Driving license type, Experience (including grouped by 5-year intervals), Seat belts (whether the person was strapped during the accident and whether the vehicle design included seat belts in general), Chemical test, Traffic flow intensity (including at crossings and at intervals of 100, 250, 500 and 1000 vehicles/hour), Month, Day of week, Number of lanes in the forward direction, Number of additional left and right lanes (their number, type and length), Longitudinal slope (including intervals of 30‰ and 50‰), Road width (including intervals of 5 and 10 meters), Type of traffic (one-way - 1, two-way - 2, mixed - 1.2), Parking (distance to it and type), Type of dividing strip (marking only – 0, dividing strip – 1, barrier fences – 2), Bus stop (type and distance to it), the Type of intersection, Traffic light control, Presence of a crosswalk within a 50-meter radius, Maximum permissible speed, Temperature (air, soil and dew point (°C)), Partial pressure of water vapor (PA), Relative humidity (%), Saturation deficiency (g/m$^{3),}$ Atmospheric pressure at station and sea level (hPa), Visibility (Code – VV), Weather (Code – ww), Wind direction (degrees), Wind speed (m/s), Precipitation (including intervals of 5 and 10 mm), Part of the day (day, night, morning and evening twilight).

3.2 Random Forest Method

It was decided to carry out further data processing to determine dependencies and predict injury rates in road accidents (absence of victims, victims and fatalities) using an ensemble machine learning method - the Random Forest Method.

Random forest ensemble uses multiple trees, which helps reduce the likelihood of model overfitting. Each tree is trained independently and makes predictions, after which the results are combined to obtain the final probability. This helps to improve the generalization ability of the model and reduce the impact of outliers and noise in the data. By combining predictions from multiple trees, an ensemble of random forest can achieve high prediction accuracy.

The machine learning project uses the Scikit-Learn library (also known as sklearn), which is a machine learning library for the Python programming language. It provides a wide range of tools for the development and application of machine learning models, including classification, regression, clustering, data preprocessing and model selection.

Scikit-Learn (https://scikit-learn.org/stable/) has a simple and uniform API interface that facilitates the use and combination of various algorithms and methods. The library also comes with many functions for data preprocessing, model selection, evaluation, and validation.

3.3 Preparing data and installing dependencies

After studying the data processing features of the Scikit-Learn method, the general population was cleaned and converted to a numeric format. For example, all missing values were analyzed and, in accordance with the semantic load, replaced with “0” if the quantitative indicator was constantly present in the DVRE system (air temperature, partial pressure of water vapor, relative air humidity, etc.) or “-1” if the indicator was qualitative or quantitative, but the absence of a value meant the absence of this indicator in a given period of time (wind speed, weather code, visibility, etc.). Letters were also replaced with numbers (Baklanova K.V., 2023).

To implement the idea in the Python programming language, a virtual environment was created in the PyCharm development environment in order to modularly separate operations for reading data from files, learning operations, and forecasting operations. It included 4 files with the py extension, hereinafter referred to as modules.

- trainer.py – model training;
- config.py – list of variables;
- predict.py – prediction;
- utils.py – encapsulation of the implementation of some functions used in several places of the program, as well as for applying the DRY (Don't Repeat Yourself) principle.

3.4 Training

Taking into account the peculiarities of working in Python, libraries, commands and functions for machine learning and data analysis were imported into the trainer.py module:

`import joblib` –saving and loading machine learning models;

`import numpy as np` – working with multidimensional arrays and matrices;

`import pandas as pd` – working with tabular data;

`import seaborn as sns` – data visualization;

`from matplotlib import pyplot as plt` – creating graphs and visualizations;

`from sklearn.multiclass import OneVsOneClassifier` – multiclass classification;

`from config import cols` – column configuration parameters;

`from config import primary_column` – main column configuration parameters;

`from sklearn.ensemble import RandomForestClassifier` – random forest classifier;

`from sklearn.metrics import r2_score, roc_curve, auc` – metrics for evaluating the quality of models;

`from sklearn.model_selection import train_test_split` – splitting data into training and test sets;

`from sklearn.preprocessing import OneHotEncoder` – transformation of categorical features;

`from sklearn.metrics import classification_report` – output of the classification report;

`from sklearn.metrics import confusion_matrix` – creating an error matrix;

`from sklearn.metrics import RocCurveDisplay` – ROC curve display;

`from sklearn.preprocessing import LabelBinarizer` – binarization of labels;

`from sklearn.inspection import permutation_importance` – feature importance assessments;

`from utils import flatten_cols, encoder` – user utilities for working with data.

The data analysis included the use of graphs, so their style had been determined in advance:

```
plt.style.use('ggplot')
```

The pre-prepared data was downloaded from a CSV file named dataset.csv as a pandas DataFrame using the pd.read_csv() function:

```
severity_df = pd.read_csv('./datasets/dataset.csv', encoding="utf-8", delimiter=";")
```

The encoding="utf-8" parameter indicates the encoding of the file, which allows special and non-English characters to be interpreted correctly, delimiter=";" specifies the column delimiter in the CSV file.

One of the ways to work with data in pandas DataFrame is to change the column structure using the flatten_cols() function. In this case, the code takes the cols variable, which contains the column names, and applies the flatten_cols() function to it with the 'name' argument:

```
cols = flatten_cols(cols, 'name')
```

The cols list is located in the config.py module of this virtual environment, and is converted using the flatten_cols function with the 'name' argument into a one-dimensional list by the given key. It contains a list of keys to be analyzed (independent features). Also in the config.py module, the primary_column variable is assigned the dependent feature general_injuries:

```
cols = [
    {"name": "time"},
    {"name": "driving_experience_5"},
    {"name": "week_day"},
    {"name": "month"},
    {"name": "type_of_road"},
    {"name": "traffic_direction_separator"},
    {"name": "intersection_type"},
    {"name": "traffic_light"},
    {"name": "availability_of_a_pedestrian_crossing_within_a_radius_of_50_m"},
    {"name": "visibility,_code_(VV)"},
    {"name": "part_of_the_day"},
    {"name": "int_250"},
    {"name": "road_width_5"},
    {"name": "number_of_forward_lanes_(total_number_in_all_directions)"},
    {"name": "number_of_left_lanes_(in_all_directions:_oncoming_and_parallel)"},
    {"name": "number_of right_lanes_(in_all_directions)"},
    {"name": "left_stripe_length"},
    {"name": "longitudinal_slope"},
    {"name": "right_stripe_length"},
    {"name": "distance_to_parking"},
    {"name": "distance_to_bus_stop_from_the_center_of_the_house"},
    {"name": "max_speed"},
    {"name": "air_temperature"},
    {"name": "soil_temperature"},
    {"name": "dew_point_temperature"},
    {"name": "partial_pressure_of_water_vapor"},
    {"name": "relative_humidity"},
    {"name": "saturation_deficit"},
    {"name": "atmospheric_pressure_at_station_level"},
    {"name": "atmospheric_pressure_at_sea_level"},
    {"name": "wind_speed"},
    {"name": "precipitation_mm"},
    {"name": "vehicle_type_category"},
    {"name": "general_injuries"},
    # {"name": "color"},        #
        # {"name": "Color"},
    # {"name": "driving_experience_years"},
    # {"name": "location", "need_encode": True}
]
primary_column = 'general_injuries'
```

Looking ahead, it is worth noting that the number of signs included in the cols list at the learning stage is significantly less than what was collected at the first stage of the study. Through experimental selection of data, focusing on the values of the coefficient of determination (r2) and accuracy, the best predictive model was selected (Accuracy =97.99, r2 = 0.8212487585413919). The remaining features were excluded as insignificant.

To ensure the purity of the experiment, accidents involving drivers in a state of intoxication were excluded from the trainer.py module. The indexes of rows in the severity_df DataFrame that have a value in the 'results_of_medical_examination' column equal to "positive" have been deleted. The psychophysical apparatus of these drivers does not react correctly to external stimuli and is abnormal, therefore they should be excluded (Mosin K.K., Kovalevsky V.E., Zhukova N.A., 2023).

```
index_names = severity_df[severity_df['results_of_medical_examination'] == 'положительный'].index

severity_df.drop(index_names, inplace=True)
severity_ml = severity_df[cols]
severity_ml = severity_ml.dropna()
```

The rows with the found indexes from the severity_df DataFrame have also been deleted. The inplace=True argument specifies that the changes should be applied to the original DataFrame rather than returned separately.

In the newly created severity_ml DataFrame, which contains only the columns from the cols list, rows with missing values (NaN) have been removed from the severity_ml DataFrame.

If it is necessary to binarize the values of variables, a cyclic function is used:

```
for col in cols:
    if "need_encode" in col:
        severity_ml[col["name"]] = severity_ml[col["name"]].astype("string")
        severity_ml = encoder(severity_ml, col["name"], True)
```

It checks for the presence of the need_encode string in the variables. If found, binarizes the values according to the conditions. In this work, there was no need for it, but to ensure the accuracy of the prediction, "need_encode": True was added to each variable, after which the accuracy of the model was re-checked.

After binarization, rows with missing values are excluded and the dependent variable is separated from the independent ones.

```
severity_ml = severity_ml.dropna()
severity_train = severity_ml.drop(primary_column, axis=1)
```

The cleared data is divided into training and test samples for training. The size of the test set is defined as 20% of the total amount of data (test_size=0.2).

```
X_train, X_test, y_train, y_test = train_test_split(severity_train.values,
severity_ml[primary_column].values,
test_size=0.2,random_state=42)
```

Random_state sets the initial state for the random number generator so that the result is reproducible (Kononchuk E.V., Ermolenko T.V., Shishunov T.O., 2022).

A RandomForestClassifier class object is created, which trains the model on the training dataset (X_train, y_train) using the fit method, then the probabilities are predicted for the test dataset (X_test) using the predict_proba method, which creates a Random Forest model with 200 trees.

```
random_forest = RandomForestClassifier(n_estimators=200)
y_score = random_forest.fit(X_train, y_train).predict_proba(X_test)
result = random_forest.predict(X_test)
```

The model is saved in a virtual environment.

```
joblib.dump(random_forest, 'model.sav')
```

3.5 Model verification

The main indicators of the model's accuracy were the determination coefficient (r2) and accuracy.

```
acc_random_forest = round(random_forest.score(X_test, y_test) * 100, 2)
print("Accuracy", acc_random_forest)
print(r2_score(y_test, result))
```

As mentioned above, by experimentally selecting features, grouping into intervals, increasing or decreasing them, and binarization, the best predictive model was selected where Accuracy =97.99, r2 = 0.8212487585413919.

The resulting indicators influence the injury rate in road accidents to varying degrees, as evidenced by the correlation matrix (Figure 3), which was obtained using the code:

```
corr = severity_ml.corr()
plt.subplots(figsize=(20, 15))
sns.heatmap(corr)
plt.show()
```

Additionally, the significance of the features was analyzed using the permutation importance method for a random forest model trained on training data (X_train and y_train).

```
result = permutation_importance(random_forest, X_train, y_train, n_repeats=10, random_state=42)
importances = result.importances_mean
indices = np.argsort(importances)[::-1]
ar_f = []
for f, idx in enumerate(indices):
ar_f.append([round(importances[idx], 4), cols[idx]])
ar_f.sort(reverse=True)
print(ar_f)
```

As a result of the above command, the following significance coefficients were obtained: [[0.1658, 'max_speed'], [0.0044, 'availability_of_ a_pedestrian_crossing_within_a_radius_ of_50_m'], [0.0041, 'part_of_the_day'], [0.0036, 'time'], [0.0036, 'driving_experience_5'], [0.0032, 'road_width_5'], [0.0032, 'longitudinal_slope'], [0.003, 'int_250'], [0.0025, 'vehicle_type_category '], [0.0019, 'atmospheric_pressure_at_station_level'], [0.0018, 'atmospheric_pressure_at_sea_l evel'], [0.0017, 'air_temperature'], [0.0016, 'relative_humidity'], [0.0014, 'soil_temperature'], [0.0014, 'distance_to_ bus_stop_from_the_center_of_the_house'], [0.0013, 'number_of_forward_lanes _(total_number_ in_ all_directions)'], [0.0012, 'week_day'], [0.0012, 'distance_to_parking'], [0.0011, 'saturation_deficit'], [0.0011, 'dew_point_temperature'], [0.001, 'partial_ pressure_of_water_vapor'], [0.001, 'left_stripe_l ength'], [0.0007, 'traffic_light'], [0.0007, 'intersection_type'], [0.0006, 'right_stripe_length'], [0.0005, 'wind_speed'], [0.0005, 'month'], [0.0004, 'visibility,_code_(VV)'], [0.0004, 'type_of_road'], [0.0004, 'number_of_left_lanes_(in_all_directions:_ oncoming_and_parallel)'], [0.0003, 'precipitation_ mm'], [0.0, 'traffic_direction_separator'], [0.0, 'number_of right_lanes_(in_all_directions)']].

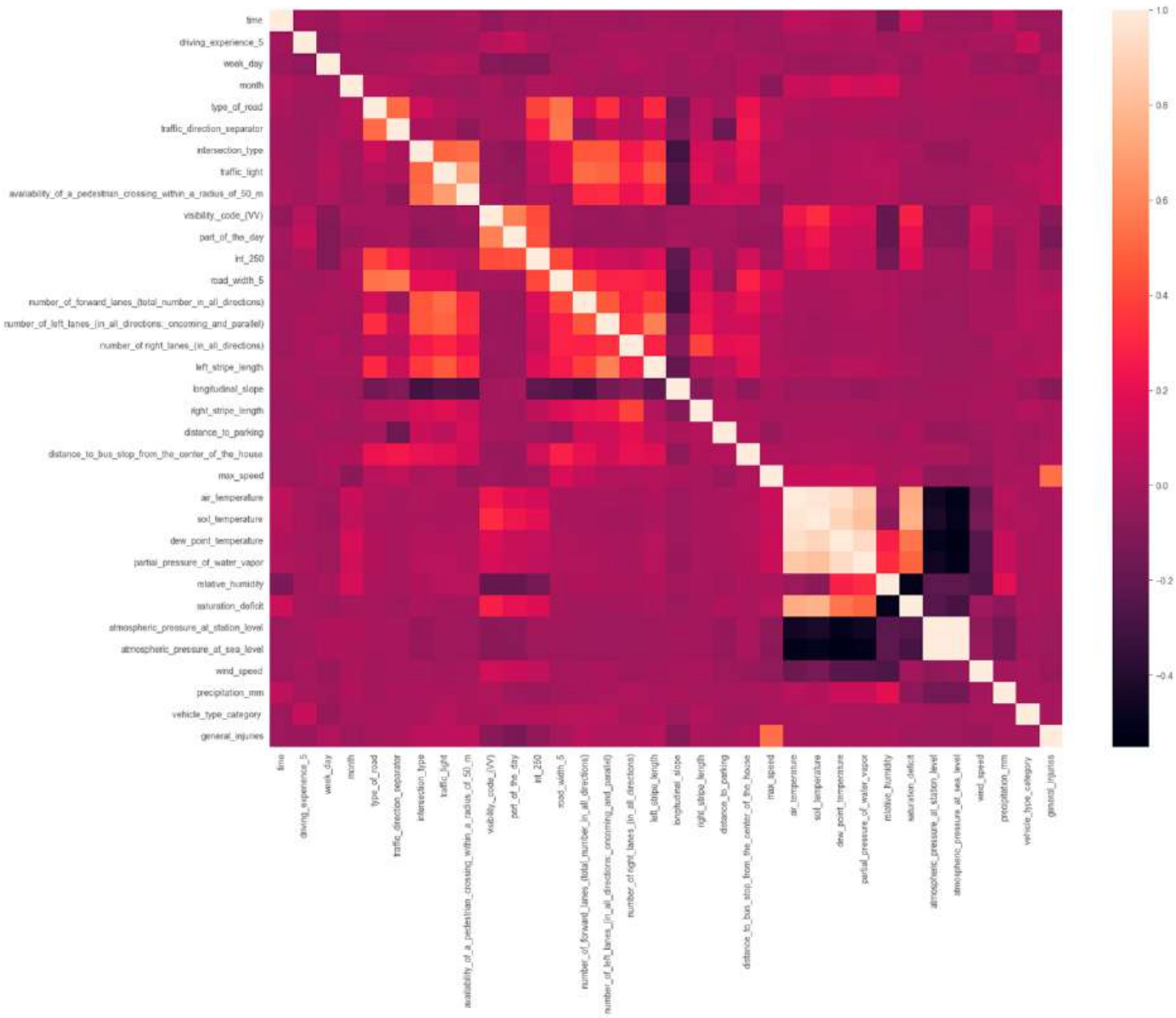


Figure 3: Correlation matrix of the influence of features.

Based on the result, it can be concluded that the indicator of the maximum speed has a strong influence. But this does not mean that the other features are not effective; on the contrary, together they create a complex effect on the injury rates in road accidents.

In order to further verify the accuracy, a matrix of the number of correctly and incorrectly guessed classes was constructed using the following line of code (Figure 4):

```
matrix = confusion_matrix(y_test, random_forest.predict(X_test))
matrix = matrix.astype('float') / matrix.sum(axis=1)[:, np.newaxis]
# Build the plot
plt.figure(figsize=(16, 7))
sns.set(font_scale=1.4)
sns.heatmap(matrix, annot=True, annot_kws={'size': 10},
            cmap=plt.cm.Greens, linewidths=0.2)
# Add labels to the plot
class_names = ["0", "1", "2"]
tick_marks = np.arange(len(class_names))
tick_marks2 = tick_marks + 0.5
plt.xticks(tick_marks, class_names, rotation=25)
plt.yticks(tick_marks2, class_names, rotation=0)
plt.xlabel('Predicted classes')
plt.ylabel('Actual classes')
plt.title('Confusion Matrix for Random Forest Model')
plt.show()
```

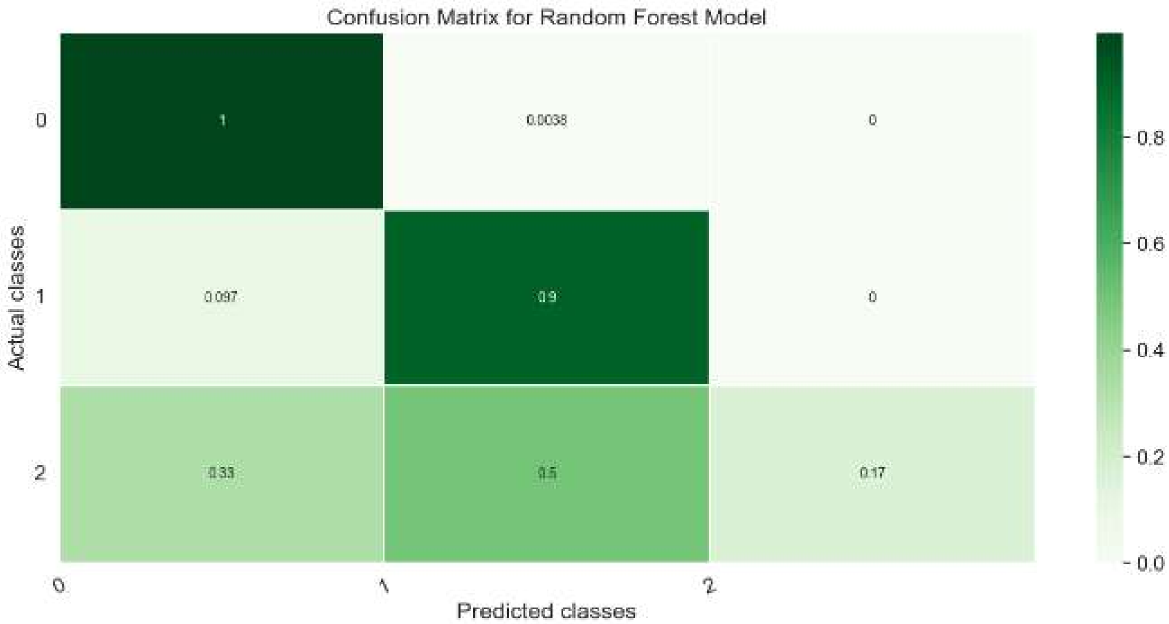


Figure 4: Error matrix

The confusion matrix is a square matrix where each element (i, j) is the number of objects that actually belong to class i but were predicted as class j. Thus, the confusion matrix provides information about correctly classified and misclassified objects for each class (Harutyunyan M.A., 2023).

The confusion_matrix method takes as arguments the true class labels (actual classes) and predicted class labels (predicted classes), and returns a confusion matrix.

As can be seen from Figure 4, the model makes errors, but they are insignificant for determining two injury rate values: 0 - not injured, 1 - injured. Predictions of the third value "2 - died" are not accurate and require further research.

4 PREDICTION

For prediction, data on 27 road accidents from the general population that did not participate in training were selected (dataset_predict.csv). The dependencies were prepared in a similar manner, and the data was initially processed to eliminate errors. The code is written in the predict.py module:

```
import joblib
import numpy as np
import pandas as pd
import warnings
from matplotlib import pyplot as plt
from config import cols, primary_column
from utils import flatten_cols, encoder
plt.style.use('ggplot')
df = pd.read_csv('./datasets/dataset_predict.csv', encoding="utf-8", delimiter=";")
cols = flatten_cols(cols, 'name')
df_test = df[cols]
df_test = df_test.drop(primary_column, axis=1)
df_test = df_test.dropna()
df = df[cols].dropna()
for col in cols:
    if "need_encode" in col:
        df_test[col["name"]] = df_test[col["name"]].astype("string")
        df_test = encoder(df_test, col["name"], True)
```

The machine learning model is loaded from the "model.sav" file using the joblib.load() function.

```
model = joblib.load('model.sav')
result = model.predict(df_test.values)
r = pd.DataFrame(np.array(result), columns=['severity'])
```

```
g = pd.concat([df.reset_index(), r], axis=1)
pd.set_option('display.max_rows', None)
g
```

The results are stored in the result variable, and then packed into a DataFrame r with the column name "severity".

A new DataFrame g is created by combining the original DataFrame df with the index prediction results (row index values). The combined DataFrame g is output, which contains the original data and the prediction ("severity").

After pre-processing, 20 of the 27 accidents remained, the rest did not include the necessary information. The prediction results are summarized in Table 1.

Table 1: Results of the prediction of road traffic accident injury rates.

No.	general_ injuries	severity	No.	general_ injuries	severity
1	1	1	11	0	0
2	0	0	12	1	1
3	0	0	13	0	0
4	0	0	14	0	0
5	0	0	15	1	1
6	1	1	16	2	1
7	1	1	17	2	2
8	0	0	18	0	0
9	0	0	19	0	0
10	1	1	20	1	1

5 CONCLUSIONS

These studies are a new step in improving the road safety system, which aims to achieve zero fatalities on the roads. The complex solution, in the version proposed by the authors of the article, has a direct impact on the management of traffic flows in an accident-free mode, which has not been previously developed or applied, this is the scientific novelty of the work.

Based on the Methodology of Accident Rates by Professor V.F. Babkov, a fundamentally new approach was developed, which was tested on a blackspot of the city of Khabarovsk, as a result of which a high accuracy of convergence of the real situation of injuries in road accidents with the prediction was demonstrated (Figure 2). The reliability of the prognostic scale was 70% (Pugachev I.N., Sheshera N.G., 2020).

To improve the accuracy of the prediction, additional studies were carried out and new parameters were included taking into account the logical justification and experimental observation. For example, the maximum permitted speed was replaced by the maximum provided speed. The intensity of traffic flows was not increased by means of control measurements with subsequent reduction, but by processing actual data from software and hardware systems. The number of classes of the dependent feature – injuries – was increased. In the first study it included: 0 – no victims and 1 – with victims; in the second study there are already three: 0 – no victims, 1 – with victims and 2 – fatalities.

Recent studies on the influence of SRN parameters have been carried out using machine learning – the Random Forest Method. After preparing the feature values, a predictive model was trained. It was tested on pre-prepared data that was not used in the training. The result is shown in Table 1. Out of 20 features, the model correctly classified 19. This indicates the high quality of the prognostic scale.

The second study gives a much better result than the first one, but this does not mean that it should be completely excluded. The two approaches have fundamentally different methods of application. In the first case, it is enough to have a pen and a piece of paper on hand, which simplifies the task of assessing road safety in the field (Pugachev I.N., Sheshera N.G., 2016). In the second case, computing technology is required, but this limitation is offset by high precision and greater detail.

The completed work solves a large number of tasks related to the design, construction and operation of transport facilities, increasing road safety, for the solution of which an algorithmic toolkit has been created, based on the theoretical results obtained and software prototypes of their main components, methods and analytical algorithms.

The full code of machine learning – the Random Forest Method and the results of the study can be found at: https://github.com/glowfisch8lan/3691308f2a4c2f6983f2880d32e29c84.git.

REFERENCES

Rg.ru. (2023, 18 noyabrya). Ezhegodno v avtomobil'nyh avariyah gibnet bolee milliona chelovek: chto mozhet izmenit' pechal'nuyu statistiku? [Online]. Dostupno: https://rg.ru/2023/11/18/ezhegodno-v-avtomobilnyh-avariiah-gibnet-bolee-milliona-chelovek-chto-mozhet-izmenit-pechalnuiu-statistiku.html. [Data dostupa: 28 noyabrya 2021 g.].

The future of the transport and logistics complex in the light of the initiated transport strategy of the Russian Federation until 2030 with a forecast for the period up to 2035 / Pugachev, I., Furman, B., Umanets, I. // AIP Conference Proceedings , 2023, 2624(1), 040033.

Pugachev, I., Kulikov, Y., Markelov, G., Ostapenko, A., 2021. Peculiarities of strategic transport development in the Russian Far East and the Arctic. Transportation Research Procedia, 57, stranicy 511–517.

Babkov, V. F., 1993. Dorozhnye usloviya i bezopasnost' dvizheniya. M.: Transport, 271 s.

Pugachev, I.N., Lopashuk, V.V., Kulikov, Y.I., Vasilev, A.Y., Barsukova, N.V., 2021. Qualimetric Road Assessment in Strategic Development. Lecture Notes in Civil EngineeringEta ssylka otklyuchena., 150 LNCE, stranicy 108–114

Pugachev I.N., Kamenchukov A.V., Kapskij D.V., Kot E.N., Burtyl' YU.V., SHCHeglov V.I., 2022. Upravlenie bezopasnost'yu dorozhnoj infrastruktury. Habarovsk.

Pugachev, I., Kulikov, Y., Markelov, G., Sheshera, N., 2017. Factor Analysis of Traffic Organization and Safety Systems.12th International Conference «Organization and Traffic Safety Management in large cities», SPbOTSIC-2016, 28-30 September 2016, St. Petersburg. P. 529-535.

Ekspluataciya avtomobil'nyh dorog : uchebnoe posobie / sost.: I.N. Pugachev, A.V. Kamenchukov, N.S. Nesterova. – Habarovsk : Izd-vo DVGUPS, 2022. – 168 s.

Pugachev, I.N., Skripko, P.B., SHeshera, N.G., 2023. Programmnyj podhod k kompleksnomu sboru i podgotovki dannyh ob intensivnosti dvizheniya transportnyh sredstv, pogodnyh uslovij i estestvennoj osveshchennosti v chasovyh intervalah. T-Comm: Telekommunikacii i transport. 2023. Tom 17. №10. S. 43-51.

Rudenko, N.V., 2022. Harakteristiki dorozhnogo dvizheniya po avtomobil'nym dorogam i metody ocenki bezopasnosti dorozhnogo dvizheniya. *Mezhdunarodnyj zhurnal informacionnyh tekhnologij i energoeffektivnosti.* T. 7. № 3-3 (25). S. 100-106.

Batishcheva, O.M., Ganichev, A.I., Starikova, A.G., 2023. Faktory, vliyayushchie na obespechenie bezopasnosti dorozhnogo dvizheniya v krupnyh gorodah. Vestnik transporta Povolzh'ya. № 2 (98). S. 110-115.

Scikit-learn. Oficial'nyj sajt. [Online]. Dostupno: https://scikit-learn.org/stable/. [Data dostupa: 27.03.2024 g.].

Baklanova, K.V., 2023. Vliyanie parametrov transportnogo potoka i harakteristik dorog na bezopasnost' dorozhnogo dvizheniya. Intellekt. Innovacii. Investicii. № 2. S. 99-110.

Mosin, K.K., Kovalevskij, V.E., ZHukova, N.A., 2023. Ispol'zovanie metodov avtomatizirovannogo mashinnogo obucheniya dlya klassifikacii dorozhno-transportnyh proisshestvij. Intellektual'nye tekhnologii na transporte. № 2 (34). S. 15-26.

Kononchuk, E.V., Ermolenko, T.V., SHishunov, T.O., 2022. Modeli mashinnogo obucheniya dlya ocenki veroyatnosti poyavleniya DTP i ego ser'eznosti. Problemy iskusstvennogo intellekta. № 1 (24). S. 4-12.

Arutyunyan, M.A., 2023. Razrabotka algoritmicheskogo apparata po obespecheniyu bezopasnosti dorozhnogo dvizheniya. *Modelirovanie, optimizaciya i informacionnye tekhnologii.* T. 11. № 3 (42). S. 9-10.

Pugachev, I. N., SHeshera, N. G., SHCHeglov, V. I., 2021. Analiz geometricheskih elementov dorog s pomoshch'yu sovremennyh geoinformacionnyh sistem pri ocenke ih avarijnosti. *Vestnik grazhdanskih inzhenerov.* № 3 (86). S. 127–133.

Pugachev, I. N., SHeshera, N. G., 2020. Primenenie metodov statisticheskogo analiza dlya ocenki parametrov transportnyh potokov i harakteristik ulichno-dorozhnoj seti. Dal'nevost. yurid. in-t MVD Rossii. Habarovsk : RIO DVYUI MVD Rossii. 108 s.

Pugachev, I. N., SHeshera, N. G., 2016. Primenenie metodiki koefficientov travmatizma v celyah kontrolya kachestva budushchih i ekspluatiruemyh dorog. *Kachestvo i zhizn'.* № 1 (9). S. 58–61.

GitHub. Repozitorij glowfisch8lan/3691308f2a4c2f6983f2880d32e29c84. [Online]. Dostupno: https://github.com/glowfisch8lan/3691308f2a4c2f6983f2880d32e29c84.git. [Data dostupa: 28 noyabrya 2021 g.].

Geometric Modeling of Virtual Museum Exhibits Using the Piecewise Polynomial Method

Jamoljon X. Djumanov[1], Temur R. Xudayberganov[2], Shukurulloh.H.Ismoilov[3], Anorgul I. Ashirova[4], Rahimjon R. Raximov[5], Azizbek B. Xasanov[6]

[1]*Computer Systems department, Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Tashkent, Uzbekistan*

[2]*Information Technologies department, Urgench branch of Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Urgench, Uzbekistan*

[3]*Director of Urgench branch of Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Urgench, Uzbekistan*

[4]*Department of Digital Educational Technologies, Urgench branch of Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Urgench, Uzbekistan.*

[5]*Interfaculty Department of General Technical Disciplines, Urgench State University, Urgench, Uzbekistan.*

[6]*Information Technologies department, Urgench State University, Urgench, Uzbekistan*

jamoljon@mail.ru, doctordrebek@gmail.com, shismailov@yandex.ru, anorgul76@gmail.com, rahimjon03021984@gmail.com, azizbek.lp@gmail.com

Keywords: geometric modeling, virtual museum, piecewise polynomial method, cultural heritage preservation, digital representation, interactive exhibits, 3d modeling, digital conservation, cultural artifacts.

Abstract: In the realm of digital preservation and virtual representation of cultural artifacts, the application of geometric modeling techniques holds significant promise. This paper focuses on the utilization of the piecewise polynomial method for the accurate and detailed modeling of museum exhibits within virtual environments. By leveraging the piecewise polynomial approach, this research aims to provide a comprehensive analysis of how intricate shapes and structures of various museum artifacts can be faithfully reconstructed and interactively presented in the digital space. Furthermore, the study delves into the technical aspects of implementing and optimizing this method for virtual museum applications. Through this rigorous exploration, the research seeks to not only demonstrate the potential of the piecewise polynomial method but also contribute to the advancement of virtual museum experiences, digital conservation, and educational outreach initiatives.

1 INTRODUCTION

After our republic gained independence, there has been an introduction of virtual reality environments by both state and private organizations to study culture, art, and historical monuments. The content of exhibits is displayed in three-dimensional and video electronic formats, and a virtual museum is designed using engineering geometry and computer graphics. The development of a national virtual environment for museums is receiving special attention. The President of the Republic of Uzbekistan has approved the "Digital Uzbekistan-2030" strategy and effective measures for its implementation. This includes the use of virtual reality, artificial intelligence, machine learning, and cloud computing in various economic sectors. The strategy also aims to promote scientific research in digital technologies and improve

[1] https://orcid.org/0000-0001-6043-2495
[2] https://orcid.org/0000-0003-0248-3619
[3] https://orcid.org/0000-0002-1469-9495
[4] https://orcid.org/0000-0002-3399-7527
[5] https://orcid.org/0000-0002-7532-5884
[6] https://orcid.org/0009-0007-6622-3839

organizational mechanisms. As technology continues to advance, a lot of people are becoming increasingly interested in exploring the virtual world of museums. Also, the demand for an electronic catalog to save a copy of cultural and artistic, spiritual and historical monuments based on applied geometry and computer graphics based on virtual reality tools has increased, and it is important to develop software tools that automate virtual environments with these types of methods, digital models and algorithms. is one of the tasks.

The exploration and presentation of museum exhibits in the virtual domain have become a significant area of interest in the digital age, blending the realms of cultural heritage with advanced computational techniques. One such cutting-edge approach to creating realistic and interactive representations of artifacts and historical pieces is through geometric modeling, specifically using the piecewise polynomial method. This technique allows for the meticulous recreation of objects in a virtual environment, offering a detailed and immersive experience for users worldwide.

Geometric modeling plays a crucial role in the digital preservation and dissemination of cultural heritage, enabling not only the safeguarding of delicate and priceless artifacts but also providing an accessible platform for education and research. The piecewise polynomial method, in particular, offers a robust framework for modeling complex shapes and surfaces with high precision. By segmenting the object into smaller, manageable pieces and approximating each segment with polynomial functions, this method can capture the intricate details and textures of museum exhibits with remarkable accuracy.

The introduction of the piecewise polynomial method into the realm of virtual museum exhibits opens up new avenues for exploration and interaction. Users can virtually navigate through collections, examine artifacts from multiple angles, and even experience historical contexts through interactive scenarios. This not only enriches the user experience but also extends the reach of museum collections, making them available to a global audience without the constraints of physical location or accessibility.

Moreover, the application of geometric modeling using the piecewise polynomial method in virtual museum exhibits holds significant potential for research and education. It enables scholars to analyze and study artifacts in detail without the risk of physical handling, preserving the artifacts' integrity while still allowing for in-depth examination. Additionally, it provides an innovative tool for educators to engage students with history and culture in a more interactive and engaging manner.

In summary, the geometric modeling of virtual museum exhibits using the piecewise polynomial method represents a convergence of technology and cultural heritage, offering new possibilities for preservation, education, and accessibility. This approach not only enhances the way we interact with museum collections but also plays a vital role in the ongoing effort to safeguard and share our global cultural heritage in the digital era.

By the general public, museologist, archeologist and historian scientists use high-resolution video, photorealistic electronic resources in the virtual world, the place, value, and adequacy level of categorization of materials in virtual electronic format in the process of museum exhibits based on engineering geometry and computer graphics, adding elements of virtual reality in the collection system. Yu.B. Bloxinova, I.G. Jurkina, V.A. Knyazya, A.N. Lobanova, A.P. Mikhaylova, A.G. Chibunicheva, Th. Luhmann, B. Keith Atkinson, Armin Gruen from foreign scientists on development of application systems, virtual environments and their implementation. , Richard Hartley, Matt Weilberg, and others' scientific work is noteworthy.

Application of virtual reality elements based on engineering geometry and computer graphics in the museum system of our republic, application of methods and algorithms for visualization of three-dimensional models of objects for the virtual environment, scientific research on software information system of virtual museum process automation, mainly A.Kh. Nishanov, J.Kh. Djumanov, F.M. Nuraliyev, A.Sh. Mukhammadiyev, Sh.A.Anarova, R.D.Aloyev, U.R.Khamdamov and others have been making their contributions. Currently, one of the urgent problems in the virtual world is that the digital collection fund of the museum in the virtual environment, the creation of 3D models of them and the development of the software tool, the integrated museum with automated information systems, the technologies of online visit to the virtual museum environment through the Internet are not sufficiently studied.

2 METHODS

We express the analytical view of the geometric model in the form of a third-order polynomial of the $Y(x) = y_i(x)$ function in each section [xi-1, xi] (i=1,2,…,N):

$$y_i(x) = a_i + b_i(x - x_i) + c_i(x - x_i)^2 + d_i(x - x_i)^3 \qquad (1)$$

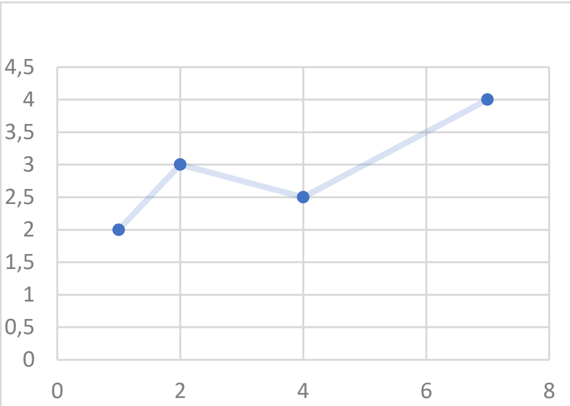
$$x_{i-1} \leq x \leq x_i \qquad , (i=0,1,2,\ldots,N)$$

where a, b, c, d are coefficients, these coefficients are found by taking derivatives from formula (1):

Given the following points (table 1):

Table 1: Given points.

№	x	y
0	1	2
1	2	3
2	4	2.5
3	7	4



Picture 1: Given points.

We interpolate through these points using formula (1). We write down the formulas for the three-part polynomial

$$\begin{cases} y_0 = a_0 + b_0(x - x_0) + c_0(x - x_0)^2 + d_0(x - x_0)^3 \\ y_1 = a_1 + b_1(x - x_1) + c_1(x - x_1)^2 + d_1(x - x_1)^3 \\ y_2 = a_2 + b_2(x - x_2) + c_2(x - x_2)^2 + d_2(x - x_2)^3 \end{cases}$$

After entering the appropriate coordinates, it will look like this:

$$\begin{cases} y_0 = a_0 + b_0(x - 1) + c_0(x - 1)^2 + d_0(x - 1)^3 \\ y_1 = a_1 + b_1(x - 2) + c_1(x - 2)^2 + d_1(x - 2)^3 \\ y_2 = a_2 + b_2(x - 4) + c_2(x - 4)^2 + d_2(x - 4)^3 \end{cases} \qquad (2)$$

We determine the equation by substituting the values of x and y through the points below.

For the 1st polynomial x_0=1, y_0=2, x_1=2, y_1=3:

$$y_0 = a_0 + b_0(x - 1) + c_0(x - 1)^2 + d_0(x - 1)^3,$$

$$\begin{cases} 2 = a_0 + b_0(1 - 1) + c_0(1 - 1)^2 + d_0(1 - 1)^3 \\ 3 = a_0 + b_0(2 - 1) + c_0(2 - 1)^2 + d_0(2 - 1)^3 \end{cases}$$

$$\begin{cases} a_0 = 2 \\ a_0 + b_0 + c_0 + d_0 = 3 \end{cases}$$

For the 2nd polynomial x_1=2, y_1=3, x_2=4, y_2=2.5:

$$y_1 = a_1 + b_1(x - 2) + c_1(x - 2)^2 + d_1(x - 2)^3,$$

$$\begin{cases} 3 = a_1 + b_1(2 - 2) + c_1(2 - 2)^2 + d_1(2 - 2)^3 \\ 2{,}5 = a_1 + b_1(4 - 2) + c_1(4 - 2)^2 + d_1(4 - 2)^3 \end{cases}$$

$$\begin{cases} a_1 = 3 \\ a_1 + 2b_1 + 4c_1 + 8d_1 = 2{,}5 \end{cases}$$

For the 3th polynomial x_2=4, y_2=2.5, x_3=7, y_3=4:

$$y_2 = a_2 + b_2(x - 4) + c_2(x - 4)^2 + d_2(x - 4)^3,$$

$$\begin{cases} 2{,}5 = a_2 + b_2(4 - 4) + c_2(4 - 4)^2 + d_2(4 - 4)^3 \\ 4 = a_2 + b_2(7 - 4) + c_2(7 - 4)^2 + d_2(7 - 4)^3 \end{cases}$$

$$\begin{cases} a_2 = 2{,}5 \\ a_2 + 3b_2 + 9c_2 + 27d_2 = 4 \end{cases}$$

In order for a polynomial line passing through each point to be smooth, the attempts to enter and exit the curve must overlap. for this

$$y_0' = y_1', y_0'' = y_1'', y_1' = y_2', y_1'' = y_2'' \qquad (3)$$

equals must be met. We find the 1st and 2nd derivatives of every polynomial.

$$\begin{cases} y_0' = (a_0 + b_0(x - 1) + c_0(x - 1)^2 + d_0(x - 1)^3)' = \\ \quad = b_0 + 2c_0(x - 1) + 3d_0(x - 1)^2 \\ y_1' = (a_1 + b_1(x - 2) + c_1(x - 2)^2 + d_1(x - 2)^3)' = \\ \quad = b_1 + 2c_1(x - 2) + 3d_1(x - 2)^2 \\ y_2' = (a_2 + b_2(x - 4) + c_2(x - 4)^2 + d_2(x-4)^3)' = \\ \quad = b_2 + 2c_2(x - 4) + 3d_2(x - 4)^2 \end{cases}$$

$$\begin{cases} y_0'' = (b_0 + 2c_0(x - 1) + 3d_0(x - 1)^2)' = \\ \quad = 2c_0 + 6d_0(x - 1) \\ y_1'' = (b_1 + 2c_1(x - 2) + 3d_1(x - 2)^2)' = \\ \quad = 2c_1 + 6d_1(x - 2) \\ y_2'' = (b_2 + 2c_2(x - 4) + 3d_2(x - 4)^2)' = \\ \quad = 2c_2 + 6d_2(x - 4) \end{cases}$$

$y_0' = y_1', y_0'' = y_1''$ for case x_1=2, y_1=3:

$$\begin{cases} b_0 + 2c_0(x - 1) + 3d_0(x - 1)^2 = \\ \quad = b_1 + 2c_1(x - 2) + 3d_1(x - 2)^2 \\ 2c_0 + 6d_0(x - 1) = 2c_1 + 6d_1(x - 2) \end{cases}$$

$$\begin{cases} b_0 + 2c_0 + 3d_0 - b_1 = 0 \\ 2c_0 + 6d_0 - 2c_1 = 0 \end{cases}$$

$y_1' = y_2', y_1'' = y_2''$ for case x_2=4, y_2=2.5:

$$\begin{cases} b_1 + 2c_1(x - 2) + 3d_1(x - 2)^2 = \\ \quad = b_2 + 2c_2(x - 4) + 3d_2(x - 4)^2 \\ 2c_1 + 6d_1(x - 2) = 2c_2 + 6d_2(x - 4) \end{cases}$$

$$\begin{cases} b_1 + 4c_1 + 12d_1 - b_2 = 0 \\ 2c_1 + 12d_1 - 2c_2 = 0 \end{cases}$$

We determine the property of polynomials at the initial and final points. We give zero curvature to polynomials.

$$y_0'' = 0,\ y_2'' = 0,\ x_0=1, y_0=2, x_3=7, y_3=4 \qquad (4)$$

$$\begin{cases} 2c_0 + 6d_0(x - 1) = 0 \\ 2c_2 + 6d_2(x - 4) = 0 \end{cases}$$

$$\begin{cases} 2c_0 = 0 \\ 2c_2 + 18d_2 = 0 \end{cases}$$

We will have a system of 12 linear equations and simplify to 8

$$\begin{cases} a_0 = 2 \\ a_1 = 3 \\ a_2 = 2{,}5 \\ c_0 = 0 \\ b_0 + d_0 = 1 \\ 2b_1 + 4c_1 + 8d_1 = -0.5 \\ 3b_2 + 9c_2 + 27d_2 = 3 \\ b_0 + 3d_0 - b_1 = 0 \\ 6d_0 - 2c_1 = 0 \\ b_1 + 4c_1 + 12d_1 - b_2 = 0 \\ 2c_1 + 12d_1 - 2c_2 = 0 \\ 2c_2 + 18d_2 = 0 \end{cases}$$

We find the coefficients by performing the necessary calculations (table 2a)

Table 2: Tables of coefficients.

b0	1,428571
d0	-0,42857
b1	0,142857
c1	-1,28571
d1	0,357143
b2	-0,71429
c2	0,857143
d2	-0,09524

a) coefficients

a0	2
b0	1,4285714
c0	0
d0	-0,428571

b) for 1st polynomial

a1	3
b1	0,142857
c1	-1,28571
d1	0,357143

c) for 2nd polynomial

a2	2,5
b2	-0,71429
c2	0,857143
d2	-0,09524

d) for 3rd polynomial

4 coefficients were known in advance. Let's summarize everything (Table 2-b-c-d).

We calculate the values of the function with a step of 0.1 by replacing the coefficients in table 4-b-c-d to the functions in formula (2) defined for each segment.

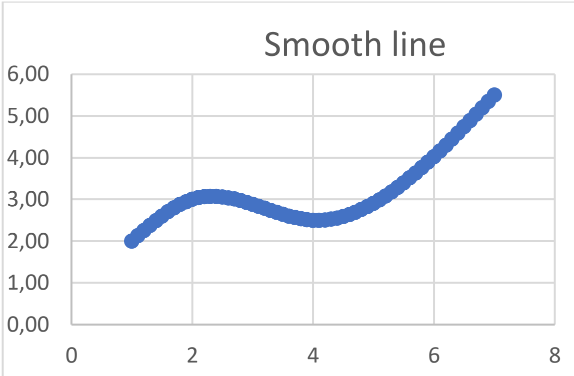


Figure 2: A smooth line generated through the function values with a step of 0.1.

Now we will consider the solutions of various functions passing through the same 4 points.

Table 3: Standard functions passing through the given 4 points.

	Linear	y = 0,2738x + 1,9167
	Exponential	y = 2,0178e0,0919x
	Logarithmic	y = 0,8213ln(x) + 2,0485
	Polynomial	y = 0,0944x3 - 1,0778x2 + 3,5722x - 0,5889

We represent the functions in table 3 in a graphic form

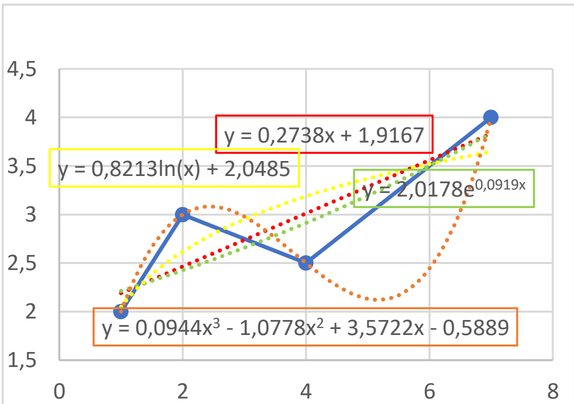


Figure 3: Comparative analysis of curves passing through the first 4 points.

It can be seen from the graphs that the curve performed by our proposed piecewise polynomial method is more efficient than the standard functions.

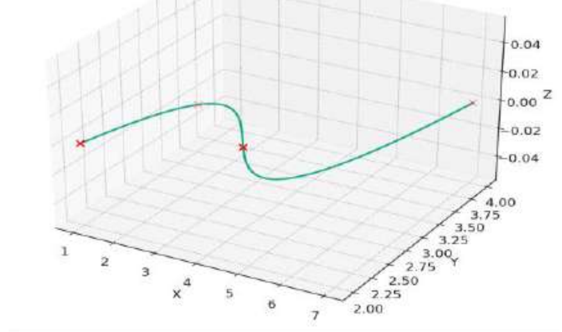
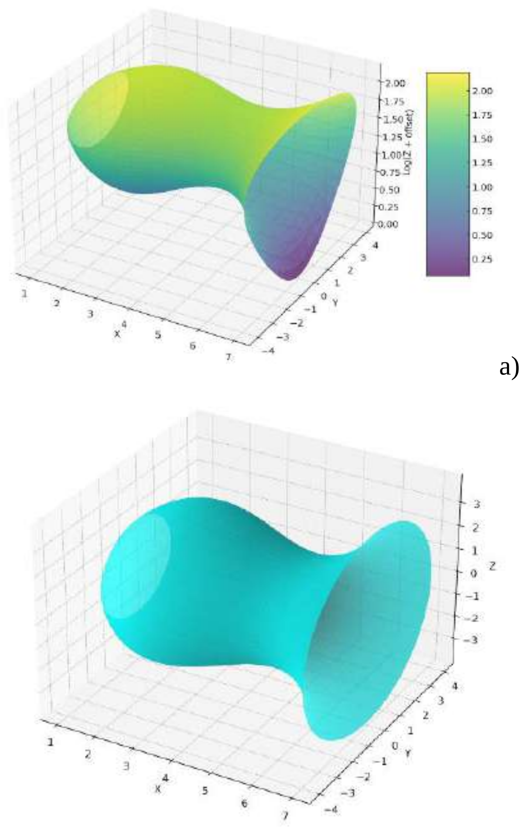


Figure 4: curve representation through given points by the proposed piecewise polynomial method.



a)

b)

Figure 5: Through the given points above: a) Case performed by Logrange spline; b) the model generated by the presented 3rd degree polynomial.

After rotating the given points (1,2,0), (2,3,0), (4,2.5,0), (7,4,0) around the X-axis of the object generated using a polynomial To find an analytical solution for the part where y > 0, we first consider the mathematical expression of this object. In this case, we need the exact cubic spline function and its expression after rotation about the X-axis.

Algorithm for intersecting an object with a plane.

1. Polynomial function

$Y(x)=a_i+b_i(x-x_i)+c_i(x-x_i)^2+d_i(x-x_i)^3$

2. Rotate around the X axis

After rotating around the x-axis, the new y' and z' coordinates are:

y' = ycos(α)-zsin(α)

z' = ysin(α)+zcos(α)

But since z=0, it looks like below:

y' = ycos(α)

y' = ysin(α)

3. Cutting the object

We use the condition y′>0 for cutting. Based on this condition, we need to consider the part of the cubic spline function y(t) where y>0. For values of y=y(t), y′=y(t)cos(a)>0, which is true for all a for which cos(a)>0.

4. Solution

To write the analytical solution directly, we need an exact representation of the function y(t), but use the given points to calculate the coefficients ai, bi, ci, and di of the polynomial. Based on the given points, it is possible to calculate these coefficients and then analytically express the cut section based on the condition y′>0, but since the calculated values are a large amount of data, its program code is presented and the result is illustrated in fig. 6:

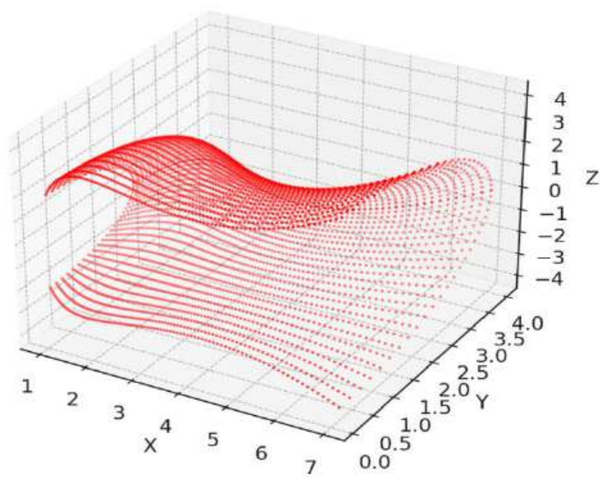


Figure 6: The model created by intersecting the created model with the y = 0 plane.

It can be seen that, on the basis of the segmented model, we achieve the desired result in contrast to the standard equations. Using formula (1), (3), (4), we draw a curve on the surface of the object (Figure 4). Turn the curve 360 degrees around the x-axis and fill the trajectory with points (Fig. 5).

It can be seen from Figures 4 that the geometric model we propose provides a more accurate solution than the Logrange spline in creating museum exhibits.

3 CONCLUSION

In conclusion, the adoption of geometric modeling using the piecewise polynomial method for virtual museum exhibits marks a significant advancement in the digital preservation and presentation of cultural heritage. This innovative approach has not only transformed the accessibility of museum collections, making them available to a global audience, but has also enhanced the educational and research value of these exhibits. By enabling highly accurate, detailed, and interactive representations of artifacts, the piecewise polynomial method offers a powerful tool for engaging with history and culture in a digital context.

The implications of this technology extend far beyond mere digital replication. It serves as a bridge between the past and the future, allowing us to preserve our cultural treasures in a format that can withstand the test of time and be accessible for generations to come. Moreover, it democratizes access to cultural education, removing physical and geographical barriers that might prevent individuals from experiencing the richness of our global heritage.

Furthermore, the piecewise polynomial method's application in geometric modeling opens up new possibilities for research, enabling scholars to examine artifacts with an unprecedented level of detail and precision. This can lead to new discoveries and insights, contributing to our understanding of history and culture.

As technology continues to evolve, so too will the methods and techniques for digital preservation and presentation. The piecewise polynomial method represents a significant step forward, but it is just the beginning. Continued innovation and development in this field promise even more sophisticated and immersive virtual museum experiences in the future.

Ultimately, the geometric modeling of virtual museum exhibits using the piecewise polynomial method exemplifies the synergy between technology and humanities. It highlights the importance of leveraging digital tools to preserve our cultural heritage, ensuring that it remains vibrant, accessible, and engaging for all.

REFERENCES

O‘zbekiston Respublikasi Prezidentining 2020-yil 5-oktabrdagi PF-6079-son Farmoni “Raqamli O‘zbekiston—2030” strategiyasini tasdiqlash va uni samarali amalga oshirish chora-tadbirlari to‘g‘risida. -T:, https://mitc-dev.egov.uz/news/1778

Djumanov, J.X., Xudayberganov, T.R., Sobirov, B.I., Raximov, R.R., 2023. Principles of creation of the virtual museum "dorul hikmat and maorif. Electronic journal of actual problems of modern science, education and training. ISSN 2181-9750, Urgench. № 4. 65-73 pp.

Xudayberganov, T.R., Xojiboyev, J.M., Boltayev, R.Sh., 2018. Autodesk 3Ds MAX dasturida modellashtirish. №14-св3. 36-38 стр.

Golovanov, N.N., 2011. Geometricheskoe modelirovanie. M.: Izdatel'sij centr “Akademiya”.

Rodzhers, D., 1989. Algoritmicheskie osnovy mashinnoj grafiki: Per. s angl. M.: Mir, 512 s., il. ISBN -03-00076-9

Daniel, P., Dries, N., 2013. Report on 3D Publication Formats Suitable for Yeuropeana, 3D Digitisation of Icons of Yeuropean Architectural and Archaeological Heritage. 43 pp.

Yeisert, P., 2006. Reconstruction of Volumetric 3D Models. 3D Videocommunication: Algorithms, Concepts and Real-Time Systems in Human Centred Communication. P.133 – 150.

Franz-Yerich, W., Reuter, M., Peinecke, N., 2009. Geometric Modeling for Yengineering Applications. 53 pp.

Gonizzi Barsanti, S., Guidi, G., 2013. 3D digitization of museum content within the 3dicons project. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol.II-5-W1. P.151-156.

Signore, G., Bandiera, A., 2016. 3D imaging and new ways of making museums interactive and enabling digital discovery and learning . Museologia scientifica. Vol. 10. P.129-136.

Relevance of Applying Artificial Intelligence in the Tourism and Hospitality Industry

Testina Yana[1][a], Kuchumov Artur[2][b], Kaledin Vladimir[1][c] and Maslova Elena[3][d]
[1]*Department of County Studies and International Tourism, Saint-Petersburg State University, University embankment, 7-9, Saint -Petersburg, Russia*
[2]*Department of Economics and Management in the Service Sector, st. Sadovaya., 21, St. PetersburgSaint-Petersburg State University of Economics, Saint -Petersburg, Russia*
[3]*Department of Management and Planning of Socio-economic Processes, Saint-Petersburg State University, University embankment, 7-9, Saint -Petersburg, Russia*
{y.testina, v.kaledin, e.maslova}@spbu.ru, arturspb1@yandex.ru

Keywords: Face recognition technology, Virtual reality technology, Chatbots, Service robots, Google maps, Translation, Optimization services, Digital Technologies.

Abstract: The purpose of the study was to consider the potential and possibilities of using the artificial intelligence technology in the field of tourism and hospitality. The authors analyzed Russian and foreign scientific literature and statistical sources and identified three reasons for using artificial intelligence in the tourism and hospitality industry: improving the quality of service, increasing the income of tourism and hotel enterprises, boosting the profitability of organizations by optimizing costs. Artificial intelligence technologies that can be used in the tourism and hospitality industry enterprises are indicated, with the authors naming the following: face recognition technology, virtual reality technology, chatbots, service robots, Google maps, translation and optimization services. The scientific significance lies in determination of the criteria necessary for artificial intelligence and automated systems to create value for customers, such as: attractive user interfaces, customizability for certain customer segments, functional similarity to other modern platforms. As the problems arising during application of artificial intelligence in the field of tourism and hospitality, the authors single out the following: lack of consistent success in replacing the provision of services in the traditional way with artificial intelligence, data security, high cost for small service providers, customer distrust when communicating with service robots. The authors indicate the need for further research in this area—it is necessary to critically assess the overall importance of the artificial intelligence technology for the tourism and hospitality industry, as well as to identify the possibilities of occurrence of adverse consequences for customers when interacting with the artificial intelligence technologies.

1 INTRODUCTION

Innovative technologies designed to improve efficiency and quality of services provided in the field of hospitality tourism were originally built on the basis of programmed actions with predetermined results. In the last 20 years of the twentieth century, these technologies were based on operational efficiency analysis and revenue management. The pricing of such hospitality services was determined using algorithms controlled by people; as such, new products were often introduced manually and quite rarely. The ability of these technologies to quickly react to actions of competitors or changing market environments was very limited.

Over the past decades, tourism has become one of the largest industries in the world. The increasingly complex relationships between the industry participants, the introduction of new technical standards and the changed needs of travellers call for

[a] https://orcid.org/ 0000-0002-0296-6162
[b] https://orcid.org/ 0000-0002-8819-2291
[c] https://orcid.org/ 0000-0002-4828-4060
[d] https://orcid.org/0000-0002-3133-0817

introduction of new technologies in the operation of tourism and hospitality enterprises.

The COVID-19 pandemic has added further new challenges to the already complex tourism and hospitality industry. The customer interaction experience accumulated pre-COVID-19 is no longer relevant to planning and organizing tourism services, and the newly received information has not yet been sufficiently analysed. Such fundamental changes in the hospitality industry are stimulating IT companies to accelerate developments in the field of artificial intelligence (AI).

The travel industry is now at a point where the transactional data need to be processed in real time in order to immediately adapt to the market conditions. Such solutions, built on AI algorithms, will be able to flexibly set prices for services taking into account the actions of competitors and consumer reactions, predict demand, segment groups of customers, and create truly personalized offers for them.

In the age of digitalization, the artificial intelligence (AI) technology is one of the most innovative inventions, and it has revolutionized various industries around the world. Artificial intelligence first appeared in 1956 in John McCarthy's research project in Dartmouth (Mccarthy and Minsky, 2006). Over the following years, AI gained wide application in various areas of human activity, ranging from facial recognition systems and speech processing to use in mobile robotics.

The rapid development of AI began in the 1990s, when advanced and new types of technologies allowed engineers to use large amounts of data, effectively create robots, and utilize increasing computing power. In the 21st century, artificial intelligence has reached its apogee—it can have a profound impact on people, organizations, and industries.

Today, AI technologies are used in a variety of industries—not just information technology (Nagaraj and Singh, 2018-2019) —for example, in self-driving vehicles, robotic nurses, navigation systems, chatbots, and various other fields. Some of the major industries in which artificial intelligence has emerged are the manufacturing and automotive industries, banking and financial services, healthcare, insurance, telecommunications, energy, tourism and hospitality, as well as media and entertainment (Samala and Katkam, 2020).

Every day, the impact of AI is rapidly expanding in an increasing number of industries around the world. In many industries, AI is used in various functions of organizations, such as sales and marketing, customer service, and finance. Thanks to the constant growth of the tourism and hospitality industry, it is considered one of the largest sectors in the world that can affect economic health of nations. In the field of tourism and hospitality, AI is successfully used to gain a competitive advantage.

In the tourism industry, AI is used for a variety of purposes, ranging from increasing the level of personalization of customer services to guaranteeing a quick response even in the absence of employees—it is even used to communicate with customers to improve the quality of services.

The authors of the book “Competing through service: insights from service-dominant logic” (Lusch and Vargo, 2007) argue that technological advances in artificial intelligence can expand the process of cooperation between sellers and buyers of tourism services helping them become more memorable for customers and, at the same time, increasing the competence of companies in providing services, thereby generating value co-creation (VCC) (Chathoth. 2013; Solakis, 2022).

AI offers advanced data processing capabilities, sufficient storage space and ultra-high speeds; for example, hotel businesses started being able to integrate information about their customers and make more accurate predictions about consumer needs (Duan, 2019). At the same time, automation allows machines to perform pre-defined and reprogrammable tasks in the collaboration process, such as personalizing and customizing proposed services based on the transmitted information about customers.

In response to these technological advances, more and more hospitality companies are giving strategic priority to offering unique services using powerful technologies, including artificial intelligence, (Orea-Giner and Muñoz-Mazón, 2022). Accordingly, recently AI has gotten into the field of academic interest among scientists in the field of hospitality and tourism (Fusté-Forné and Ivanov, 2021; Haynes, 2020; Parvez, 2021).

2 MANUSCRIPT PREPARATION

2.1 Materials and Methods

The purpose of this study is to consider the potential and possibilities of using the artificial intelligence technology in the field of tourism and hospitality.

In order to conduct the study, the authors, using the method of analysis of scientific literature, studied an extensive amount of scientific Russian and foreign sources (eighteen total), as well as national and international statistical sources (five). The literature for the study was selected using the digital service Emerald Insight and the scientific social and collaborative network ResearchGate. The authors carried out an analysis of the scientific literature relevant to the queries “tourism and artificial intelligence” and “hospitality and artificial intelligence”. During further study, it was decided to limit the selection of scientific papers with those published no earlier than 2018. Modern researchers on the one hand try to emphasize the need for companies to introduce new technologies, such as AI, to improve the effectiveness of VCC activities (Katsoni and Sheresheva, 2019; Kumova, 2021), and on the other hand, focus on the complexity of introduction of this technology and its adoption by customers (Bolton and Mccoll-Kennedy, 2018; Ruel, 2019). In particular, S. Shebalov (Shebalov, 2009) affirms the inherent benefits of using AI to anticipate customer expectations and personalize unique offerings for them. In turn, R. Bolton and his co-authors (Bolton and Mccoll-Kennedy, 2018), as well as the authors of the work (Ruel, 2019) argue that the prospects for AI as an effective mechanism for value co-creation are still associated with problems of implementation and acceptance by customers.

The main research objectives are:

- identification of the reasons for application of artificial intelligence in the tourism and hospitality industry,
- selection of artificial intelligence technologies that can be used in the operation processes of enterprises in the tourism and hospitality industry,
- definition of the criteria necessary for artificial intelligence to create value for customers,
- indication of problems in application of artificial intelligence in the field of tourism and hospitality.

2.2 Results

Over the past few years, a number of studies have been conducted on the use of AI in the tourism and hospitality industry. For example, during his keynote presentation, Sergey Shebalov, vice president and head of research at Sabre Corporation (Southlake, Texas, US) shared the company's extensive expertise in the field of artificial intelligence and machine learning and described key areas of their application in the tourism industry. According to the expert, these technologies have the potential to radically change the way tourism companies shape their offerings, make decisions, and serve travellers (Shebalov, 2009).

The Libra Hospitality company (Moscow, Russia) presented studies that revealed some important findings useful to companies working in the field of tourism.

A survey conducted by the National Agency of Financial Research (NAFR) (Moscow, Russia) analytical center showed that 85% of suppliers of tourist and hotel services use artificial intelligence in their business. Studies show that this may be due to the rapid growth in sales of digital travel. Researchers also note that 61% of Russian customers plan their tourist trips using the Internet, and make lists of places to visit on their vacations (78%). Other studies show that 85% of customers decide what to do on a trip after arriving at their destination. Thirty-six percent of customers prefer interactive booking processes, and 80% of them prefer self-service technologies to traditional services (Peranzo, 2019). Ninety percent of customers expect up-to-date information about the trip while they travel to their destination. Together, these results indicate the preference of customers to use the Internet and self-service technologies.

Sabre and Google are now partnering to create AI solutions specifically for the travel industry, which are designed to enrich the technological capabilities of all industry participants, airlines, hotels, and travel agencies.

AI technologies are able to help the tourism industry through three avenues at once:

- improve the quality of service through gaining a deeper understanding of the individual needs of guests;
- increase revenues through flexible pricing and calculation of the best price for each client;
- boost business profitability by optimizing costs at each stage of customer service.

The innovation, which the partners called Sabre Travel AI, will allow travel service providers and agencies to create personalized offers for travelers, promote these products in the right channels and monitor the provision of purchased services.

These findings could prompt marketers to use artificial intelligence in the form of interactive and self-service technologies to improve the customer experience. The results of the surveys not only indicate the tendency of customers to prefer self-service technologies over traditional services, but also show the relevance of the introduction of the AI technology.

Modern hospitality clients are very demanding on the timeliness of the services they receive, and there is a tendency to prefer self-service technologies to traditional services. Self-service technologies become largely possible through the use of artificial intelligence.

Important factors influencing the choice of services in the field of tourism and hospitality are natural resources, general infrastructure, and tourism infrastructure. Artificial intelligence can provide a wide range of information about all of these key factors. AI technology can surpass human capabilities by offering a wide range of information about all key factors in virtually no time. This information can be presented in the shape of interactive messages, chatbots, audio tours, virtual tours, interactive booking process, facial recognition technology, translation services, etc.

Let us consider these possibilities in more detail (See Table 1).

Table 1**:** Application of the artificial intelligence technology in the field of tourism and hospitality.

Name of the AI Technology	Characteristic	Application scope	Advantages
Face recognition	AI technology recognizes the faces of tourists, compares them with the faces in the documents and provides seamless check-in boarding.	Going through a repetitive set of complex and lengthy processes in the form of thorough checks of travel documents by various authorities, such as customs and boarding pass registrations and checks at airports.	The use of AI allows to reduce the time of airport checks, including during transfers, without participating in the verification of documents by various bodies and services, such as the immigration service, passport control, etc.
Virtual Reality (VR) technology	A customer using VR equipment largely perceives the environment in a three-dimensional digital world.	Employees of the marketing services of travel agencies can cooperate with the marketing services of hotels, museums, zoos, etc., in order to provide their client with a virtual journey to a hotel or some tourist destination; for example, the marketing service of Atlantis Dubai Hotels does just that.	Travel managers can showcase travel destinations and hotels using 3D video to bridge the gap between customer expectations and the reality, including helping the customer in making a decision to buy a tour.
Chatbots	A piece of software participating in a discussion through audial or textual methods. There are mainly two types of chatbots, namely, text-based chatbots and voice chatbots. Text-based chatbots provide messaging services for customer requests in the form of text messages. Voice chatbots provide messaging services for customer requests in the form of voice messages. Chatbots have built-in programs, which identify keywords in questions that elicit a certain number of	One of the varieties of chatbots used in tourism is the audio tour technology, which is preferred by travelers who do not want to participate in organized tours with groups. With the help of voice chatbots, they can still acquire high-quality personalized services. Chatbots can facilitate a wide range of services, such as ordering food, hailing taxis, reading messages, scheduling tasks and meetings, setting alarms, calling for room service, cleaning services, informing hotel	Chatbots can be accessed 24/7 all 365 days a year. This key feature makes chatbots a replacement for employees. Chatbots can also store previous guest data with which they can offer recommendations based on their past orders, purchases and actions; thus, they increase the level of hospitality and, consequently, the quality of service.

	answers in response to a particular question.	facilities, etc.	
Robots	These technology-driven assistants use the Internet of Things (IoT) technology to perform simple actions such as turning on the lights in the bedroom, turning off the TV, controlling systems to automatically check in luggage, and receiving guests at the hotel.	Robots began to appear at airports; there they are used as conductors and assistants. For example, the well-known Japanese tourist and hotel company Henn-a Hotel has introduced various types of robots into its workforce, including dinosaur robots. These robots are responsible for manning the reception and receiving guests. Also, robots for registering guests are used by the Marriott network, St. Regis, Westin and Aloft hotels among others, and then there exists the Alexa robot.	Some of the main advantages of robots in the travel industry include improved customer experience, simplified workflow, giving an opportunity for the existing human personnel to focus on other activities, and an increase in the efficiency of the tourism business.
Google Maps including the Visual Positioning System (VPS)	A visual positioning system (VPS) differs from the global positioning system (GPS). The visual positioning system uses artificial intelligence technologies that allow travelers to see the real world and visual landmarks in real time. Google Maps can now use artificial intelligence to display the real world in real time.	A new feature in Google Maps immediately activates the camera and starts scanning around to find visual landmarks like buildings, storefronts, etc.	Travelers can turn on the Google Maps app to determine their exact location and view Google Maps in real time. It will provide detailed information about shops, companies, hotels, shopping malls, cinemas, restaurants, canteens, recreation areas, etc., thereby providing a location-based experience. Using real-time viewing, travelers can head in the right direction without any confusion.
Translation services	There are several software applications capable of translating one language into another. Google Translate provides speech services when a traveler clicks on the "Conversation" option.	This option allows travelers to speak their language, captures their voice message, translates that voice message into the target language (the local language), and dictates the translation into the target language, thereby transmitting the traveler's message to the locals.	This feature is especially useful for illiterate travelers who can't type messages into Google Translate. The best part of this app is its ability to work offline. It can download languages to the app and work offline. Another extremely useful feature is the "Camera Integration" option allowing to read menus in restaurants or shop signs

Optimization services	By using artificial intelligence combined with a maximum likelihood algorithm, service providers can ensure that services are optimized. The maximum likelihood algorithm uses past data and suggests price likelihood values. This algorithm suggests times of price increase and reduction. Therefore, it can report to customers the best timeline in terms of price.	This technology is used in many areas of tourism, such as booking hotels / plane tickets / taxis.	Using this technology, customers can decide whether to book a hotel/flight/taxi or wait until the price drops. Similarly, artificial intelligence helps in cross-selling. Cross-selling is a sales strategy in which additional products are sold to buyers. For example, if a tourist is looking for a taxi service, artificial intelligence can output a pool of offers where there are offers about taxi services, as well as about hotel services, recreation areas nearby, etc. Few online companies such as "Hopper.com" optimize the travel experience, providing information not only about the key service, but also about additional services that complement the key service.

Source: compiled independently on the basis of (Fusté-Forné and Ivanov, 2021; Haynes, 2020; Orea-Giner and Muñoz-Mazón, 2022; Ruel, 2019; Solakis and Katsoni, 2022)

The use of AI technologies can provide tourism and hospitality organizations with a platform to attract customers. In addition, advances in the application of AI technologies offer certain advantages in terms of efficiency, speed, accuracy of forecasts, and consistency in the provision of services to customers. Additional benefits of AI include its ability to offer a wide range of information about key factors, such as natural resources, shared infrastructure, and tourism infrastructure.

In the context of the concept of VCC, artificial intelligence and automation functions are now part of service robots that allow these robots to interact with customers like ordinary employees. One example of such virtual (online) co-creation communities is Starbucks' (Seattle, Vashington, US) "mystarbucksidea.com" and McDonald's (Chicago, Illinois, US) "Make Your Own Burger." In addition, more and more hotel brands are introducing AI-enabled chatbots to facilitate interaction and service to customers in the online environment. These include Chatbotlr and Rose, supported by Marriot Hotel and The Cosmopolitan Hotel of Las Vegas, (US), respectively.

AI used in tourism and hospitality organizations provides efficient storage and retrieval of large amounts of customer data, integrates consumer information, predicts consumer preferences, provides general and personalized information to guests, personalizes guest experiences, receives voice commands, manages facial expressions, and recognizes speech. Customer data can then be used to create a unique and consistent customer experience through automation. For example, information about customer preferences on a previous visit can facilitate meaningful interaction with customers and create a more memorable experience on the next visit.

Further, we will single out the criteria necessary for an automated system equipped with artificial intelligence to create value for customers.

First, the AI medium must have an attractive user interface capable of evoking impressions and emotions. These interfaces can be managed through digital devices such as computers, smartphones, tablets, and other similar devices.

Second, it should be customizable enough to appeal to different user segments.

Third, its use should be similar in functionality to other modern platforms.

These criteria allow AI and automated systems to seamlessly integrate into the service environment, thereby improving the quality of services provided.

Despite the fact that digitalization currently all over the world is almost an imperative, hotel and tourism businesses face a number of problems when introducing AI. The first problem is the need to reduce costs of everything in the postpandemic period, especially those related to introduction of new technologies. Secondly, we can note that the hospitality sphere is deeply rooted in traditions and quite often implies close spiritual contact and individual approach.

We can mention a fact in favor of AI introduction: currently, there is a significant outflow of qualified personnel from the hospitality sphere to other industries. For example, a receptionist earns significantly less than a deliveryman. And deliverymen do not need to spend money on their studies. Therefore, process automation comes to the fore to reduce the number of personnel. A probability of self-service hotels becoming the new reality in the under-four-stars segment is rather high.

Doubtlessly, the introduction of AI into the activities of tourism industry enterprises allows to facilitate higher level of service; meanwhile, the issues of data security may arise. Then, during the collection and analysis of data and large volumes of information about clients, it is necessary to take the topics of information security into account.

2.3 Discussion

The authors of current study agree with the authors of papers (Fusté-Forné and Ivanov, 2021; Kumova, 2021, Orea-Giner and Muñoz-Mazó, 2022; Ruel and Njoku, 2021), which point out that despite the fact that AI boosts tourism and hospitality enterprises' economic efficiency, replacing employees, it also provides customers with a unique experience, unfortunately, not always successful in comparison with that of traditional services. Cases of mutual misunderstanding of customers and service robots with artificial intelligence are not uncommon.

Agreeing with the opinion of N.C. Haynes (Haynes, 2020), we can single out another major concern when using AI, which is data security, especially when using facial recognition technology due to privacy concerns, as well as when storing history of past purchases, travel, etc. in chatbots. The main problem is that a small malware attack can disrupt programs and operations performed by service providers, resulting in significant chaos.

An analysis of the official websites of organizations involved in the supply of artificial intelligence technologies to hospitality and tourism enterprises allows us to agree with the opinion of the authors of works (Haynes, 2020; Katsoni and Sheresheva, 2019; Parvez, 2021) that although artificial intelligence technology is advanced and promising, small service providers cannot afford these technologies as they require huge investments.

In summary, despite the fact that chatbots and service robots can replace human staff, many customers still prefer to rely on humans, especially when it comes to complex queries. A similar opinion was expressed in (Samala and Katkam, 2020; Solakis and Katsoni, 2022) .

3 CONCLUSIONS

Every day the presence of artificial intelligence in all spheres of human life is increasing. However, the use of innovative technologies, such as artificial intelligence, has led to significant changes in employment in tourism and hospitality. As the overall application of AI in the tourism and hospitality industry grows, many jobs may be cut, but at the same time, many new jobs may be created. It is believed that, for example, in the aviation industry accompanying tourism, as well as in the tourism industry itself, there will be a wave of retraining so that the human personnel can adapt to the developing technological infrastructure.

With the introduction of AI, customers of the tourism industry have a higher level of satisfaction. In turn, tourism business enterprises can better control business processes, which will be largely automated, while business operations and some procedures are simplified. Although application of the AI technology will bring many benefits at the industry, organizational, and consumer levels, it can also lead to numerous challenges and complexities. For example, introducing different types of AI into the business context of the tourism industry will not be an easy task. Commercial enterprises will need adequate financial resources to create a safe and reliable technical infrastructure.

The increased use of robots, chatbots, and other artificial intelligence technologies will mean that actual human interaction in the tourism industry will be limited. This can have adverse effects on the consumers of the tourism industry. There may also arise new and complex technical problems that are not yet known. The IT professionals working in the tourism industry should constantly monitor the ease of use of newly introduced technologies, as well as ensure that those are fully useful to all stakeholders.

Such a process can be quite lengthy, since the technology of artificial intelligence is still at its early stage of implementation. More research is needed on the concept of introducing AI, as well as its application in different types of tourism. Additional research will shed light on the difficulties that may arise for commercial enterprises in the tourism industry due to application of the AI technology. Therefore, it is necessary to conduct a holistic assessment of whether the consequences of employing a new and unique technology will be severe. The concept of artificial intelligence can have a direct impact on the human personnel currently operating in the industry; accordingly, it is necessary to conduct comprehensive studies of AI in tourism so that the overall significance of this technology can be critically assessed. This will help to identify both the positive and negative impact of the technology on the industry, businesses, and customers.

REFERENCES

Bolton, R.N., Mccoll-Kennedy, J.R., Cheung, L., Gallan, A., Orsingher, C., Witell, L., Zaki, M., 2018. Customer experience challenges: bringing together digital, physical and social realms. *Journal of Service Management* 29:776–808.

Chathoth, P., Altinay, L., Harrington, R.J., Okumus, F., Chan, E.S.W., 2013. Co-production versus co-creation: a process based continuum in the hotel service context. *International Journal of Hospitality Management* 32:11–20.

Duan, Y., Edwards, J.S., Dwivedi, Y.K., 2019. Artificial intelligence for decision making in the era of Big Data – evolution, challenges and research agenda. *International Journal of Information Management* 48:63–71.

Fusté-Forné, F., Ivanov, S., 2021. Robots in service experiences: negotiating food tourism in pandemic futures. *Journal of Tourism Futures* 7:303–310.

Haynes, N.C., 2020. Robots, artificial intelligence and service automation in travel, tourism and hospitality. *Journal of Tourism Futures* 6:191–192.

Katsoni, V., Sheresheva, M., 2019. *Sharing economy in the hospitality and tourism industry. Moscow University Bulletin. Series 6: Economy* 1:71–89

Kumova, D.M., 2021. The use of platforms based on artificial intelligence in the field of tourism. *Service in Russia and abroad* 15(3(95)):18–26

Lusch, R.F., Vargo, S.L., O'brien, M., 2007. Competing through service: insights from service-dominant logic. *Journal of Retailing* 83:5–18

Nagaraj, S., Singh, S., 2018. Investigating the role of customer brand engagement and relationship quality on brand loyalty: an empirical analysis. *International Journal of E-Business Research* (IJEBR) 14(3):34–53

Nagaraj, S., Singh, S., 2019. Millennial's engagement with fashion brands: a moderated-mediation model of brand engagement with self-concept, involvement and knowledge. *Journal of Fashion Marketing and Management: An International Journal* 23(1):2–16.

Orea-Giner, A., Muñoz-Mazón, A., Villacé-Molinero, T., Fuentes-Moraleda, L., 2022. Cultural tourist and user experience with artificial intelligence: a holistic perspective from the Industry 5.0 approach. *Journal of Tourism Futures (in press)*.

Parvez, M.O., 2021. Use of machine learning technology for tourist and organizational services: high-tech innovation in the hospitality industry. *Journal of Tourism Futures* 7: 240–244

Ruel, H., 2019. Artificial intelligence-facilitated global talent management (AI-GTM) in the international hospitality industry: a research agenda.

Ruel, H., Njoku, E., 2021. AI redefining the hospitality industry. *Journal of Tourism Futures* 7:53–66

Samala, N., Katkam, B.S., Bellamkonda, R.S., Rodriguez, R.V., 2020. Impact of AI and robotics in the tourism sector: a critical insight. *Journal of Tourism Futures* 8(1):73–87

Shebalov, S., 2009. Practical overview of demand-driven dispatch. *Journal of Revenue and Pricing Management*. 8. 166-173. 10.1057/rpm.2008.65.

Solakis K, Katsoni V, Mahmoud AB, Grigoriou N, 2022. Factors affecting value co-creation through artificial intelligence in tourism: a general literature review. *Journal of Tourism Futures*

Mccarthy, J., Minsky, M., Rochester, N., Shannon, C.E., 2006. A Proposal for the Dartmouth Summer Research Project on Arti cial Intelligence. *AI Magazine*. 27.

Analysis of the Efficiency of the Use of Assets of the Electronic Industry in Russia

Filatov Evgeniy Aleksandrovich[a] and Guseva Maria Mikhailovna[b]
Department of Regional Economic and Social Problems, A. E. Favorsky Irkutsk Institute of Chemistry of the Siberian Branch of the Russian Academy of Sciences, Favorsky str. 1, Irkutsk, Russian Federation
johnru3000@rambler.ru, mguseva2021@oresp.irk.ru

Keywords: Factor analysis, Return on assets, Return on sales, Asset turnover, Asset structure coefficients, Electronic industry.

Abstract: **Relevance.** Attracting investments is a necessary condition for the development of any industry. In recent years, the electronic industry has become an industry of paramount importance in the face of increased sanctions. Its connection with the military-industrial complex, sub-branches of mechanical engineering and other fields of activity determines its importance, the need for development and support at the state level. However, in addition to the planned budget funds, private investments are no less important for it. Currently, among the largest producers in the industry, there are relatively new companies created exclusively at the expense of private investors, including foreign ones. Due to the increasing role of this industry and more active state support, the relevance of its analysis increases. The most important indicator of economic efficiency is the return on assets, which shows the return on invested capital. **Goal.** The author's 3-factor models of the profitability of current and non-current assets allow us to determine which factors caused the change in profitability. The object of the study is the electronic industry of Russia. **Methods.** The article describes 10 methods of factor analysis by Filatov E.A., which make it possible to make an accessible and relatively simple conclusion about changes in the financial position of the object of study, as well as to assess the degree of influence of factors on changes in the studied indicator. This article consolidates knowledge in the field of the theory of economic analysis, the acquisition of skills in applying methods of modeling factor systems, assessing the impact of quantitative and qualitative factors on indicators characterizing the results of financial and economic activities and their effectiveness. **Results.** The methods of factor analysis presented in the article developed by Filatov E.A. in comparison with the most common traditional methods can reduce the complexity by several iterations by entering the author's comparative coefficients. In addition, the author's methods of deterministic factor analysis complement the process of cognition of the functioning of economic systems, revealing the existing economic patterns and objectively existing cause-and-effect relationships between the phenomena of economic life. **Conclusions**. This publication analyzes the return on assets in general for manufacturers of computers, electronic and optical products of the Russian Federation. This type of activity is the most profitable compared to other manufacturing industries. In recent years, the indicators of return on assets, for the real industry as a whole, have been unstable. Their variation may be the result of changes in the profit received and/or the total value of assets, which in turn also depend on a variety of external and internal factors.

1 INTRODUCTION

A special position among all industries is occupied by high-tech industries, in particular the production of electronic and optical products. In recent years, the number of studies and publications describing the development of its producers in a variety of aspects has increased: import substitution, expansion of cooperative ties, features of technology and organization of production, the current state and trends in production development (Basmanova and Medushevskaya, 2016; Brykin and Kolegov, 2013; Evstigneev, 2005; Khromykh, 2016; Kolegov,

[a] https://orcid.org/0000-0001-8090-6926
[b] https://orcid.org/0009-0006-1048-2885

Vlasov and Korotkov, 2016; Turtsevich, Guminskiy and Peretz, 2012; Vermel, 2010; Veselova, 2015). According to many researchers, a comprehensive analysis of return on assets is also relevant and in demand. It shows how various macroeconomic processes affect the final financial results of the production of electronic products, in particular the impact of the restructuring of logistics links, which by 2020 was already observed on a national scale. In recent years, such a study has not been conducted at the level of a large manufacturing sector using a significant sample of manufacturers.

This publication analyzes the final reporting indicators of the «production of computers, electronic and optical products» for 2020 and 2021, which can be considered a new stage in its development due to a significant increase in state support. Sustainable production growth is planned for 2026-2030, ensuring its leading positions in promising markets and global technological leadership. From 2020 to 2023, the budget of the Russian Federation for its development includes about 235 billion rubles. This figure looks more modest than the corresponding budgets announced by some technology leaders, but it is a record for Russia for the entire period after the collapse of the USSR (Kovalevskiy, 2021). In addition, a significant difference in this period is the presence of covid restrictions (due to the pandemic of coronavirus infection COVID-19), which were introduced for all enterprises in the country from the second quarter of 2020. In 2021, they were already less stringent and manufacturers began to recover. A comparison of 2020 and 2021 shows the financial condition of manufacturers after the 2020 crisis.

The return on assets indicator depends on the efficiency of production activities and asset management, which are divided into two main groups (according to their role in the production process): non-current and negotiable (Dilworth, 1992; Dilworth, 1993). Due to various external factors, the growth of current assets in the production of computers, electronic and optical products significantly exceeded the growth of non-current assets. Perhaps, along with this, his «return» (the impact on profit growth) grew. A smaller increase in the value of non-current assets (compared with current assets) can be explained by the 2012 decree «On Long-term State Economic Policy», on the basis of which programs were created to identify and dispose of non-core assets. After the restructuring, it became possible to obtain a more accurate value of return on assets, taking into account the value of the property that is directly needed for the production of products.

In this study, a factor analysis of changes in the return on non-current and current assets in the industry under study was carried out. To accomplish this task, the authors have developed two three-factor models.

The results of the analysis may be relevant for government agencies, first of all, to understand how global challenges have affected the state of this group of producers. In addition, the new state concept for the development of the industry (from 2020) assumes a comprehensive solution of tasks in nine key areas, one of which is «economic efficiency». The results of the study can be taken into account when developing measures for its implementation. At the regional level, it is also possible to look for ways to improve the financial condition of producers working in their territory.

This study contains the following sections: literature review, methodology, result and discussion, conclusion.

2 LITERATURE REVIEW

Return on assets analysis is a fairly simple and popular research method. In the scientific literature, various approaches can be found to various variations of this research method, in particular using factor analysis. In this case, the object of research may be the application of models and their methodology (Safonov, 2020; Zykova, 2020), analysis within the enterprise or application to the industry. In relation to an individual enterprise, it is important from the point of view of investors. The industry approach shows how efficiently assets are used, how optimal the industry structure is and, of course, depends on the complexity and duration of the production cycle. In addition, it may reflect the impact of various macroeconomic processes and the effectiveness of public policy. Examples of use in industries: a study of the profitability of high-tech industries, a study of the profitability of assets of enterprises in the wine industry (Cheremisinova, Krichevets and Pliner, 2019; Spitsyn, 2019). According to the authors, there are currently relatively few examples of industry analysis. Earlier, the authors analyzed the profitability of assets of manufacturers of computers, electronic and optical products located in the territory of one region of the country based on this model (Filatov and Guseva, 2023).

The production of computers, electronic and optical products belongs to medium-sized mechanical engineering and unites a wide range of manufacturers of products of various purposes. It is a part of the information technology industry that provides a hardware platform for processing information and implementing further digitalization processes. In the Russian Federation, the above-mentioned productions were merged into a single group in 2017. This is the production of both ready-to-use products and electronic components intended for further assembly. The finished products include computers, products of communication, irradiation and electrotherapeutic equipment, consumer electronics, control and measuring, navigation, optical devices, as well as information carriers and consumer electronics. The above-mentioned products may have different technical solutions and, accordingly, a very high or rather low cost. In general, the production of computers, electronic and optical products is a high-tech activity, up to 2/3 of its products are the most sophisticated high-tech equipment. Studies of production processes have shown that it has a higher level of complexity compared to other industries (Kurchenkov and Cherednichenko, 2007; Trofimov et al., 2014).

The specifics of the production of computers, electronic and optical products in Russia are the assembly of products from imported components. To date, their share in various products remains quite high. In addition to extensive logistics links, obtaining government orders is of great importance for industry manufacturers (Komarov, 2013; Kovalevskiy, 2021; Kulikova, 2017; Nikishina, 2014; Nikolaev, 2015; Nizovkina, 2015; Rakhlis et al., 2016). The industry is dominated by large enterprises, which account for the bulk of revenue and profits. The share of the small sector is up to 10% (in terms of staff). The central Federal District remains the most developed territory – the locomotive of the industry's development, which is distinguished by a developed infrastructure and scientific potential. The main part of production is concentrated in the European part of Russia, more than half of which are in the Central Federal District.

After 2014, this industry sector, like many others, came under the influence of sanctions. As a result, the restructuring of production relations began, as many foreign suppliers of components and software completely or partially suspended their activities in Russia. Among them are large companies that are technology platforms. These are, for example, AMD, Intel, IBM, Oracle, SAP, Cisco Systems, Microsoft and others. Against the background of the annual strengthening of sanctions, the logistics links of manufacturers in this sector were being restructured to alternative suppliers. In 2019, the main suppliers of equipment and components for Russian manufacturers were the countries of Southeast Asia: China ($210.8 million), Taiwan ($73.4 million), Malaysia ($80.9 million). According to experts, the sanctions restrictions imposed by Western countries have not yet affected the production of civilian electronic products, and manufacturers belonging to the military-industrial complex have already shifted to domestic suppliers. It can be noted that all Russian manufacturers, regardless of size and form of ownership, have suffered from sanctions. Of course, large enterprises with financial resources had advantages in increasing the cost of components. In addition, they could still maintain production using stocks (Larin, Sokolov and Khrustalev, 2022). Even the giants of production, which have foreign owners in the authorized capital, were on the verge of bankruptcy.

2020 and 2021 are of particular importance due to the beginning of the implementation in the state of new approaches to the development of industries subject to import substitution. These measures should ensure an increase in the share of electronic products produced in the domestic market by increasing the production volumes of existing Russian enterprises. At the beginning of 2020, according to forecasts of the leading manufacturers of the industry, a forced decrease in production activity could be expected against the background of a decrease in supply and demand from customers (Larin, Sokolov and Khrustalev, 2022).

One of the reasons for the growth of the Russian electronics industry is the increased use of IT solutions in the public sector. For example, the total revenue of the 50 largest suppliers (manufacturers of this industry) to the public sector increased by almost 30% by the end of 2020. By the end of 2021, the implementation of a number of major projects in the industry is celebrated. These are, for example, the launch of mass production of 360 thousand tablets for the population census (such devices have never been produced in Russia before), more than 33 thousand personal computers for health authorities in the regions, the purchase by the Pension Fund of the Russian Federation of more than 10 thousand domestic automated workplaces. However, against the background of production growth, profitability indicators are decreasing.

The year 2021 can be characterized as a period of recovery after the crisis, in which some enterprises had an increase in production under import substitution programs, while others were on the verge of bankruptcy or had already been liquidated. On the eve of 2020, this production sector is experiencing an unstable financial condition, an increase in the value of assets, and an increase in the ratio of non-current and current assets.

3 METHODOLOGY

10 methods of factor deterministic analysis developed by Filatov E.A. are aimed at qualitative improvement of the methodology of this type of analysis to calculate the influence of any number of factors used in the initial model for analysis. Filatov's methods allow us to assess the influence of factors on performance indicators, while factors, unlike other methods, may not be ranked by significance and nature of influence.

This section of the article presents the author's developed functional models of return on assets, which make it possible to find the root causes of changes in this profitability more comprehensively than other models.

3.1 Analysis of Return On Current Assets of the Electronic Industry of the Russian Federation

For factor analysis of the author's 3-factor model of return on current assets, four indicators were used: revenue, net profit, value of current assets, value of non-current assets.

Further, based on the methods of deterministic (functional) factor analysis developed by Filatov E.A. (Filatov, 2021a; Filatov, 2021b), we will assess the degree of influence of three factors on the change in the return on current assets of the electronic industry enterprises of the Russian Federation.

The initial data for an alternative factor analysis of the return on current assets of the electronic industry enterprises of the Russian Federation are presented in Table 1 based on the data of «BIR-Analyst» (AEI (Agency of economic information) «Prime» (2022, June 1) Retrieved from https//bir.1prime.ru). For the analysis, the accounting data of more than 6.5 thousand Russian enterprises that have the main activity «production of computer equipment, electronic and optical products» were used. Their share of revenue is more than 90% of the total number of enterprises in the above-mentioned type of activity.

Table 1: Initial data for factor analysis of the return on current assets of enterprises of the electronic industry of the Russian Federation.

№	Indicators	No. factor's	2020 (0)*	2021 (I)**	Deviation (Δ)***
1	***NR*** – Net Revenue, thousand rubles		1246530705	1274290306	27759601
2	***NP*** – Net Profit, thousand rubles		96471773	67532072	-28939701
3	***CA*** – Current Assets, thousand rubles		1293562734	1328301266	34738532
4	***NA*** – Non-Current Assets, thousand rubles		449621914	482616377	32994463
5	**RC** – Return On Current Assets (2/3) = 6 * 7 * 8		0.074578	0.050841	**-0.023737**
6	**ROS** – Return On Sales (2/1)	H_1	0.077392	0.052996	-0.024396
7	**TONA** – Turnover Of Non-current Assets (1/4)	H_2	2.772398	2.640379	-0.132018
8	**RNCA** – Ratio of Non-current and Current Assets (4/3)	H_3	0.347584	0.363334	0.015749

where: * **0** – past (basic) period (year), taken as reference base; ** **I** – reported (current) period (year); *** **Δ** – change for the period, calculated as the difference between the fact and the plan (**I – 0**).

The initial formula derived by the authors for factor analysis of the return on current assets will have the following form (formula 1):

$$RC = \frac{NP}{NR} * \frac{NR}{NA} * \frac{NA}{CA} = ROS * TONA * RNCA = H_1 * H_2 * H_3 = \prod_{n=1}^{3} H_n \qquad (1)$$

The author's model of return on current assets consists of 3 factors:

F_1 – ROS – Return On Sales – this is a financial indicator used to calculate the share of net profit in the total income received by the enterprise. This indicator is used to assess the operational efficiency of companies (Harper, 1989; Higgins, 1989).

F_2 – TONA – Turnover Of Non-current Assets – This is the ratio of sales revenue (***NR***) to the value of non-current assets (***NA***). This indicator is an important indicator of the efficiency of non-current assets of the enterprise (Baker, Lembke and King, 1989).

F_3 – RNCA – the Ratio of Non-current and Current Assets is calculated as the ratio of the value of non-current assets (***NA***) to the value of current assets (***CA***) and characterizes the overall structure of the assets of the enterprise. The ratio of immobilized and mobile assets shows how many non-current assets of the enterprise account for current assets.

The resulting indicator – **RC** – the Return On Current Assets is calculated as the ratio of net profit

(***NP***) to the value of current assets (***CA***). This indicator characterizes the efficiency of the company's current assets.

Based on the data in Table 1, it can be seen that:

- the return on sales of enterprises of the electronic industry of the Russian Federation in 2020 was 7.74%, then in 2021 it was 5.30%, a decrease of -2.44% over the study period;

- the turnover of non-current assets of the electronic industry enterprises of the Russian Federation in 2020 was 277.24%, then in 2021 it was 264.04%, a decrease of -13.20% over the study period;

- the ratio of non-current and current assets of the electronic industry enterprises of the Russian Federation in 2020 was 34.76%, then in 2021 it was 36.33%, an increase of 1.57% over the study period.

The resulting indicator of the author's model of the return on current assets of the electronic industry enterprises of the Russian Federation in 2020 was 7.46%, then in 2021 it was 5.09%, a decrease of **-2.37%** over the study period.

The cumulative deviation of the resulting indicator ($\Delta \boldsymbol{RC}$) is determined by the formula 2:

$$\Delta RC = \sum_{n=1}^{3} RC\ (H_n) = \Delta RC\ (H_1) + \Delta RC\ (H_2) + \Delta RC\ (H_3) \qquad (2)$$

Further, to calculate the influence of factors on the change in the return on current assets of enterprises of the electronic industry of the Russian Federation, we apply methods of deterministic factor analysis developed by Filatov E. A.

Auxiliary data on the author's comparative coefficients for factor analysis are presented in Tables 2, 3.

Table 2: Multiple comparative coefficients by one factor.

Comparison of factors	Designation of comparative coefficients	Value	The product of coefficients (value)
$H_{1(I)} / H_{1(0)}$	K_1	0.684770	1.00
$H_{1(0)} / H_{1(I)}$	K_2	1.460345	
$H_{2(I)} / H_{2(0)}$	K_3	0.952381	1.00
$H_{2(0)} / H_{2(I)}$	K_4	1.050000	
$H_{3(I)} / H_{3(0)}$	K_5	1.045311	1.00
$H_{3(0)} / H_{3(I)}$	K_6	0.956653	

Table 3: Multiplicative comparative coefficients for two factors.

Comparison of factors	The designation of comparative coefficient	Factor factors	Value
$(H_{1(I)} * H_{2(I)}) / (H_{1(0)} * H_{2(0)})$	M_1	$K_1 * K_3$	0.652162
$(H_{2(0)} * H_{3(0)}) / (H_{2(I)} * H_{3(I)})$	M_2	$K_4 * K_6$	1.004486

10 methods of Filatov E.A. are presented in Table 4, in which the result is equal to the product of the main part of the formula and the corresponding correction coefficients.

Table 4: Methods of alternative factor analysis using comparative coefficients.

No. of methods	No. of formulae	Formulas/calculations: The main part of the formula	Formulas/calculations: Adjustment factors
1.1	1.1	$\Delta RC\ (H_1) = RC_0 *(K_1) - RC_0$	–
	1.2	$\Delta RC\ (H_2) = (RC_0 *(K_3) - RC_0)*$	K_1
	1.3	$\Delta RC\ (H_3) = (RC_0*(K_5) - RC_0)*$	$(K_1 * K_3)$ or M_1
1.2	2.1	$\Delta RC\ (H_1) = (RC_I - RC_I * (K_2))*$	$(K_6 * K_4)$ or M_2
	2.2	$\Delta RC\ (H_2) = (RC_I - RC_I * (K_4))*$	K_6
	2.3	$\Delta RC\ (H_3) = RC_I - RC_I * (K_6)$	–
2.1	3.1	$\Delta RC\ (H_1) = (\Delta H_1 / H_{1(0)}) * RC_0$	–
	3.2	$\Delta RC\ (H_2) = (\Delta H_2 / H_{2(0)}) * RC_0)*$	K_1
	3.3	$\Delta RC\ (H_3) = ((\Delta H_3 / H_{3(0)}) * RC_0)*$	$(K_1 * K_3)$ or M_1
2.2	4.1	$\Delta RC\ (H_1) = ((\Delta H_1/H_{1(I)}) * RC_I)*$	$(K_6 * K_4)$ or M_2
	4.2	$\Delta RC\ (H_2) = ((\Delta H_2/H_{2(I)}) * RC_I)*$	K_6
	4.3	$\Delta RC\ (H_3) = ((\Delta H_3/H_{3(I)}) * RC_I$	–
3.1	5.1	$\Delta RC\ (H_1) = (RC_I*K_4*K_6) - RC_0$	–
	5.2	$\Delta RC\ (H_2) = ((RC_I*K_2*K_6) - RC_0)*$	K_1
	5.3	$\Delta RC\ (H_3) = ((RC_I*K_2*K_4) - RC_0)*$	$(K_1 * K_3)$ or M_1
3.2	6.1	$\Delta RC\ (H_1) = (RC_I - (RC_0*K_3*K_5))*$	$(K_6 * K_4)$ or M_2
	6.2	$\Delta RC\ (H_2) = (RC_I - (RC_0*K_1*K_5))*$	K_6
	6.3	$\Delta RC\ (H_3) = RC_I - (RC_0*K_1*K_3)$	–
4.1	7.1	$\Delta RC\ (H_1) = \Delta RC - (RC_I - (RC_0*K_1)$	–
	7.2	$\Delta RC\ (H_2) = \Delta RC - (RC_I - (RC_0*K_3))*$	K_1
	7.3	$\Delta RC\ (H_3) = \Delta RC - (RC_I - (RC_0*K_5))*$	$(K_1 * K_3)$ or M_1
4.2	8.1	$\Delta RC\ (H_1) = \Delta RC - ((RC_I *K_2) - RC_0)*$	$(K_6 * K_4)$ or M_2
	8.2	$\Delta RC\ (H_2) = \Delta RC - ((RC_I *K_4) - RC_0)*$	K_6
	8.3	$\Delta RC\ (H_3) = \Delta RC - ((RC_I *K_6) - RC_0)$	–
5.1	9.1	$\Delta RC\ (H_1) = \Delta RC - (RC_I - (RC_I*K_4*K_6))$	–
	9.2	$\Delta RC\ (H_2) = \Delta RC - (RC_I - (RC_I*K_2*K_6))$	K_1
	9.3	$\Delta RC\ (H_3) = \Delta RC - (RC_I - (RC_I*K_2*K_4))*$	$(K_1 * K_3)$ or M_1
5.2	10.1	$\Delta RC\ (H_1) = \Delta RC - (RC_0*K_5*K_3) - RC_0)*$	$(K_6 * K_4)$ or M_2
	10.2	$\Delta RC\ (H_2) = \Delta RC - ((RC_0*K_5*K_1) - RC_0)*$	K_6
	10.3	$\Delta RC\ (H_3) = \Delta RC - ((RC_0*K_3*K_1) - RC_0)$	–

3.2 Analysis of return on non-current assets of the electronic industry of the Russian Federation

For factor analysis of the author's 3-factor model of return on non-current assets, four indicators were used: revenue, net profit, value of current assets, value of non-current assets.

Further, based on the methods of deterministic (functional) factor analysis developed by Filatov E.A. (Filatov, 2021a; Filatov, 2021b), we will assess the degree of influence of three factors on the change in the return on non-current assets of the electronic industry enterprises of the Russian Federation.

The initial data for an alternative factor analysis of the return on non-current assets of the electronic industry enterprises of the Russian Federation are presented in Table 5 based on the data of «BIR-Analyst» (AEI (Agency of economic information) «Prime» (2022, June 1) Retrieved from https//bir.1prime.ru).

Table 5: Initial data for factor analysis of the return on non-current assets of enterprises of the electronic industry of the Russian Federation.

No.	Indicators	No. factor's	2020 (0)*	2021 (I)**	Deviation (Δ)***
1	***NR*** – Net Revenue, thousand rubles		1246530705	1274290306	27759601
2	***NP*** – Net Profit, thousand rubles		96471773	67532072	-28939701
3	***CA*** – Current Assets, thousand rubles		1293562734	1328301266	34738532
4	***NA*** – Non-Current Assets, thousand rubles		449621914	482616377	32994463
5	**RN** – Return On Non-current Assets (2/4) = 6 * 7 * 8		0.214562	0.139929	**-0.074633**
6	**ROS** – Return On Sales (2/1)	H_1	0.077392	0.052996	-0.024396
7	**TOCA** – Turnover Of Current Assets (1/3)	H_2	0.963641	0.959338	-0.004303
8	**RCNA** – Ratio of Current and Non-current Assets (3/4)	H_3	2.877001	2.752292	-0.124709

where: * **0** – past (basic) period (year), taken as reference base; ** **I** – reported (current) period (year); *** **Δ** – change for the period, calculated as the difference between the fact and the plan (**I – 0**).

The initial formula derived by the authors for factor analysis of the return on non-current assets will have the following form (formula 3):

$$\mathrm{RN} = \frac{\mathrm{NP}}{\mathrm{NR}} * \frac{\mathrm{NR}}{\mathrm{CA}} * \frac{\mathrm{CA}}{\mathrm{NA}} = \mathrm{ROS} * \mathrm{TOCA} * \mathrm{RCNA} = \mathrm{H}_1 * \mathrm{H}_2 * \mathrm{H}_3 = \prod_{n=1}^{3} \mathrm{H}_n \qquad (3)$$

The author's model of return on non-current assets consists of 3 factors:

H_1 – **ROS** – The Return On Sales is calculated as the ratio of net profit (***NP***) per unit of revenue from sales (revenue) (***NR***). This indicator shows the percentage of the share of profit from all revenue. This indicator characterizes the efficiency of the main (operational) activity of the enterprise (Jennings, 2002).

H_2 – **TOCA** – Turnover Of Current Assets is the ratio of sales revenue (***NR***) to the value of current assets (***CA***). This indicator is an important indicator of the efficiency of the company's current assets.

H_3 – **RCNA** – the Ratio of Current and Non-current Assets is calculated as the ratio of the value of current assets (***CA***) to the value of non-current assets (***NA***) and characterizes the overall structure of the assets of the enterprise. The ratio of mobile and immobilized funds shows how many current assets of the enterprise account for non-current assets.

The resulting indicator – **RN** – the Return On Non-current Assets is calculated as the ratio of net profit (***NP***) to the value of non-current assets (***NA***). This indicator characterizes the efficiency of non-current assets of the enterprise.

Based on the data in Table 5, it can be seen that:

- the return on sales of enterprises of the electronic industry of the Russian Federation in 2020 was 7.74%, then in 2021 it was 5.30%, a decrease of -2.44% over the study period;

- the turnover of current assets of the electronic industry enterprises of the Russian Federation in 2020 was 96.36%, then in 2021 it was 95.93%, a decrease of -0.43% over the study period;

- the ratio of current and non-current assets of the electronic industry enterprises of the Russian Federation in 2020 was 287.70%, then in 2021 it was 275.23%, a decrease of -12.47% over the study period.

The resulting indicator of the author's model of return on non-current assets of the electronic industry enterprises of the Russian Federation in 2020 was 21.46%, then in 2021 it was 14.00%, a decrease of **-7.46%** over the study period.

The cumulative deviation of the resulting indicator (Δ***RN***) is determined by the formula 4:

$$\Delta RN = \sum_{n=1}^{3} RN\,(H_n) = \Delta RN\,(H_1) + \Delta RN\,(H_2) + \Delta RN\,(H_3) \tag{4}$$

Further, to calculate the influence of factors on the change in the return on current assets of enterprises of the electronic industry of the Russian Federation, we apply methods of deterministic factor analysis developed by Filatov E. A.

Auxiliary data on the author's comparative coefficients for factor analysis are presented in Tables 6, 7.

Table 6: Multiple comparative coefficients by one factor.

Comparison of factors	Designation of comparative coefficients	Value	The product of coefficients (value)
$H_{1(I)} / H_{1(0)}$	K_1	0.684770	1.00
$H_{1(0)} / H_{1(I)}$	K_2	1.460345	
$H_{2(I)} / H_{2(0)}$	K_3	0.995534	1.00
$H_{2(0)} / H_{2(I)}$	K_4	1.004486	
$H_{3(I)} / H_{3(0)}$	K_5	0.956653	1.00
$H_{3(0)} / H_{3(I)}$	K_6	1.045311	

Table 7: Multiplicative comparative coefficients for two factors.

Comparison of factors	The designation of comparative coefficient	Factor factors	Value
$(H_{1(I)} * H_{2(I)}) / (H_{1(0)} * H_{2(0)})$	M_1	$K_1 * K_3$	0.681712
$(H_{2(0)} * H_{3(0)}) / (H_{2(I)} * H_{3(I)})$	M_2	$K_4 * K_6$	1.050000

10 methods of Filatov E.A. are presented in Table 8, in which the result is equal to the product of the main part of the formula and the corresponding correction coefficients.

Table 8: Methods of alternative factor analysis using comparative coefficients.

No. of methods	No. of formulae	Formulas/calculations	
		The main part of the formula	Adjustment factors
1.1	1.1	$\Delta RN\,(H_1) = RN_0 *(K_1) - RN_0$	–
	1.2	$\Delta RN\,(H_2) = (RN_0 *(K_3) - RN_0)*$	K_1
	1.3	$\Delta RN\,(H_3) = (RN_0 *(K_5) - RN_0)*$	$(K_1 * K_3)$ or M_1
1.2	2.1	$\Delta RN\,(H_1) = (RN_I - RN_I * (K_2))*$	$(K_6 * K_4)$ or M_2
	2.2	$\Delta RN\,(H_2) = (RN_I - RN_I * (K_4))*$	K_6
	2.3	$\Delta RN\,(H_3) = RN_I - RN_I * (K_6)$	–
2.1	3.1	$\Delta RN\,(H_1) = (\Delta H_1 / H_{1(0)}) * RN_0$	–
	3.2	$\Delta RN\,(H_2) = (\Delta H_2 / H_{2(0)}) * RN_0)*$	K_1
	3.3	$\Delta RN\,(H_3) = ((\Delta H_3 / H_{3(0)}) * RN_0)*$	$(K_1 * K_3)$ or M_1
2.2	4.1	$\Delta RN\,(H_1) = ((\Delta H_1/H_{1(I)}) * RN_I)*$	$(K_6 * K_4)$ or M_2
	4.2	$\Delta RN\,(H_2) = ((\Delta H_2/H_{2(I)}) * RN_I)*$	K_6
	4.3	$\Delta RN\,(H_3) = ((\Delta H_3/H_{3(I)}) * RN_I$	–
3.1	5.1	$\Delta RN\,(H_1) = (RN_I*K_4*K_6) - RN_0$	–
	5.2	$\Delta RN\,(H_2) = ((RN_I*K_2*K_6) - RN_0)*$	K_1
	5.3	$\Delta RN\,(H_3) = ((RN_I*K_2*K_4) - RN_0)*$	$(K_1 * K_3)$ or M_1
3.2	6.1	$\Delta RN\,(H_1) = (RN_I - (RN_0*K_3*K_5))*$	$(K_6 * K_4)$ or M_2
	6.2	$\Delta RN\,(H_2) = (RN_I - (RN_0*K_1*K_5))*$	K_6
	6.3	$\Delta RN\,(H_3) = RN_I - (RN_0*K_1*K_3)$	–
4.1	7.1	$\Delta RN\,(H_1) = \Delta RN - (RN_I - (RN_0*K_1)$	–
	7.2	$\Delta RN\,(H_2) = \Delta RN - (RN_I - (RN_0*K_3))*$	K_1
	7.3	$\Delta RN\,(H_3) = \Delta RN - (RN_I - (RN_0*K_5))*$	$(K_1 * K_3)$ or M_1
4.2	8.1	$\Delta RN\,(H_1) = \Delta RN - ((RN_I *K_2) - RN_0)*$	$(K_6 * K_4)$ or M_2
	8.2	$\Delta RN\,(H_2) = \Delta RN - ((RN_I *K_4) - RN_0)*$	K_6
	8.3	$\Delta RN\,(H_3) = \Delta RN - ((RN_I *K_6) - RN_0)$	–
5.1	9.1	$\Delta RN\,(H_1) = \Delta RN - (RN_I - (RN_I*K_4*K_6))$	–
	9.2	$\Delta RN\,(H_2) = \Delta RN - (RN_I - (RN_I*K_2*K_6))$	K_1
	9.3	$\Delta RN\,(H_3) = \Delta RN - (RN_I - (RN_I*K_2*K_4))*$	$(K_1 * K_3)$ or M_1
5.2	10.1	$\Delta RN\,(H_1) = \Delta RN - (RN_0*K_5*K_3) - RN_0)*$	$(K_6 * K_4)$ or M_2
	10.2	$\Delta RN\,(H_2) = \Delta RN - ((RN_0*K_5*K_1) - RN_0)*$	K_6
	10.3	$\Delta RN\,(H_3) = \Delta RN - ((RN_0*K_3*K_1) - RN_0)$	–

4 RESULTS

4.1 Results for analysis of return on current assets of the electronic industry of the Russian Federation

The results for analysis of return on current assets of the electronic industry of the Russian Federation of 10 methods of Filatov E.A. is presented in Table 9.

Table 9: The results of the author's methods of factor analysis.

No. of methods	**No. of formulae**	**The main part of the formula**	**Adjustment factors**		**Result**
	1	$\Delta RC\,(H_1) = -0.023509$	–		-0.023509
	2	$\Delta RC\,(H_2) = -0.003551$	0.684770	K_1	-0.002432

1.1, 2.1, 3.1, 4.1, 5.1	3	$\Delta RC\ (H_3) = 0.003379$	0.652162	$K_1 * K_3$	0.002204
	Total	**-0.023681**			**-0.023737**
1.2, 2.2, 3.2, 4.2, 5.2	1	$\Delta RC\ (H_1) = -0.023404$	1.004486	$K_6 * K_4$	-0.023509
	2	$\Delta RC\ (H_2) = -0.002542$	0.956653	K_6	-0.002432
	3	$\Delta RC\ (H_3) = 0.002204$	–		0.002204
	Total	**-0.023743**			**-0.023737**

As can be seen from the final result of Tables 1 and 9, the purpose of the analysis has been achieved – the determination of the influence of factors has been disclosed without deviations.

The final change in the return on current assets of the electronic industry enterprises of the Russian Federation was positively influenced by:

- an increase in the ratio of non-current and current assets by 1.57% caused an increase in the studied indicator of **0.22%**.

The final change in the return on current assets of the electronic industry enterprises of the Russian Federation had a negative impact:

- a decrease in the return on sales by -2.44%, caused a decrease in the studied indicator by **-2.35%**;
- a decrease in the turnover of non-current assets by -13.20% caused a decrease in the studied indicator of **-0.24%**.

The combined influence of three factors led to a decrease in the return on current assets of the electronic industry enterprises of the Russian Federation by **-2.37%**.

Over the five years under study (from 2017 to 2021), the return on current assets of the Russian electronics industry was not stable and had various variations:

- the minimum in 2018 is about 4.3%;
- the maximum in 2020 is about 7.5%.

4.2 Results for analysis of return on non-current assets of the electronic industry of the Russian Federation

The results for analysis of return on non-current assets of the electronic industry of the Russian Federation of 10 methods of Filatov E.A. is presented in Table 10.

Table 10: The results of the author's methods of factor analysis.

No. of methods	No. of formulae	The main part of the formula	Adjustment factors		Result
1.1, 2.1, 3.1, 4.1, 5.1	1	$\Delta RN\ (H_1) = -0.067636$	–		-0.067636
	2	$\Delta RN\ (H_2) = -0.000958$	0.684770	K_1	-0.000656
	3	$\Delta RN\ (H_3) = 0.009301$	0.681712	$K_1 * K_3$	-0.006340
	Total	**-0.077895**			**-0.074633**
1.2, 2.2, 3.2, 4.2, 5.2	1	$\Delta RN\ (H_1) = -0.064416$	1.050000	$K_6 * K_4$	-0.067636
	2	$\Delta RN\ (H_2) = -0.000628$	1.045311	K_6	-0.000656
	3	$\Delta RN\ (H_3) = -0.006340$	–		-0.006340
	Total	**-0.071384**			**-0.074633**

As can be seen from the final result of Tables 5 and 10, the purpose of the analysis has been achieved – the determination of the influence of factors has been disclosed without deviations.

The final change in the return on non-current assets of the electronic industry enterprises of the Russian Federation had a negative impact:

- a decrease in the return on sales by -2.44%, caused a decrease in the studied indicator by **-6.76%**;
- a decrease in the turnover of current assets by -0.43%, caused a decrease in the studied indicator by **-0.07%**;
- a decrease in the ratio of current and non-current assets by -12.47% caused a decrease in the studied indicator by **-0.63%**.

The combined influence of three factors led to a decrease in the return on non-current assets of the electronic industry enterprises of the Russian Federation by **-7.46%**.

Over the five years under study (from 2017 to 2021), the return on non-current assets of the Russian electronics industry was not stable and had various variations:

- the minimum in 2018 is about 9.8%;
- the maximum in 2020 is about 21.5%.

5 DISCUSSION

The average absolute indicators of the electronic industry of the Russian Federation for the period under study (2020-2021), with the exception of net profit, increased:

- net profit by -30.00% (-28939.701 million rubles);
- revenue by +2.23% (+27759.601 million rubles);
- total assets by +3.89% (+67732.995 million rubles);
- current assets by +2.69% (+34738.532 million rubles);
- non-current assets by +7.34% (+32994.463 million rubles).

According to Rosstat, inflation in the Russian Federation as a whole for 2021 amounted to 8.39%, that is, the increase in income for the electronic industry was lower than the inflation rate.

The structure of assets of enterprises of the electronic industry of the Russian Federation during the study period changed slightly less than by %:

- the share of current assets decreased by -0.86%;

- the share of non-current assets increased by +0.86%.

Profitability, in contrast to absolute indicators, is a relative indicator, which makes it possible to compare companies and industries of different activities and different sizes. The return on assets in its own way is the economic efficiency of the entire company's property as a whole.

In 2021, compared with 2020, the efficiency of the electronic industry of the Russian Federation decreased by an average of 1.5 times. This is due to a decrease in net profit with a slight increase in resources (Awad, 1988; Cash, McFarlan and McKenney, 1988; Courtney and Paradice, 1988; Meigs and Meigs, 1993; Smith, 1989; Spiller and May, 1990).

6 CONCLUSION

The final results of the two calculation methods are presented in Table 11, calculated on the basis of the author's models of return on assets (formulas 1 and 3).

Table 11: The final results of the author's models of return on assets.

The factor influencing the change in return on assets, %	Deviation of return, %	
	current assets	non-current assets
Decrease in return on sales by -2.44	-2.35	-6.76
Reduction asset turnover: - current assets by -0.43 - non-current by -13.20	-0.24	-0.07
Reduction of the ratio of current and non-current assets by -12.47 (calculation of return on non-current assets)		-0.63
Increase in the ratio of non-current and current assets by +1.57 (calculation of return on current assets)	+0.22	
Total deviation	**-2.37**	**-7.46**

The difference in financial results for the electronics industry between 2020 and 2021 shows a decrease in profit (by -30%) against the background of revenue growth, current and non-current assets (+2,23%, +2,69%, +7,34%), what was reflected in the decrease in the return on assets from 5.53% to 3.73%. At the same time, the return on non–current assets decreases by -7.46%, current assets - by -2.37%. Factor analysis showed that the main impact on the decline in the above indicators was a decrease in return on sales (Table 11). Less significant was the decrease in the turnover of assets (especially non-current ones), an increase in their value and a slight change in the ratio.

In 2020 and 2021, two poles of positive and negative impact on production can be distinguished:

1. state support measures (government orders, investments, introduction of new forms of business organization, tax incentives, bans on imported components and expansion of the sales market);

2. sanctions, inflationary processes (price increases), pandemic (temporary production stoppages, loss of specialists), the growth of the US dollar.

Currently, several large enterprises are directly under sanctions, while other manufacturers are experiencing difficulties from the ban on the purchase of components and equipment for production. Assessing the impact on the state of producers, we can say that the processes in the second group had the greatest impact on the final financial indicators for the period under study. They affected the growth of costs and assets, which led to a decrease in profits. Moreover, both small and medium-sized and large enterprises are affected, which by the end of 2021 have achieved a significant decrease in profits or a negative financial result. For example, the reduction in net profit of the largest manufacturer Samsung Electronics Rus Kaluga LLC from 2020 to 2021 is 791.8 million rubles. In the Central Federal District, there is also a decrease in return on assets from 3.61 to 1.23 due to a significant decrease in net profit (almost three times). The most developed region was also affected by sanctions, inflation and the pandemic.

Net profit. The reduction in return on sales from an average value (the range of average profitability values is from 5% to 20%) in 2020 to a low one (the range of low values is up to 5%) in 2021 can be primarily explained by the losses of the largest manufacturers (who fall into the top 50 in this type of activity). According to the federal districts, the level of profitability has a large variation. At the same time, many of them, especially those far from the center, have negative values.

Current assets. The increase in the value of working capital occurred due to the growth of «stocks» and «accounts receivable». The increase in the cost of materials and components, as well as an increase in inventories against the background of the introduction of new bans on their purchase, the restructuring of logistics, taking into account the reorientation to other suppliers, affected the total cost of «stocks» necessary for production. The main reasons for the growth of accounts receivable are higher interest rates on loans and high inflation, with many companies postponing payments for purchased goods at a later date. In addition to the increase in accounts receivable from 2020 to 2021, for the studied production group, there is an increase in overdue (accounts receivable) by 21% (as of October 2021), while its overall increase compared to the average for 2017 to 2019 is almost twofold (Rosstat of the Russian Federation). An increase in the cost of working capital allows you to work in new conditions, increases the stability of production activities, but does not ensure efficiency, at which there is an increase in profit (for the analyzed period).

Non-current assets. Considering the increase in the value of non-current assets, it can be noted that their value (in addition to revaluation) increased due to an increase (several times) in the cost item «research and development results», which is a positive fact. However, time must pass from research to the start of production (especially mass production), and perhaps more than one year. For example, large manufacturers in the field of production of computing and communication equipment note that there is import substitution in some positions, but there is no mass production yet. Because of this, the situation of enterprises remains quite difficult, even despite solving problems by changing suppliers (Kovalevskiy, 2022). In addition, despite significant investments, there is still no increase in fixed assets in the group of fixed assets «machinery and equipment» due to the creation of new value (commissioning, modernization, repair) (Rosstat of the Russian Federation). Which is extremely important for this type of production.

The preservation of the ratio of revenue and property (in terms of value and structure) indicates that there have been no significant changes in the production under study as a whole during the period under review. The departure of some large and significant manufacturers of the industry, which is expected to happen in 2022 (which has not yet been observed in 2021), should already affect the level of production, the property of producers and, accordingly, the profitability of assets in the short term. State support for manufacturers has ensured an increase in production, but sufficient conditions for improving efficiency in general have not yet been observed across the entire group of manufacturers of «computers, electronic and optical products».

ACKNOWLEDGEMENTS

The article was carried out within the framework of the scientific project of the Siberian Branch of the Russian Academy of Sciences «Socio-economic development of a resource region in the conditions of changing external factors (on the example of the Irkutsk region)» (Research Work of the ISC SB RAS No. 1210218000157-8).

REFERENCES

Awad, E. M., 1988. *Management information systems: concepts, structure and applications*, Menlo Park, California; Reading, Massachusetts: The Benjamin / Cummings Publishing Company.

Basmanova, A. V., Medushevskaya, I. E., 2016. Economic prerequisites for the development of the radioelectronic industry in modern Russia. *Izvestia of higher educational institutions. Volga region. Economic sciences*. no. 1 (4), pp. 95–104.

Baker, R. E., Lembke, V. C., and King, T. E., 1989. *Advanced Financial Accounting*, New York; St. Louis; San Francisco: McGraw-Hill Publishing Company.

Brykin, A. V., Kolegov, K. A., 2013. Cluster policy of the holding company JSC «Russian Electronics» – ensuring the innovative development of the company. *Innovations*. no. 6 (176), pp. 39–42.

Cash, J. I., McFarlan F. W., and McKenney, J. L., 1988. *Corporate information systems management: the issues facing senior executives*, Homewood, Illinois: DOW JONES-IRWIN.

Cheremisinova, D. V., Krichevets, E. A., and Pliner, A. A., 2019. Development of the methodology of factor analysis of the profitability of assets of enterprises of the wine industry of the Southern Federal District. *Financial research*. no. 3 (64), pp. 155–169.

Courtney, J. F., Paradice, D., 1988. *Database systems for management*. St. Louis; Toronto; Santa Clara: Times Mirror/Mosby College Publishing.

Dilworth, J. B., 1992. *Operations management: design, planning and control for manufacturing and services*, New York; St. Louis; San Francisco: McGraw-Hill Book Company.

Dilworth, J. B., 1993. *Production and operations management: manufacturing and services*, New York; St. Louis; San Francisco: McGraw-Hill Book Company.

Evstigneev, V., 2005. State and strategy of joint development of domestic microelectronics and radioelectronics. *Components and technologies*. no. 5 (49), pp. 10–13.

Filatov, E. A., 2021a. Author's factor analysis of the profitability of fixed assets in the construction industry of the Russian Federation. *IOP Conf. Series: Earth and Environmental Science*. no. 751, 012144.

Filatov, E. A., 2021b. Author's factor analysis of financial dependence of the Russian construction industry. *IOP Conf. Series: Earth and Environmental Science*, 751, 012145.

Filatov, E. A., Guseva, M. M., 2023. Analysis return on assets of electronic industry enterprises of Irkutsk region. *Advances in transdisciplinary engineering series procedia*, vol. 38, pp. 852–859.

Harper, W. M., 1989. *Management accounting*, London: Longman Group UK Ltd; [S. l.]: Macdonald & Evans Ltd.

Higgins, R. C., 1989. *Analysis for financial management*, Homewood, Il: IRWIN.

Jennings, J. 2002. *Less is more: how great companies use productivity as a competitive tool in business*, Harmondsworth: Portfolio.

Khromykh, N. N., 2016. Analysis of the world market of electronic components. *Econominfo*, no. 26, 114–120.

Kolegov, K. A., Vlasov, O. V., and Korotkov, A. S., 2016. Import substitution of electronic component base and localization of production and technological centers, *Innovations*. no 7 (213), 71–74, 2016.

Komarov, A. S., 2013. Formation of clusters for the creation of domestic microelectronics. *Innovations,* no 12 (182), 90–97.

Kovalevskiy, Yu. S., 2021. Main theses of an interview with the Director of the Department of Radioelectronic Industry V. V. Shpak. *Electronics: science, technology, business,* no. 1 (00202), 22–23.

Kovalevskiy, Yu. S., 2022. Problems and opportunities for the development of domestic computing and communication equipment in new conditions (interview with the director of Dannie, a domestic contract developer and manufacturer of electronic equipment). *Electronics: science, technology, business,* no. 4 (00215), 36–37.

Kulikova, N. N., 2017. The current state and trends in the development of the electronic industry in Russia. *Theory and practice of social development*, no. 12, 87–92.

Kurchenkov, V. V., Cherednichenko, L. K., 2007. Industry specifics of restructuring processes in the electronic industry. *Bulletin of Volgograd State University, Series 3,* vol. 11, 118–121.

Larin, S. N., Sokolov N. A., and Khrustalev, O. E., 2022. The development of the Russian electronic industry: the search for competitive advantages in the context of sanctions. *Economics and business: theory and practice*, 7 (89), pp. 104–110.

Meigs, R. F., Meigs, W. B., 1993. *Accounting: the basis for business decisions*, New York; St. Louis; San Francisco: McGraw-Hill.

Nikishina, O. S., 2014. The current state and trends in the development of the electronic industry in Russia. *European student scientific journal*, no. 2.

Nikolaev, I. A., 2015. Problems and opportunities of innovative development in the radioelectronic industry of Russia (assessment of the current state of the radioelectronic industry). *Innovations,* no 5 (199), 53–60.

Nizovkina, N. G., 2015. Evaluation of the effectiveness of competitive actions in microelectronics. State and municipal management. *Scientific notes of NCAPS,* no. 1, 89–95.

Rakhlis, T. P., Skvortsova, N. V., Koptyakova, S. V., and Balynskaya, N. R., 2016. Development of microelectronics in the conditions of innovative and technological growth of the Russian economy. *International business management.* vol. 10, no. 4, 401–407.

Safonov, A. B., 2020. Profitability as a criterion for the effectiveness of a commercial organization. *Vector of economics.* 3 (45), p. 60.

Smith, J. L., 1989. *Accounting principles*, New York; St. Louis; San Francisco: McGraw-Hill Book Company.

Spiller, E. A., May, P. T., 1990. *Financial accounting: basic concepts*, Homewood, Il; Boston, Ma: IRWIN.

Spitsyn, V. V., 2019. Profitability of enterprises of high-tech industries and factors influencing it: analysis and modeling, *Scientific and technical bulletin of SPbSPU. Economic sciences,* vol. 12, no. 6, pp. 149–160.

Trofimov, O. V., Efimychev, Yu. I., Efimychev, A. Yu., and Shipilov, A. G., 2014. Problems of increasing the efficiency of the radio-electronic industry of Russia in modern conditions. *Russian entrepreneurship,* no 3 (249), 89–100.

Turtsevich, A., Guminskiy, V., and Peretz, A., 2012. Buildup, borrowing, continuity – postulates of innovative development of JSC Integral. *Science and innovation*. no. 3, 9–12.

Vermel, M. V., 2010. International experience of cooperation in microelectronics: modern trends and prospects, *Innovations*, no 11 (145), 52–61.

Veselova, E. S., 2015. Russian microelectronics: renaissance or reanimation? *Eco,* no 4 (490), 36–49.

Zykova, N. V., 2020. Methodological approaches to assessing the profitability of assets. *Society: politics, economics, law,* 12 (89), pp. 78–81.

Innovative Methods and Technologies to Increase the Efficiency of Solar Collectors

Zaitov Ruslan Ildarovich[1] [1], Yusupova Angela Sulunbekovna[2] [2]
and Tabachnikova Tatiana Vladimirovna[3] [3]
[1]*Kazan State Power Engineering University, Department: "Energy Supply for Enterprises, Building Construction and Structures", Postgraduate student, Kazan, Russia*
[2]*Senior Lecturer at the Department of Programming and Infocommunication Technologies, Chechen State University named after A.A. Kadyrov, Grozny, Russia*
[3]*Ph.D., Associate Professor, Analyst at the Center for Technological Development of Tatneft PJSC, Almetyevsk, Republic of Tatarstan, Russia*
zaitov_ruslan@rambler.ru, *yusupova-as@mail.ru* , tvtab@mail.ru

Keywords: innovations, solar collectors, energy, efficiency, technologies, thin films, perovskite solar panels, solar energy concentration.

Abstract: This article discusses innovative methods and technologies aimed at enhancing the efficiency of solar collectors. Various approaches are considered, including thin-film technologies, perovskite solar collectors, solar energy concentration technology, the use of nanomaterials, and the integration of solar collectors into architectural solutions. Special attention is paid to the significance of integrating solar collectors into architectural designs to enhance their efficiency. The article underscores the importance of innovations in solar energy for creating a sustainable and environmentally friendly energy future.

1 INTRODUCTION

In an era where global communities increasingly recognize the urgency of transitioning to sustainable energy sources, solar energy emerges as a cornerstone in building the future. It not only offers an inexhaustible source of energy but also has the potential to significantly reduce dependence on fossil fuels and mitigate negative environmental impacts. In the context of solar energy, solar collectors are a key element, converting solar radiation into energy. However, despite significant advancements in this field, the ongoing pursuit of enhancing their efficiency and productivity remains pertinent. This is why innovations in the methods and technologies used in solar collectors become an important component of energy progress. In this article, we will discuss several cutting-edge approaches and technologies that are not only aimed at increasing the efficiency of solar collectors but also contribute to their wider application in various fields. From thin-film technologies to the use of nanomaterials, from perovskite solar panels to integration into architectural solutions, these innovations help expand the boundaries of solar energy possibilities and bring us closer to a more sustainable energy future. So, solar energy is not only an important source of renewable energy but also a key component in the fight for our planet's sustainable future. Solar collectors play a central role in converting solar radiation into electricity or thermal energy. However, like in any technology, there is a constant need for innovation and improvement to enhance their efficiency and make solar energy even more accessible and competitive. In this article, we will explore several innovative methods and technologies aimed at increasing the efficiency of solar collectors. One of the most promising directions in the field of solar collectors is the use of thin-film technologies based on chemical compounds with high electrochemical efficiency. These compounds,

[1] https://orcid.org/0009-0002-8363-8407
[2] https://orcid.org/0009-0005-8430-7601
[3] https://orcid.org/0009-0005-8430-7601

presented in the form of thin films on the surface of solar panels, have the ability to absorb solar radiation and convert it into electrical energy.

2 EXAMPLES OF CHEMICAL COMPOSITIONS

1. *Amorphous Silicon (a-Si):* Si Amorphous silicon possesses several advantages that make it attractive for use in solar panels. Firstly, its structure allows for thin film deposition on various surfaces, providing flexibility and ease in the production of solar collectors. Additionally, amorphous silicon exhibits stability and durability, making it an ideal material for use in various climatic conditions. Thin-film technologies based on amorphous silicon have the potential to significantly reduce the cost of solar collector production and expand their applications in various sectors, including residential and industrial installations.

2. *Cadmium Telluride (CdTe):* CdTe Cadmium telluride (CdTe) is one of the most promising materials in the field of solar energy due to its high efficiency in converting solar radiation into electrical energy and low production costs. CdTe solar panels demonstrate high stability and durability, making them an attractive choice for industrial use. Thanks to its superior optical and electronic properties, CdTe is one of the leading materials in solar collector production, ensuring high efficiency and reliability of solar systems.

3. *Organic Polymers (OPV):* C6H9S Organic polymers represent a unique class of materials that possess conductivity and light-absorption properties necessary for converting solar energy into electrical energy. One of the most well-known organic polymers used in solar collectors is poly(3-hexylthiophene) (P3HT). P3HT exhibits good electrical conductivity and the ability to absorb light in the visible and near-infrared ranges, allowing it to efficiently convert solar radiation into electrical energy. Additionally, its flexibility and lightweight nature make it an ideal material for creating flexible and convenient solar panels that can easily integrate into various surfaces and structures.

These chemical compounds possess unique properties that enable the creation of thin, flexible, and lightweight solar panels. In particular, amorphous silicon provides high transparency and resistance to external factors, making it an ideal material for use in thin film technologies. Cadmium telluride also exhibits high efficiency in converting solar energy into electrical energy, allowing for the creation of compact and cost-effective solar panels. Organic polymers, such as poly(3-hexylthiophene), offer the possibility of producing flexible and lightweight solar panels with low production costs.

Thin film technologies based on these chemical compounds represent a promising direction in the development of solar energy, opening up new possibilities for creating efficient and economically viable solar collectors.

Perovskite solar collectors represent an innovative direction in the field of solar energy, based on the use of perovskite structures. They are perovskite hybrid materials with the formula ABX3, where A is a cation, B is an anion, and X is a halogen anion (usually iodide or bromide ion).

The chemical composition of perovskite solar collectors can vary, but one of the most common is the organic material methylammonium lead iodide (CH3NH3PbI3). This material possesses excellent optical and electronic properties, making it ideal for converting solar radiation into electrical energy.

The principle of operation of perovskite solar collectors is based on the process of photoelectric conversion of solar energy into electrical energy. To better understand this principle, let's consider the main steps of this process using mathematical and chemical formulas:

1. **Light Absorption:** When sunlight falls onto the surface of the perovskite material, light energy is absorbed. This process can be described using the light absorption equation: $S = \alpha \cdot I \cdot d$ Where:

- S is light absorption (energy absorption);
- α is the absorption coefficient (determined by the properties of the perovskite material);
- I is the intensity of incident light;
- d is the thickness of the perovskite layer.

2. **Generation of Electron-Hole Pairs:** After light absorption in the perovskite material, electron-hole pairs are formed. Electrons transition to higher energy levels (conduction band), and holes transition to lower levels (valence band). This process can be described using the equation for the generation of charge carriers: $G = \eta \cdot \phi \cdot S$ Where:

- G is the density of generated charge carriers;
- η is the quantum yield (efficiency of converting light into charge carriers);
- ϕ is the light flux (incident light power);

- S is the surface area absorbing light.

3. Charge Separation and Transport: After the generation of charge carriers, electrons and holes must be separated and directed into the electrical circuit to create an electric current. In perovskite solar cells, this is typically achieved using electronic conductors such as transport layers.

4. **Current Generation:** As electrons and holes move along the electrical circuit, an electric current is generated. This current can be described using Ohm's law: I = RV Where:

- I is the electric current;
- V is the voltage;
- R is the resistance of the electrical circuit.

Thus, perovskite solar collectors convert solar energy into electrical energy through sequential processes of light absorption, generation of electron-hole pairs, charge separation and transport, and then generation of electric current. Concentrated solar power technology is an innovative approach aimed at increasing the intensity of solar radiation reaching the solar collector. Optical systems such as mirrors or lenses are used to focus solar light onto a small surface, increasing the temperature and enhancing the efficiency of solar energy conversion (Popov, 2021).

One of the most common examples of concentrated solar power technology is the parabolic collector, which collects sunlight and focuses it onto a point where a heat transfer fluid is located. The heat transfer fluid typically consists of thermal oil, which is heated to high temperatures and used to drive turbines that generate electricity.

The chemical process that occurs within such systems can be represented as follows:

1. Light focusing: Solar light, represented by the formula hν, where *h* is Planck's constant and ν is the frequency of light, is focused by an optical system onto the surface of the solar collector.
2. Light absorption: Solar energy is absorbed on the collector surface, causing the heat transfer fluid to heat up to high temperatures. This process can be represented by a chemical reaction equation, for example:

Heat transfer fluid (oil) + Solar light → Thermal energy

3. Heat transfer: The heated heat transfer fluid transfers thermal energy through a heat exchanger, which can be used to drive turbines, generate electricity, or for other purposes.

Concentrated solar power technology is a powerful tool for increasing the efficiency of solar collectors and expanding the scope of solar energy applications in various industries, from electricity generation to heat supply and industrial production.

In modern solar energy research, nanomaterials occupy a central place due to their unique properties and potential for enhancing the efficiency of solar collectors. The use of nanotechnologies opens up new prospects for the development of more efficient and economically viable solar systems.

For example, the use of carbon nanotubes (CNTs) in solar collectors allows for increased absorption of solar radiation due to their high surface area and excellent electrical and optical properties. The chemical formula of carbon nanotubes is represented as C_n, where n is the number of carbon atoms.

Additionally, quantum dots (QDs) represent another class of nanomaterials that are attracting attention in the field of solar energy. Quantum dots possess quantum size effect properties, allowing them to absorb solar radiation over a wide range of wavelengths. The chemical formula of quantum dots can be represented as CdSe, PbS, etc., where Cd, Se, Pb, and S denote cadmium, selenium, lead, and sulfur, respectively (Gavrilov, Kuznetsov, 2018).

The use of such nanomaterials in solar collectors allows for a significant increase in the conversion efficiency of light into electricity, making solar systems more compact and efficient. Thus, chemical formulas of nanomaterials such as carbon nanotubes (C_n) and quantum dots (CdSe, PbS) become an integral part of the development of new and improved solar collectors, providing prospects for more efficient use of solar energy.

Solar collectors integrated into architectural solutions represent an important step in the development of solar energy. These innovative approaches not only allow for the efficient use of available space but also integrate solar systems into the surrounding environment, making them part of the building structure.

1. Solar roofs: Advancements in technology enable the creation of building roofs covered with integrated solar panels. These panels can be made from transparent materials or have various color shades, providing flexibility in design and allowing solar collectors to blend with the architecture of the building. Such innovative roofs not only generate electricity but also serve as protection against atmospheric precipitation, reducing roof wear and extending its service life. Additionally, integrating solar panels into the roof efficiently utilizes available space and reduces the need for separate structures, making this solution more economically viable.
2. Facade solar panels: Solar collectors can be integrated directly into the building facade, creating

not only an efficient energy source but also a unique appearance. Such solutions not only save space but also contribute to the aesthetic renewal of urban development. One of the key advantages of facade solar panels is their ability to integrate into various architectural styles and concepts. Thanks to diverse materials and color options, these panels can be adapted to different buildings – from residential complexes to commercial and public buildings. This allows architects and designers not only to reduce building energy consumption but also to create attractive and modern exteriors.

Another important aspect of facade solar panels is their ability to improve the energy self-sufficiency of buildings. By integrating solar collectors directly into building facades, dependence on traditional energy sources can be significantly reduced, which is particularly relevant given rising energy prices and the desire to reduce greenhouse gas emissions.

3. Integrated solar windows: Special solar windows with integrated solar panels can serve as both an energy source and illumination for indoor spaces. These windows can be installed in both residential and commercial buildings, increasing energy efficiency and improving comfort indoors. The benefits of integrated solar windows extend far beyond simply providing energy for household needs. They also contribute to improving indoor lighting, creating a comfortable and attractive living or working space.

4. Solar balconies and terraces: Integrating solar collectors into balconies and terraces allows vertical space to be used for solar energy generation. Installing solar panels on balcony railings or terrace structures enables the use of undeveloped surfaces for solar energy collection. This is particularly useful in urban environments where access to open land may be limited. Additionally, solar balconies and terraces can serve as places for relaxation, providing residents and visitors with the opportunity to enjoy beautiful views while implementing sustainable energy solutions. Such integrated systems can contribute to increasing the energy independence of buildings and reducing the burden on grids during peak energy consumption periods.

These innovative architectural solutions demonstrate the potential for integrating solar energy generation into various aspects of urban and building design, paving the way for a more sustainable and energy-efficient future.

Integration of solar collectors into architectural solutions not only enhances the energy efficiency of buildings but also contributes to the creation of sustainable and innovative urban and rural spaces. These solutions underscore the importance of collaboration between energy specialists and architects in creating future energy-efficient and environmentally sustainable structures.

3 CONCLUSION

In the modern world, where issues of sustainable development and environmental protection are becoming increasingly relevant, solar energy is becoming an integral part of our future. Solar collectors play a key role in this transition, converting solar radiation into energy that can be used to power our homes, businesses, and cities. However, for solar energy to become even more accessible and efficient, constant innovation and improvement in solar collector technologies are necessary. From thin-film technologies to the use of nanomaterials, from perovskite solar panels to integration into architectural solutions, innovative methods and technologies are opening new horizons for the development of solar energy.

The integration of solar collectors into architectural solutions not only enhances the energy efficiency of buildings but also contributes to the creation of sustainable and innovative spaces. This allows us not only to use solar energy more efficiently but also to make it an integral part of our everyday experience.

In conclusion, innovative methods and technologies for increasing the efficiency of solar collectors not only improve the performance of solar systems but also make solar energy more accessible and economically viable for everyone. By continuously implementing new ideas and developments, we can continue to move forward towards a more sustainable and environmentally friendly energy future for all.

REFERENCES

Voropai, N.I., 2020. Innovative methods for increasing the efficiency of solar collectors. *Journal "Energy and Energy Saving"*, vol. 5, no. 2, pp. 45-52.

Gavrilov, A.S., Kuznetsov, I.V., 2018. Prospects for the application of perovskite solar collectors in Russia. Collection of scientific papers "Prospects of Renewable Energy Sources", issue 3, pp. 112-120.

Demidov, A.P., Sharov, V.A., 2019. Thin film technologies for solar collectors. Moscow: Publisher "Technika", 240 p.

Kalinin, D.S., Petrov, V.N., 2017. Integration of solar collectors into architectural solutions: experience of

implementation in Russia. *Journal "Architecture and Ecology"*, vol. 8, no. 4, pp. 78-85.
Mikhailova, E.G., 2019. Nanomaterials for solar collectors: prospects and challenges. Moscow: Publisher "Nauka", 180 p.
Popov, S.A., 2021. Application of solar energy concentration technology in Russia: challenges and prospects. *Journal "Energy Technologies and Innovations"*, vol. 12, no. 1, pp. 32-40.
Smirnov, A.I., 2018. Development of solar energy in Russia: analysis of the current state and prospects. Moscow: Publishing House "Energy Efficiency", 150 p.
Titov, V.P., Ivanova, L.M., 2016. Concentrated solar energy technologies: experience of application in Russia. *Journal "Solar Systems"*, vol. 7, no. 3, pp. 56-64.
Ulyanov, K.N., Grigoryeva, T.V., 2017. Use of solar energy in architecture: implementation experience and prospects in Russia. Moscow: Publisher "Architectural World", 200 p.
Kharitonov, V.D., Novikova, O.Yu., 2020. Economic aspects of the application of solar collectors in Russia. *Journal "Economics and Energy"*, vol. 15, no. 2, pp. 88-95.

Enhancing Digital Education through Real Time Communication with SignalR

Maxim R. Volkov[1][a], Marat G. Nuriev[1][b], Oksana V. Panchenko[2][c] and Marina G. Lapteva[2][d]
[1]*Institute of Computer Technologies and Information Security, Kazan National Research Technical University named after A. N. Tupolev – KAI, Kazan, Russia*
[2]*Institute of Management, Automation and Information Technologies, Kazan National Research Technological University, Kazan, Russia*
volkovmaxim02@mail.ru, marat_nu1@mail.ru, ov_panchenko@mail.ru, marinnay1@mail.ru

Keywords: SignalR, Real-Time Communication, Digital Education, Collaborative Learning, ASP.NET, Web Application, Interactive Learning, Accessibility.

Abstract: This article delves into the innovative integration of SignalR, a real-time web application library, within digital educational platforms, highlighting its transformative potential in enhancing interactive and collaborative learning experiences. With the digital landscape of education rapidly evolving, the need for real-time communication tools has become paramount. SignalR emerges as a powerful solution, enabling instant, bi-directional messaging that significantly improves the dynamics of online learning and teaching.The article begins with an introduction to the necessity of robust informational environments in large corporations, setting the stage for the exploration of real-time web applications as a critical component of modern digital education systems. It further elaborates on the technical mechanisms of SignalR, including WebSockets, Server-Sent Events, and Long Polling, showcasing how these technologies facilitate seamless and efficient communication between clients and servers. A comprehensive guide on implementing a SignalR-based chat application in an ASP.NET framework is provided, offering insights into the development process, from setting up MVC applications and configuring SignalR hubs to client-side JavaScript for engaging user interfaces. This practical implementation underscores the accessibility and feasibility of incorporating real-time communication functionalities into educational platforms. The core of the article emphasizes the application of SignalR-based chats in digital educational settings. It explores various use cases, including enhanced student-teacher interaction, collaborative learning opportunities, administrative communication, and fostering accessibility and inclusion. These applications illustrate the significant impact of real-time communication on creating more interactive, engaging, and supportive learning environments. In conclusion, the integration of SignalR into digital education platforms represents a leap towards a future where education is characterized by immediacy, connectivity, and inclusivity. This article provides a foundational understanding of SignalR's capabilities and offers a blueprint for educators and developers to innovate their digital educational offerings, ultimately enriching the learning experience in the digital age.

1 INTRODUCTION

In the digital age, the essence of effective communication within large corporations cannot be overstated. As businesses expand and diversify, the complexity of managing work processes and addressing problems promptly intensifies. Traditional communication channels often fall short in meeting these dynamic needs, paving the way for corporate chat solutions to become a linchpin in modern corporate strategy. These platforms offer a plethora of benefits, transforming the way companies operate internally and how they engage with the broader digital educational environment.

[a] https://orcid.org/0009-0005-0284-6821
[b] https://orcid.org/0009-0003-0741-1734
[c] https://orcid.org/0009-0006-9440-6563
[d] https://orcid.org/0009-0007-1727-0460

Corporate chat services and web-based communication tools have emerged as vital assets for facilitating rapid and straightforward interaction among employees. Their adoption underscores a strategic shift towards leveraging technology to achieve operational efficiency and information accessibility. The immediacy provided by these platforms enables real-time discussions, decision-making, and the swift dissemination of important updates, thereby enhancing organizational responsiveness.

Moreover, these digital tools play a crucial role in streamlining the coordination of work across different teams, simplifying the distribution of tasks, and ultimately fostering a collaborative work culture. The intrinsic value of these platforms lies in their ability to bridge communication gaps, mitigate misunderstandings, and promote a unified approach to achieving corporate goals.

Against this backdrop, our article focuses on the exploration of SignalR, a state-of-the-art library designed for ASP.NET developers to add real-time web functionality to applications. SignalR is instrumental in developing applications that require live interaction between the server and the client, such as live chat systems, real-time data updates, and interactive gaming experiences. The choice of SignalR for creating a corporate web chat is predicated on its robust features that support high-frequency messaging and real-time content updates, making it an ideal tool for fostering interactive and engaging communication platforms.

This comprehensive analysis aims to unravel the potential of SignalR in revolutionizing corporate communication, particularly in the context of digital educational platforms. We will delve into how SignalR-based web chats can significantly enhance the learning experience by facilitating instant feedback, promoting interactive discussions, and creating a more connected and engaging educational environment. By offering a detailed examination of SignalR's technical capabilities, implementation strategies, and practical benefits, this article aspires to serve as an invaluable resource for organizations looking to enrich their communication systems and educational practitioners aiming to integrate more collaborative and interactive tools into their digital learning ecosystems.

2 REAL-TIME WEB APPLICATIONS

In the digital era, the transition towards applications that operate in real-time is not just a trend but a fundamental shift in how interactive experiences are crafted on the web. This section aims to dissect the essence of real-time web applications, shedding light on their operational mechanisms, the technological advancements they embody, and their transformative impact on user engagement and data interaction.

At the heart of real-time web applications lies a paradigm shift from the conventional request-response model, which has governed the internet since its inception. Traditional web applications rely on a passive data retrieval mechanism where the server waits for requests from the client before sending updates. This model, while foundational, introduces a delay in communication, as users must manually initiate a request for data—be it through refreshing a web page, clicking a button, or submitting a form.

Real-time web applications, however, revolutionize this interaction by establishing persistent, bi-directional connections between the client and server. Through technologies such as WebSockets, Server-Sent Events (SSE), and long polling, these applications maintain an open communication channel, enabling the server to push updates to the client instantaneously, without the need for explicit requests. This evolution not only facilitates immediate data transfer but also supports a continuous and interactive user experience, mirroring the fluidity of real-world conversations and interactions.

The technical underpinning of real-time web applications involves maintaining a live connection through which the server can transmit updates as soon as they occur. Unlike the disjointed nature of traditional web interactions, this approach ensures that the client is always in sync with the server, reflecting changes in real-time. For instance, in a real-time chat application, messages are instantly visible to all participants without the need for refreshing the page. Similarly, in collaborative tools, users can see edits and contributions from others unfold live, fostering a sense of immediacy and collaboration.

SignalR, a prominent library in the .NET ecosystem, exemplifies the advancements in facilitating real-time web application development. By abstracting the complexities involved in managing real-time connections, SignalR allows developers to focus on building feature-rich, interactive applications without delving into the intricacies of the underlying communication protocols. SignalR seamlessly handles connection management, supports automatic reconnection, and provides a high-level API that developers can use to enable real-time features such as live chats, notifications, and collaborative editing.

The advent of real-time web applications has profound implications for digital platforms, especially in corporate and educational settings. By enabling instantaneous communication and collaboration, these applications not only enhance the efficiency of internal operations but also elevate the learning experience in digital educational environments. Real-time interactions mimic the immediacy and dynamism of physical classrooms and meetings, bridging geographical gaps and fostering a more engaged and connected community.

The shift towards real-time web applications signifies a pivotal development in the digital landscape, offering unparalleled immediacy and interactivity. As we delve deeper into the capabilities and applications of technologies like SignalR, it becomes evident that the future of web development is inherently real-time, driven by the demand for more responsive, engaging, and collaborative digital experiences.

3 SIGNALR TRANSPORTS

SignalR, a prominent library within the ASP.NET framework, simplifies the implementation of real-time web functionalities, playing a crucial role in developing applications that require seamless, two-way communication between clients and servers. At the core of its operation, SignalR employs various transport mechanisms to establish and maintain these connections, each with its unique characteristics and use cases. This section explores the intricacies of these transport mechanisms, namely WebSockets, Server-Sent Events, and Long Polling, and how SignalR intelligently selects the most appropriate transport based on the client and server capabilities.

WebSockets represent the pinnacle of real-time communication technologies, enabling full-duplex communication channels over a single TCP connection. This means that data can flow freely in both directions simultaneously, from client to server and vice versa, without the need for multiple connections or the overhead associated with traditional HTTP requests. The persistent nature of WebSocket connections eliminates the latency and resource consumption typically involved in establishing new connections, making it the most efficient transport mechanism for real-time applications.

SignalR prioritizes WebSockets due to their low latency and high efficiency in real-time data exchange. However, the use of WebSockets requires support from both the client's browser and the server. Modern browsers widely support WebSockets, but in environments where this is not the case, SignalR seamlessly falls back to other transport methods.

Server-Sent Events offer a lightweight and standardized way for servers to push updates to the client over a single, long-lived HTTP connection. Unlike WebSockets, SSE supports only unidirectional communication—from the server to the client. This makes SSE an excellent choice for scenarios where client-to-server communication is minimal or not required, such as live news feeds or updates in a dashboard application.

SSE's simplicity and efficient use of HTTP make it a valuable option in the real-time communication spectrum. SignalR leverages SSE when it detects that the client supports it and the application's communication pattern fits the unidirectional model that SSE best serves.

Long Polling is a technique where the client makes a request to the server, which the server holds open until new data is available to send back to the client. This approach minimizes the latency usually associated with polling by eliminating the constant opening and closing of connections. While not as efficient as WebSockets or as straightforward as SSE, Long Polling provides a viable fallback for real-time communication when more advanced transports are not supported by the client or server environment.

SignalR utilizes Long Polling as a last resort, ensuring that real-time functionalities remain accessible across a wide range of devices and network conditions, even when the more efficient transports cannot be utilized.

SignalR abstracts the complexities of transport management, allowing developers to focus on building their applications without worrying about the underlying communication protocols. Upon establishing a connection, SignalR conducts a negotiation process with the client, determining the best available transport mechanism based on the client's capabilities and the application's requirements. This negotiation ensures optimal performance and compatibility, leveraging WebSockets when possible but seamlessly falling back to SSE or Long Polling as necessary.

This intelligent transport selection mechanism ensures that SignalR applications can provide real-time functionalities across diverse environments, making SignalR a powerful tool for developers aiming to build responsive, engaging, and interactive web applications. Through its sophisticated handling of different transport technologies, SignalR paves the way for more dynamic and connected digital experiences, underscoring its importance in the modern web development landscape.

4 IMPLEMENTING SIGNALR IN ASP.NET

In the rapidly evolving world of web development, the demand for real-time, interactive applications is surging. ASP.NET, with its comprehensive framework, stands at the forefront of this movement, offering developers an efficient pathway to integrate real-time functionalities through SignalR. This exploration delves into the nuances of embedding SignalR within an ASP.NET application, with Visual Studio Community 2022 serving as the platform for our demonstration.

The process begins by laying the foundation with a new MVC application created in Visual Studio. This initial step is critical as it sets the stage for the subsequent integration of SignalR capabilities. The journey progresses with the inclusion of the SignalR client package into the application. This inclusion is pivotal as it equips the application with the necessary JavaScript library, enabling the client side to engage in interactive dialogues with SignalR hubs.

Central to the configuration of SignalR is the creation and setup of a hub, a specialized class designed to orchestrate client-server interactions. It's advisable to house all hubs within a dedicated directory, fostering a structured and maintainable project environment. The setup extends into the `Program.cs` file, where essential configurations are applied to initialize SignalR, including the strategic routing for hub connections, notably mapping the `ChatHub` to the "/chatHub" endpoint.

On the client side, the narrative unfolds as a connection to the SignalR hub is meticulously established. This is achieved using the `HubConnectionBuilder`, coupled with the `withUrl` method, which dutifully specifies the hub's URL, "/chatHub" in this scenario. The setup for receiving messages is crafted through the `ReceiveMessage` handler function. This function is ingeniously designed to process incoming messages, equipped to handle parameters such as the sender's identity, the message content, and the precise timestamp of the message's dispatch. Employing JavaScript, dynamic elements are created within the Document Object Model to elegantly display these messages.

A pivotal aspect of the client-side functionality is the handling of the connection through the `then()` method. This method plays a crucial role in ensuring that, upon successful connection, certain user interface elements, such as the send button, are activated. Conversely, the `catch()` block is adeptly employed to manage any aberrations during the connection process, meticulously logging them to the console for scrutiny.

The narrative of interaction is further enriched as messages are dispatched to the server through the `hubConnection.invoke("SendMessage", user, message)` method. This method not only specifies the hub method to be invoked but also conveys the requisite parameters, such as the username and the text of the message. The robust framework of error handling during message transmission is underpinned by a `catch()` function, ensuring a comprehensive feedback mechanism for diagnosing and rectifying errors.

The culmination of this intricate setup is a thorough phase of testing and validation. This critical phase assures that messages are relayed and received in real time, devoid of significant delays or complications. It affords a golden opportunity to refine the application, guaranteeing that the flow of real-time communication is both smooth and efficient.

Noteworthy is the built-in support for the server-side SignalR library within the ASP.NET Core 6 Framework, which obviates the necessity for additional server-side NuGet packages. This integral support streamlines the development process, enabling developers to concentrate on crafting the application's functionality rather than entangling themselves in the complexities of server configuration.

The integration of SignalR into an ASP.NET application heralds a new era of possibilities for crafting interactive, real-time web applications. Through the methodical steps delineated in this exploration, developers are empowered to seamlessly embed real-time features into their ASP.NET applications, catapulting user engagement and interaction to new heights. SignalR, in concert with ASP.NET, emerges as a formidable solution, capable of breathing life into dynamic content and real-time functionalities, thereby redefining the landscape of web development.

5 LAUNCHING THE APPLICATION AND VERIFYING THE RESULTS

The true measure of success for any real-time application is observed in its operational efficacy post-deployment. This crucial phase involves launching the application across various browsers, simulating distinct user scenarios to scrutinize the real-time messaging capabilities enabled by SignalR. The procedure is straightforward yet pivotal to validating the seamless interaction and communication between the client and server, ensuring the integrity and responsiveness of the application under real-world conditions.

Upon initiating the application in diverse browser environments, the simulation entails logging in as different users—a process that is not merely procedural but critical for assessing the multi-user functionality and real-time data synchronization across sessions. This step is fundamental to the testing phase, as it mirrors the varied real-user interactions within a dynamic web application context.

The essence of this phase lies in the real-time transmission of messages. As a message is dispatched from one browser session, the expectation is set for an instantaneous reflection of this message across all active sessions. This demonstration of real-time communication is the hallmark of SignalR's capabilities, showcasing the efficient and synchronous data exchange that is critical for interactive applications. Each browser, acting as a standalone client, becomes a recipient of the broadcasted message, displaying it on the web page without necessitating a page refresh or manual intervention. This is where the application's real-time feature transcends into a tangible user experience, affirming the efficacy of the SignalR implementation.

The process of verifying results extends beyond the superficial layer of message exchange. It encompasses a thorough examination of the application's performance, including but not limited to, the latency in message delivery, the stability of the connection under varying network conditions, and the scalability of the solution to accommodate a growing number of concurrent users. These metrics are crucial for ensuring that the application not only functions as intended but also delivers a robust, efficient, and user-friendly experience.

The launching and result verification phase is a testament to the application's real-time communication prowess, enabled by SignalR. This phase is critical for developers and stakeholders to witness firsthand the interactive capabilities of their application, ensuring that it meets the intended design specifications and user expectations. Through meticulous testing and validation in a controlled yet diverse environment, the application is vetted for its readiness to be deployed in a live setting, marking a significant milestone in the development lifecycle.

6 TRANSFORMING DIGITAL EDUCATION WITH REAL-TIME COMMUNICATION

Integrating a SignalR-based chat application within digital educational environments marks a significant leap forward in enhancing the interactive and collaborative aspects of learning. This real-time communication tool profoundly impacts the educational experience by facilitating instant interactions, fostering a vibrant community, and enabling dynamic learning opportunities that transcend traditional boundaries.

The application serves as a conduit for enhanced student-teacher interaction, offering a platform where instant feedback and clarifications become the norm, not the exception. It revolutionizes the way queries are addressed during live lectures or when students grapple with assignments, effectively closing the communication gap that plagues online education. Furthermore, it allows teachers to host virtual office hours and tutoring sessions, providing personalized support that is both timely and impactful.

Collaborative learning, a cornerstone of educational advancement, is significantly bolstered by this real-time chat capability. It transforms group projects and discussions, enabling students to share ideas, engage in meaningful discourse about course materials, and tackle problems together. Beyond academic collaborations, the chat fosters peer support networks, where students encourage one another, exchange study tips, and extend academic assistance, nurturing a supportive learning ecosystem.

The dynamic classroom environment is further enriched through live Q&A sessions during online lectures, engaging students directly with the material and the instructor in real-time. This interactivity is augmented by the ability to conduct instant polls or quizzes, injecting an element of engagement and participation that elevates the learning experience.

On the administrative front, the chat application proves invaluable for disseminating announcements, updates, and reminders about classes, assignments, and upcoming events, ensuring swift and efficient communication. It also serves as an essential tool for conveying emergency notifications, providing a rapid response mechanism to reach students and faculty instantaneously.

Accessibility and inclusion are at the heart of this technological integration. By incorporating automatic translation services and accessibility features like voice-to-text and text-to-voice options, the chat application ensures that education is more inclusive, catering to non-native speakers and students with disabilities. These features democratize access to communication and learning opportunities, making education more accessible to a diverse student body.

The figure provides a flowchart that visualizes the process of applying SignalR in an educational environment, illustrating the steps from initiating a SignalR connection to terminating a session and disconnecting.

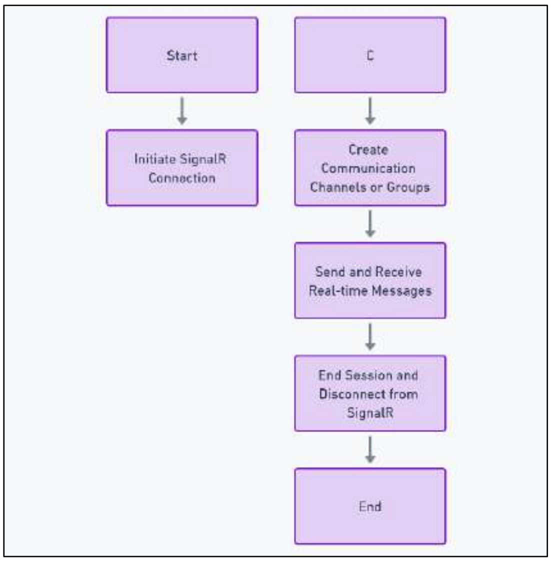


Figure1 : The process of applying SignalR in the educational environment.

Block "C" in the diagram refers to "Register Users (Students and Teachers)". This step describes the process where users, whether they are students or teachers, register to use the system based on SignalR. Registration might involve creating accounts, entering personal information, and setting preferences to participate in the educational process. This is a crucial step as it allows the system to identify users and provide them with appropriate access to communication channels and groups.

Moreover, the chat application extends engagement beyond the confines of the classroom. It facilitates homework help and virtual study sessions outside formal class hours, encouraging continuous learning. Faculty members can leverage this tool for providing ongoing feedback on assignments, offering mentorship on academic progress, and guiding students along their career paths.

In essence, the introduction of a SignalR-based chat into digital educational platforms not only enriches the learning experience but also forges a more connected, interactive, and supportive educational community. It leverages the immediacy of real-time communication to dismantle barriers, making education more engaging, accessible, and effective for both students and educators. This technological enhancement embodies the future of education, where learning is not just about the transfer of knowledge but about building connections, fostering inclusivity, and inspiring collaboration.

7 CONCLUSION

The exploration into the realm of SignalR and its integration within digital educational platforms illuminates a path towards revolutionizing the educational landscape. Through the detailed examination of creating and implementing a SignalR-based chat application, we've unveiled the substantial benefits and transformative potential that real-time communication holds for enhancing the interactive and collaborative dimensions of learning.

SignalR, with its robust capabilities for facilitating instant, bi-directional communication, emerges not just as a tool but as a cornerstone for building dynamic, responsive, and inclusive digital educational environments. The ability to instantaneously exchange messages, share insights, and collaborate in real-time transcends traditional educational boundaries, fostering a more engaged, supportive, and interactive learning community.

The application of real-time chat functionalities extends beyond mere communication; it enriches the educational experience by enabling instant feedback, facilitating collaborative learning, enhancing administrative efficiency, and promoting accessibility and inclusion. These features collectively contribute to creating a learning atmosphere that is more adaptable, engaging, and inclusive, catering to the diverse needs of the modern student body.

Moreover, the practical implementation guide provided for setting up a SignalR-based chat application within an ASP.NET framework showcases the accessibility of integrating such technologies into existing educational platforms. It demystifies the technical complexities, offering a roadmap for educators and developers to enhance their digital offerings with real-time communication capabilities.

In conclusion, the advent of real-time web applications powered by SignalR represents a significant leap forward in digital education. It underscores the evolving nature of learning environments, which are increasingly becoming more interactive, collaborative, and student-centered. By harnessing the power of SignalR, educational institutions can unlock new potentials in teaching and learning, paving the way for a future where digital education is characterized by its immediacy, connectivity, and inclusivity. As we move forward, the integration of real-time communication tools like SignalR into educational platforms is not just an option but a necessity to meet the dynamic demands of the 21st-century learner.

REFERENCES

Bakonyi, V., Illés, Z., Pšenáková, I., Szabó, D., 2023. SignalR based Real-Time applications in education. In *2023 3rd International Conference on Innovative Practices in Technology and Management (ICIPTM)*, pp. 1-6.

Adhiarta Wikantyasa, I. M., Sarno, R., Triajo, S., 2023. Development of Large-Scale Precision Farming Monitoring System based on REST API and SignalR. In *2023 International Conference on Computer Science, Information Technology and Engineering (ICCoSITE)*, pp. 832-837.

Abramov, V. I., Mindzaeva, E. V., Beshenkov, S. A., Yalamov, G. Y., Alexandrovna, A. A., Vadimovna, D. Y., 2022. In *2022 2nd International Conference on Technology Enhanced Learning in Higher Education (TELE)*, pp. 14-16.

Gizatullin, Z. M., Shleimovich, M. P., 2023. A Technique for Research of the Conducted Interferences from Power Devices of the Aircraft under Modernization. *Russian Aeronautics* 66(1): 154-161.

Soloveva, O., Solovev, S., Zaripova, R., Khamidullina, F., Tyurina, M., 2021. Evaluation of the effective porosity of an open cell foam material for using in heat and mass transfer numerical simulations. *E3S Web of Conferences* 258: 11010.

Gerasimov, V. A., Nuriev, M. G., Gashigullin, D. A., 2022. The fiber-optic communication system in the enterprise. In *2022 International Russian Automation Conference (RusAutoCon)*, pp. 75-79.

Nuriev, M., Zaripova, R., Sitnikov, S., Nurgaliev, R., 2023. The principles of building a parallel program for steganographic file protection. *E3S Web of Conferences* 458: 09027.

Nuriev, M., Zaripova, R., Potapov, A., Kuznetsov, M., 2023. Achieving new SQL query performance levels through parallel execution in SQL Server. *E3S Web of Conferences* 460: 04005.

Viktorov, I., Gibadullin, R., 2023. The principles of building a machine-learning-based service for converting sequential code into parallel code. *E3S Web of Conferences* 431: 05012.

Kozlov, E, Gibadullin, R, 2023. Prerequisites for developing the computer vision system for drowning detection. *E3S Web of Conferences* 474: 02031.

Gizatullin, Z. M., Shkinderov, M. S., Mubarakov, R. R., 2022. Experimental studies of building access control systems under the influence of electrostatic discharge. In *2022 Conference of Russian Young Researchers in Electrical and Electronic Engineering (ElConRus)*, pp. 1350-1353.

Yoqubjonov, J., Gibadullin, R., Nuriev, M., 2023. Advanced robotic process automation for enterprise efficiency. *E3S Web of Conferences* 431: 07011.

Khasanov, S. R., Gracheva, E. I., Toshkhodzhaeva, M. I., Dadabaev, S. T., Mirkhalikova, D. S., 2020. Reliability modeling of high-voltage power lines in a sharply continental climate. *E3S Web of Conferences* 178: 01051.

Shakirzyanov, M., Gibadullin, R., Nuriyev, M., 2023. Prerequisites for the development of the system of automatic comparison of video and audio tracks by the speaker's articulation. *E3S Web of Conferences* 419: 02029.

Shakirzyanov, R. M., Shakirzyanova, A. A., 2021. Object Detection Using Color Segmentation, Radial Symmetry Detector, and Hough Method. In *2021 International Russian Automation Conference (RusAutoCon)*, pp. 714-718.

Studying the Mechanism of Using Grain Husks to Remove Dissolved Petrochemicals from Test Water

Svetlana V Stepanova[1][a], Anna A. Alekseeva [1][b], Amina Sh. Khisamova[1][c] and Leysan Y. Khafizova [2][d],

[1]Department Environmental Engineering, Kazan National Research Technological University, Karl Marx street, Kazan, Russia

[2]Department of Foreign Languages in Professional Communication, Kazan National Research Technological University, Karl Marx street, Kazan, Russia

ssvkan@mail.ru, annank90@mail.ru, aminalatipova@mail.ru

Keywords: Water purification, oil products, grain husks, modification, adsorption.

Abstract: This paper presents our research on removing dissolved petrochemicals from water by sorption using vegetable matters. For this purpose, we used grain crop husks and their modifications as sorbents. We prepared test solutions and experimented on sorption in static and dynamic conditions. Grain husks were modified chemically and thermally. The experiments showed that modifying with 1% sulfuric acid (SA) solution and heating allow increasing the adsorption capacity by 10-15 % and 35-40 %, respectively. Dependencies obtained for the adsorption capacity of original and modified samples indicate that the isotherm of adsorbing the dissolved petrochemicals by grain husks is described by the Freundlich equation, which is evidence of a mixed-diffusion sorption mode. To identify the filter bed operation time, we measured the dynamic exchange capacity of five filter bed samples. According to various combinations of modified samples proposed as filter bed, heat-treated oat husks : acid-modified oat husks : heat-treated oat husks at a ratio of 4:6:4 at a water flow rate of 10-15 cm^3/min allows maintaining the filter operability of up to 6 hours. Oil gets adsorbed at WGH in the mixed-diffusion mode, while the internal diffusion is a stage that limits adsorption according to the activation energy estimates (6-20 kJ/mol). This is due to the structural features of cellulose and lignin contained in sorption materials (SM) that have a complex amorphous crystalline structure. Presumably, petrochemicals (PC) are adsorbed on the surface of SMs at the beginning of adsorption process, forming a monomolecular layer, and then, with increase in concentration, start penetrating into internal pores and filling out the amorphous crystalline zones in the composite structure.

1 INTRODUCTION

Oil production rates and oil refining industry development are increasing year on year both in Russia and around the globe. Despite the ongoing environmental protection measures, oil and petrochemicals cause significant damage to the environment, both during the normal course and resulting from various accidents. The hydrosphere is especially affected, as approximately 10-15% of petroleum hydrocarbons entering water bodies dissolve. The composition of the oil and the turbulent regime of water masses influence upon generating of oil emulsions (Davydova, Tagasov, 2004). Nowadays, there is a large number of methods to remove oil from aqueous media: Mechanical, physical, biological, etc. (Peregudov, 2021,Tatarintseva, Bukharova & Ol'shanskaya, 2014). The sorption method is essential due to its advantages, such as removal of both dissolved, emulsified, and immiscible petrochemicals from water. In addition, the sorption method involves a wide range of raw materials, including synthetic polymer sorbents to agricultural wastes (Stepanova,

[a] https://orcid.org/0000-0003-4831-313X
[b] https://orcid.org/0000-0002-6119-1934
[c] https://orcid.org/0009-0007-2755-6753
[d] https://orcid.org/0000-0002-0339-0791

Alekseeva & Khafizova, 2021, Malyshkina, Vyalkova & Osipova, 2019). Despite the diverse market, search for an effective, selective, and also cheap sorption material (SM) is an important task. In this regard, we performed a study of water purification by removing dissolved petrochemicals using modified samples of wheat grain husks (WGH), barley grain husks (BGH), and oat grain husks (OGH), all being agricultural wastes.

2 MATERIALS AND METHODS

We strongly encourage authors to use this document for preparation This study is aimed at research in removing dissolved petrochemicals (PC) from water by plant materials, based on grain crop husks (GCH) and their modifications. To achieve this goal, the following tasks were solved:

• Modifying SMs with an SA solution and heating the GCH samples;

• Preparing test solutions (TS);

• Determining the static (A) and dynamic exchange capacity (DEC) of original and modified materials;

• Examining the mechanism of adsorbing dissolved PCs by the SMs obtained; and

• Checking the applicability of SM as a filter bed.

Husks were modified chemically as follows: We took 10 g of GCH and 200 cm3 of 1% SA solution and stirred them for 60 minutes. Upon the contact completion, we separated the sample and washed it repeatedly with distilled water until the medium became neutral. Then we dried the samples to constant weight in a dry-heat oven at a temperature of 100 ± 5 °C.

We heated the GCH samples weighing 20 g in a dry-heat oven with forced convection, which ensures temperature uniformity throughout the oven chamber, at a temperature of 150-160°C for 15-20 minutes, with a constant stirring.

We prepared TSs containing dissolved PC concentrations of 8.76, 26.3, 43.84, 65.7, and 87.68 mg/dm3, respectively (approved by Deputy Chairman of the State Committee of the Russian Federation for Environmental Protection, 2000).

Water was purified from dissolved PCs under static conditions as follows: We placed the pre-weighed portions of the GCH under study, 1 g each, into five flat-bottomed flasks with the capacity of 250 cm3 and poured TS into the flasks, 100 cm^3 each. The flasks, with the portions of the samples and the solutions inside, were tightly closed with stoppers and shaken vigorously for one hour. Then we removed GCHs and computed the residual concentrations of petrochemicals in the filtrates according to the methods (Deputy Chairman of the State Committee of the Russian Federation for Environmental Protection, 2000, Deputy Chairman of the State Committee of the Russian Federation for Environmental Protection, 1997, Stepanova, Alekseeva & Khafizova, 2020).

To study the dynamic exchange capacity (DEC), we used filters of various fillings. Contaminated water was prepared with the initial concentration of 0.5 ± 0.2 mg/dm^3 in a vessel with the capacity of 5 dm3. To achieve a uniform concentration of oil in the water, we stirred it for 60 minutes. Then we found the initial concentration of PCs in water. The water flow rate was set at 0.003 m^3/min and passed through a glass column with the diameter of 4.5 cm, filled with samples (Table 2).

To estimate the filter bed operation time, we sampled water and evaluated the residual oil content in it at certain time intervals (every 20 minutes). The experiment was carried out up to the point of "breakthrough."

Dynamic exchange capacity (DEC, mg/g) was calculated by the formula:

$$\mathrm{DEC} = \frac{V \cdot C_{\mathrm{e}}}{m}, \tag{1}$$

where m is the mass of the LCCM portion, g;

Ce is equilibrium concentration, mg/dm^3; and

V is the volume of the model solution, dm^3

3 RESULTS

As a result of the experiments carried out, we obtained the dependencies of the adsorption capacity of native GCHs and of ones modified with the SA solution (GCH + SA) and thermally modified wheat grain husks (TMWGH) on concentration (Fig. 1).

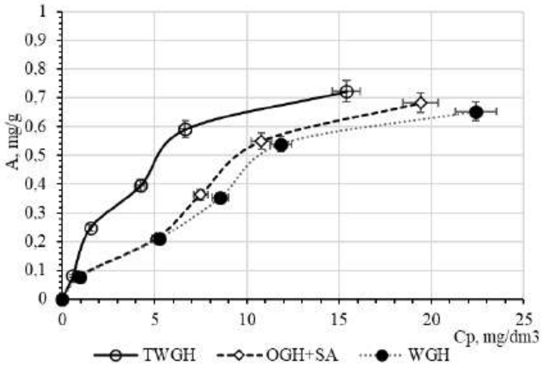


Figure 1: Dependence of the adsorption capacity of WGH samples on the concentration of petrochemicals in water

To study the curves and the mechanism of adsorbing the dissolved PCs from water in more detail, we computed the Langmuir and Freundlich equations. Table 1 shows the results of the computations on the original and modified samples of OGH, WGH, and BGH, including thermally modified oat grain husks (TMOGH).

Table 1: This caption has more than one line so it has to be set to justify.

SM Samples	Model by Langmuir $A = \frac{A_\infty \cdot K \cdot C}{(1+K \cdot C)}$,		
	K_L	A_m	R^2
WGH	1.1208	0.0202	0.6016
WGH+SA	1.2786	0.0205	0.6264
TMWGH	1.7932	0.0165	0.756
OGH	1.1436	0.0237	0,468
OGH+SA	1.1105	0.0221	0.5283
TMOGH	1.6094	0.0292	0.4731
BGH	1.3399	0.0230	0.421
SM Samples	Model by Freundlich $A = K \cdot C^n$		
	K_f	N	R^2
WGH	2.8164	1.4162	0.8976
WGH+SA	3.3822	1.5494	0.9383
TMWGH	5.1940	1.4275	0.9594
OGH	3.0186	1.6396	0.7799
OGH+SA	2.5562	1.5085	0.9585
TMOGH	3.6050	2.2305	0.8998
BGH	3.3067	1.6647	0.784

As it follows from Table 1, the isotherm of dissolved PC adsorption from water by samples of lignin cellulose containing materials (LCCM) is most accurately described by the Freundlich equation.

Since modifying the GCH samples contributes to an increase in the static adsorption capacity and there is a need for increasing the efficiency of the filters, we studied the DEC of the GCH samples prepared in various combinations (Table 2). For this purpose, we proposed five filters with different SM ratios and TS usage rates of 10-15 cm^3/min.

Table 2: Parameters of filling the filters to remove the dissolved PCs.

Filter No		Component	Weight, g
1	Lower layer	TMOGH	4.90
	Middle layer	OGH+SA	6.11
	Upper layer	TMOGH	4.49
2	Lower layer	WGH+SA	2.55
	Middle layer	BGH+SA	4.72
	Upper layer	WGH+SA	2.99
3	Lower layer	TMOGH	3.96
	Middle layer	OGH+SA	6.18
	Upper layer	TMOGH	4.50
4	First (lower) layer	BGH+SA	3.90
	Second layer	OGH+SA	2.00
	Third layer	WGH+SA	5.00
	Forth layer	TMOGH	1.80
5	Lower layer	WGH+SA	2.40
	Middle layer	TMOGH	4.50
	Upper layer	WGH+SA	2.90

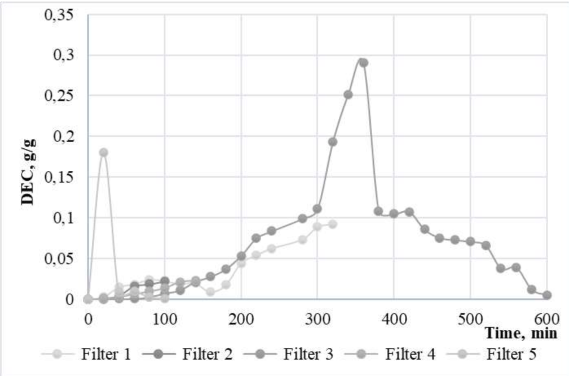


Figure 2: Dependence of the adsorption capacity of WGH samples on the concentration of petrochemicals in water

Figure 2 shows that Filter 3 has the longest operation time with the ratio of TMOGH : OGH+SA: TMOGH = 4: 6: 4. This ratio is the most optimal among the investigated ones. Thus, we can recommend this ratio as a filter filling, since it ensures the longest operation time and has the highest DEC.

4 DISCUSSION

Studying the WGH adsorption capacity in relation to dissolved PCs under static conditions shows that the curves (Fig. 1) of the samples are of a stepped nature, which indicates the presence of both micro- and macropores. According to the Gils classification, all isotherms can be categorized to L (Langmuir) class. At the initial stage, isotherms of this class are concave with respect to the concentration axis. Moreover, this type is characteristic of polymolecular adsorption and adsorption of surfactant associates (Tovbin, 2013). In this case, the adsorption capacity of TMWGH is higher than that of the original samples and those treated with a sulfuric acid solution.

With GCHs, oil is adsorbed in a mixed-diffusion mode, with the internal diffusion as a stage limiting the adsorption process, according to the activation energy estimates (6-20 kJ/mol) (Shaidullina, Stepanova 2017). Probably, the reason lies in the structural features of cellulose and lignin, which are part of SMs and have a complex amorphous-crystalline structure. Presumably, at the beginning of the adsorption process, PCs are adsorbed on the surface of SMs, forming a monomolecular layer; later, with increasing concentration, they start penetrating into the internal pores, filling the amorphous-crystalline zones of the composite structures (Alekseeva, Stepanova, 2019). Modifying the samples allowed us to increase the adsorption capacity by 10-15 % with acid treatment and by 35-40 % with heat treatment. It is possible to conclude that the modification has a positive effect on the adsorption properties of the presented material in relation to oil.

5 CONCLUSION

Within this research, we prepared TSs and examined the static and dynamic adsorption capacity of original and modified lignin and cellulose containing material samples in relation to dissolved petrochemicals. It is shown that the grain crop husks modification allows increasing the adsorption capacity of vegetable waste in relation to petrochemicals, namely: By 10-15% with acid treatment and by 35-40% through heating. We also found that the isotherm of adsorbing dissolved petrochemicals from water by the samples of lignin cellulose containing materials is most accurately described by the Freundlich equation. GCH-based oil adsorption runs in a mixed-diffusion mode, while internal diffusion is a stage that limits the adsorption process, according to the calculated activation energy figures. To increase the efficiency of removing petrochemicals from water, we propose various combinations of modified samples of vegetable matters at different ratios. We consider the ratio of TMOGH: OGH+ SA: TMOGH = 4: 6: 4 to be the most optimal, with the filter bed operation time reaching 6 hours. Using this type of material, we solve two problems: the removal of petrochemical substances from water and the rational use of plant waste.

REFERENCES

Alekseeva, A. A., Stepanova, S. V., 2019. Effect of Plasma Surface Modification of Mixed Leaf Litter on the Mechanism of Oil Film Removal from Water Bodies. In: Russian Journal of General Chemistry, 13, 2763–2768.

Federal environmental regulatory document “Method for measuring the mass concentration of petroleum products in drinking, natural and purified wastewater by the method of IR spectrophotometry at concentratometer kn-2m” FER D (approved by Deputy Chairman of the State Committee of the Russian Federation for Environmental Protection on March 17, 2000). P. 22

Federal environmental regulatory document “Quantitative chemical analysis of waters. Methods for measuring the mass concentration of oil products in natural and wastewater samples by column chromatography with a gravimetric end” (approved by Deputy Chairman of the State Committee of the Russian Federation for Environmental Protection on March 21, 1997). P. 18

Latypova A. Sh, Stepanova S. V., 2021. Study of the influence of modification of the surface of wheat husk on its sorption properties relative to oil. materials of the All-Russian scientific conference Innovative technologies for environmental protection in the modern world, Pp. 277-280

Malyshkina, E S, Vyalkova, E. I., Osipova, E. Y., 2019. The use of natural sorbents in the process of water purification from oil products. In: Bulletin of the Tomsk State University of Architecture and Civil Engineering 1(21). Pp. 188-200.

Peregudov, Yu., 2021. Magnetic Oil Sorbents based on Technogenic and Natural Inorganic Materials. In: Ecology and Industry of Russia 25(2). Pp. 34-40.

Shaidullina, A. A., Stepanova, S. V., 2017. Thermodynamic parameters of oil adsorption by modified waste of cereals (oats). Proceedings from: The 3rd Int. scientific and technical conf. Belgorod: Publishing House of BSTU. Pp. 150-152

Stepanova, S. V., Alekseeva, A. A., Khafizova, L. Y., 2020. Technological recommendations for the use of leaf litter based adsorption material to remove an oil slick from water bodies surface IOP Conf. Series: Materials Science and Engineering 791 (2020) 012076.

Stepanova, S. V., Alekseeva, A. A., Khafizova, L. Y., 2021. Studies on the Sorption Mechanism of Removing Nickel Ions from Model Waters by Cereal Grain Husks IOP Conf. Series: Earth and Environmental Science (2021) 720(1), 012038

Tatarintseva, E. A., Bukharova, E. A., Ol'shanskaya, L. N., 2014. Sorption Material for Water Cleaning from Petroleum Products. In: Ecology and Industry of Russia (7) 26-28.

Tovbin, Yu. K., 2013. Molecular theory of adsorption in porous bodies. Moscow: Fizmatlit. P. 624.

Potential and Risks of Using Artificial Intelligence in the Public Sector of the Subjects of the Russian Federation

Bezvikonnaya E.V. [1]
Omsk State Pedagogical University, Omsk 644099, Russia
bezvikonnaja@rambler.ru

Keywords: Public sector, Artificial intelligence, Digital skills, Digital risks.

Abstract: The article substantiates the need to introduce progressive digital technologies in various spheres of public administration as a condition for ensuring the competitiveness of the Russian economy. Artificial intelligence turns out to be a source of new digital technologies in various areas of management (for example, in the provision of public services, citizen appeals, etc.), however, it is necessary to take into account the obstacles to its implementation (digital distrust, lack of human resources, gaps in legal support). The purpose of the article is to identify the potential and risks of using artificial intelligence in the sphere of public authority of the subjects of the Russian Federation. The source base for the study is regulations, statistical data and sociological surveys demonstrating attitudes towards artificial intelligence technologies in the public sector. Achieving the purpose of the study becomes possible due to the use of a systematic approach to assessing the prospects for the spread of digital technologies in the public sector of the subjects of the Russian Federation.

1 INTRODUCTION

In the context of digital transformation, artificial intelligence becomes a tool for expanding the number of subjects with a high level of digital competence. There is a constant improvement of algorithms, the amount of funding for digital big data projects is increasing, the volume of digitized data is growing exponentially, the potential of cloud computing is expanding, etc. The inevitability of the expansion of the field of digitalization is associated with the unlimited possibilities of statistics for generalizing large databases and the ability of artificial intelligence to perform regularly repetitive actions without human intervention.

In order to assess the potential of artificial intelligence, it is necessary to determine its content. The National Strategy for the Development of Artificial Intelligence for the period until 2030 evaluates artificial intelligence as a set of technological solutions (actions) that replicate human cognitive functions. At the same time, the results must be comparable to human intellectual activity. Artificial intelligence products are evaluated in relation to human intelligence products, which gives rise to digital distrust on the part of society and the state.

Despite the limitations on the use of artificial intelligence, it is becoming an integral part of the public sector. The main reasons for the active spread of digitalization technologies are the following: firstly, the predictive potential, which allows obtaining reliable results in a short time; secondly, the possibility of solving complex social problems; thirdly, the effectiveness of using the experimental method to predict political decisions in conditions of uncertainty and risk; fourthly, the automation of simple tasks that do not require human participation in their solution (Banerjee, Pradeep Kumar, Bajpai, 2018). A fairly illustrative example of the use of artificial intelligence is the sphere of providing public services. It provides personalization of applicants, their needs, and assessment of the possibilities and risks of the technologies used.

An integral part of artificial intelligence in the public sector is the protection of personal data based on compliance with digital security ethics. The current legislation sets fairly strict limits on the use and dissemination of personal data by public

[1] https://orcid.org/0000-0002-2837-8609

authorities (Boyd, Wilson, 2017). For example, one of the reasons for not using the potential of the government portal "gossluzhba.ru" is the need to obtain consent for the processing of personal data from candidates for vacant positions in the civil service when passing an online test on knowledge of current legislation. Automation of the process makes it possible to reduce the costs of testing in government agencies and redirect resources to organizing a competition of documents and interviews with candidates.

The state policy of the Russian Federation in the field of using artificial intelligence in the public sector began to take shape in 2019, from the moment of signing the National Strategy for the Development of Artificial Intelligence until 2030. Authorities are officially identified as the authors of the strategy, responsible for both the introduction of digital technologies within both the management sector within their competence and the internal environment of the authority. Unlike the private sector, public authorities are more often faced with low dynamics and slowness in the process of implementing artificial intelligence. Despite certain difficulties, digitalization processes in the public sector are currently the most intensive and ensure the effectiveness of the management decision-making process.

2 MATERIALS AND METHODS

Achieving the goal of the study to assess the potential of artificial intelligence in the public sector becomes possible by solving the following tasks: analyzing the legal framework governing digitalization processes, assessing trends in the use of artificial intelligence in the public sector in the subjects of the Russian Federation, identifying the risks and prospects for the implementation and diffusion of artificial intelligence in the public sector. The solution to the set tasks is provided through the use of an institutional methodological approach that allows evaluating artificial intelligence technologies as a set of goals, objectives, directions and mechanisms for achieving public administration results. The approach directly links the tasks of digitalization and achieving the effectiveness of all technologies, including artificial intelligence.

Among the qualitative research methods used are the logical method of analysis and synthesis, as well as the method of structural and functional analysis, which provided an assessment of external and internal factors influencing the content and directions of implementation and diffusion of artificial intelligence technology. The sociological method refers to quantitative methods, allowing to identify the specifics of the implementation of the tasks of the diffusion of artificial intelligence in the practice of the subjects of the Russian Federation. The validity of the results obtained is ensured by the integrity of the methodological and source base of the study.

3 RESULTS

The use of artificial intelligence in the public sector is driven by the need to achieve effective public administration. To identify the potential of this technology, it is necessary to analyze the criteria for evaluating the effectiveness of the public sector.

Firstly, obtaining accurate results from big data processing, on the basis of which management decisions are made. In this case, the variable parameters are successfully ignored and excluded from the selection. Decisions of public authorities are regularly tested and adjusted, taking into account the identified shortcomings. This criterion is reflected in numerous state (municipal) strategies and programs that are subject to regular monitoring, control and adjustment. For example, many public authorities of the subjects of the Russian Federation tend to establish criteria for evaluating the effectiveness of individual management decisions, taking into account the position held and the official duties of a civil servant.

Secondly, the presence and degree of human control over the process of data processing by artificial intelligence and its results. In the public sector, decisions are of fundamental importance for the development of the territory, industry, and citizens, which is why the level of control is the highest. For example, in the field of public services, administrative regulations usually assume a mixed nature of receiving services – electronic or personal.

Thirdly, ensuring transparency at all stages of processing databases by artificial intelligence. This criterion seems to be one of the key criteria in evaluating the effectiveness of management decisions, because, for example, when providing public services, it is almost impossible to ensure transparency at all stages of the process, since there is interdepartmental interaction and limited access databases are used. Providing access to databases does not mean the completeness of the calculation of the result, due to the presence of objective legal and economic reasons.

Fourthly, equal conditions for all variables and algorithms guarantee the objectivity of the results of using artificial intelligence. For example, statistical accounting of the small peoples of Russia, conducted using artificial intelligence, involves the use of uniform criteria for describing population groups. At the same time, artificial intelligence does not replace humans, but is intended to help them in making management decisions.

Fifthly, the universality of the requirements for the protection of personal data allows artificial intelligence to use various combinations of them in the process of identifying information. The anonymity of information containing personal data is provided by artificial intelligence quite effectively. Despite the possibility of reusing anonymous data, but at another stage of management decision-making, often in violation of the autonomy of the subject of personal data.

Artificial intelligence is radically transforming the public sector, giving it the ability to effectively make and implement management decisions. A large amount of data can be processed quickly and without errors using digital technologies. The influence of the human factor on the result is minimized. The quality of decisions is improved by appealing to generalized databases, trends and patterns. We should not forget about the enormous predictive (strategic) potential of artificial intelligence in the sphere of public authority.

Digital technologies create conditions for ensuring transparency of the public sector, its openness to citizens and society as a whole. E-government, which provides real-time feedback, remains a key instrument of openness. The level of trust of citizens in public authorities is determined by the degree of its openness. Artificial intelligence is becoming a source of creating a comfortable environment and increasing the level of trust among citizens – signs of digital maturity of public authorities. The use of digital technologies in the public sector also makes it possible to solve communication, administrative and educational tasks.

The use of digital technologies in the public sector ensures that citizens have access to digital services and platforms. Officials, whose responsibilities include the introduction of digital technologies into the practice of regional management, initiate the creation of new services to solve complex management tasks. For example, one of the most effective digital technologies is the Internet of Things, which forms the basis of the Smart City tool.

The use of artificial intelligence, despite its full potential in the public sector, should not upset the balance of interests of citizens and public interest. To assess the limitations of artificial intelligence, it is necessary to conduct an analysis of possible risks (Hacker, 2018). 1. Dependence on subjective assessments (opinions) of artificial intelligence developers. The result is the persistence of inequality and discrimination in society. This risk is most critical in a state governed by the rule of law. Unlike the human mind, artificial intelligence operates according to an algorithm, so the subjectivity of the results becomes systemic. 2. The risk of depriving a person of autonomy, the inability to determine who is responsible for the difficulties that arise in the process of implementing a management decision. The rights of the affected subject are violated by the impossibility of holding the perpetrators accountable. 3. The risk of unjustified (unexplained) results from the point of view of human intelligence. The result is doubts about the objectivity of the results obtained, especially if the data conceal the facts of inequality (discrimination). 4. Violation of personal space, invasion of privacy. The amount of information to be processed by artificial intelligence makes it impossible to obtain the consent of the personal data subject. People's private lives are being affected by artificial intelligence, depriving them of the ability to control their own lives. 5. The risk of isolation of a person from society. The result is an inability to build relationships based on mutual understanding and trust. The integration of society is possible only if the risk of isolation is eliminated. 6. The risk of obtaining unreliable results could undermine public trust in artificial intelligence. Carelessness in the design and implementation of processes can make this risk fatal for the public sector.

To analyze the risks and potential of artificial intelligence in the public sector, we used the results of a sociological survey of the Center for Strategic Research conducted from February 10 to 24, 2022 in 46 regions of the Russian Federation. The representativeness of the sample allows us to note the following trends in the use of artificial intelligence in the public sector.

Firstly, the solution to current territorial management problems is not linked to the prospects of artificial intelligence expansion. Even in the perspective of the coming decades, technology is not considered effective for achieving the goals of management decisions. Some favorable opportunities were noted only in three sectors of the economy: the social sphere, industry and the management activities of public authorities. The reason for choosing these sectors is the most intensive interaction of authorities with the population, which significantly complicates management tasks. Artificial intelligence is evaluated only as an auxiliary tool in human activity. This conclusion is confirmed by the confidence that the transition to a proactive mode of providing public services will become the key to the sustainability of the public sector.

Secondly, the sectoral nature of the use of artificial intelligence makes it possible to use its capabilities only within one industry and one technology that has proven its effectiveness. Taking into account the regional peculiarities of socio-economic development, various examples of successful practices of using artificial intelligence are formed. Generalization of regional practices may become a condition for their application in other subjects of the Russian Federation.

Thirdly, there is a tendency to use artificial intelligence technology in the social sphere, which is experiencing the greatest financial difficulties. For example, the healthcare sector (primarily medical services). In the process of providing medical services, as a rule, there is a need to algorithmize the entire process through the use of artificial intelligence. The social sphere is becoming an object of application of digital technologies also due to the high degree of uncertainty and complexity of the databases being processed.

Fourthly, the traditional stages of implementing management decisions: monitoring, control and audit, which require the processing of big data, are becoming areas of use of artificial intelligence. The latter turns out to be in demand within the framework of project management, which forms the basis of territorial planning in the Russian Federation.

Fifthly, the potential risk of artificial intelligence to the personal safety of citizens is noted. For example, in connection with the need to compensate for moral damages in connection with the dissemination of restricted information. But for the subjects, economic risks are the most pressing, as they lead to an increase in the cost of the project.

Sixthly, the factors limiting artificial intelligence in the public sector are: limited financial resources, digital incompetence and lack of infrastructure. We have identified similar risks previously. It can be stated that regional practices demonstrate identical trends that limit the realization of the potential of artificial intelligence.

Seventhly, minimizing risks becomes possible only by increasing the trust of authorities and citizens in digital technologies. The level of trust will increase only if the regulatory framework is improved, recommendations are issued and public servants undergo internships in the largest companies ready to demonstrate successful experience in using artificial intelligence.

Eighthly, the creation of a federal digital platform containing software solutions based on artificial intelligence inspires a high level of trust. At the same time, it is important that these solutions can be integrated into specific sectors of the socio-economic development of the region. To achieve this goal, integrated Competence Centers should be created on the basis of public-private partnership, including representatives of public authorities and IT companies in the region.

The dependence of the use of artificial intelligence in the regions on the availability of human resources with a high level of digital competencies is quite obvious. The level of salary expectations of specialists is much higher than their qualification level, which leads to an outflow of personnel to the commercial sector. Regional practices are dependent on the federal IT platform because they are limited in resources and innovative digital technologies. Meanwhile, artificial intelligence technologies demonstrate their high efficiency in the provision of public services, for example, in the format of a virtual assistant. Despite the high cost of technologies, the willingness of public authorities to use them in the social sphere reaches 25%. For comparison, in the commercial sector it is up to 97%. However, the most productive area of application of digital technologies is the area of interaction between public authorities and consumers of public services, and not the sphere of their receipt ("end service").

The level of trust of citizens and public authorities in artificial intelligence remains low (no more than 34%). The reason lies in the limited number of successful examples of its use in the public sector and poor communication with the commercial IT sector. Technological problems of using artificial intelligence, in particular, the power of computing infrastructure, are recognized by all regional entities.

The results of the analysis of the sociological survey data indicate the presence of mutual interest (dialogue platform) of public authorities and the public in the use of artificial intelligence in the implementation of industry projects. Regional practices indicate dependence on federal artificial intelligence platforms that demonstrate the technological and economic potential of digital technologies.

The public sector has shown a high degree of interest in using artificial intelligence in recent decades. The transition to program-target and project management has expanded the range of digital technologies used in the process of achieving results, from robots to artificial intelligence. The practice of the subjects of the Russian Federation demonstrates a high level of risks hindering the introduction of artificial intelligence technologies: limited financial resources, underdeveloped infrastructure, low level of digital literacy and gaps in the regulatory framework. The elimination of risks becomes possible only with the participation of the federal center.

4 DISCUSSION

The problems of artificial intelligence as a digital technology in the field of public sector are in the range of interests of numerous researchers. Theoretical approaches to determining the potential of this technology can be divided according to the criterion: priority of opportunities or threats. One of the supporters of the introduction of artificial intelligence at all stages of making and implementing management decisions is T.M. Kosovskaya (Kosovskaya, Petrov, D.A) such a project in the public sector may be the conclusion of a public-private partnership agreement. Another group of researchers draws attention to social crises as a result of the introduction of artificial intelligence (Bure, Karelin, Polyakova, 2016). Unemployment and social instability turn out to be an integral part of the use of artificial intelligence technology. The prevention of these negative consequences requires a broad discussion with the participation of all social groups. Supporting the position of opponents of the large-scale introduction of artificial intelligence into the public sector, A.M. Gortsev emphasizes the moral and ethical problems caused by encroachment on personal autonomy (Gorcev, Bocharova, 2022).

Despite the existence of two diametrically opposed approaches to assessing the prospects for the spread of artificial intelligence technology in the public sphere, the vast majority of authors adhere to related positions. For example, A.A. Sidorov insists that in conditions of high uncertainty in the public sector, it is artificial intelligence that is called upon to choose the optimal vector of public administration strategy (Sidorov, Senchenko, Tarasenko, 2020). It is the strategic vector of technology that turns out to be most in demand in the works of Russian authors (V.V. Moskvichev, V.P. Potapov, etc.) (Moskvichev, Nicheporchuk, Potapov, Tasejko, 2021). The task of public authorities is to minimize the risks of introducing artificial intelligence, the Internet of Things and big data.

The legal nature of artificial intelligence is addressed in the works of A.M. Lepihin (Lepihin, Mahutov, SHokin, YUrchenko, 2020). Drawing attention to the need to tighten legal liability measures for digital technology developers, the author establishes the priority of human rights to personal information over achieving the effectiveness of public decisions. The legal conflicts of using artificial intelligence are emphasized by almost all experts. This problem is especially acute at the stage of data perception and self-learning of a complex autonomous cybernetic system. Attention is drawn to the legal capacity of a special electronic person – artificial intelligence (Suchkov, 2022). This status is not fixed in the current Russian legislation and requires taking into account the foreign practice of legal regulation of digital entities.

5 CONCLUSION

Digitalization processes cover various areas of the public sector, requiring an assessment of the potential of artificial intelligence, taking into account the limitations inherent in the latter. Successful application of technologies in the commercial sector requires their adaptation to the needs of the state and society. The strategic task of increasing the efficiency of public administration requires the use of key artificial intelligence technologies. The digital state must stop being document centric and move towards big data analysis. In particular, in the field of public services, quantitative indicators should become the responsibility of artificial intelligence, and solving the strategic task of improving the quality of public services should become a priority for public authorities and their officials.

Artificial intelligence technologies are becoming no less important for ensuring the digital security of the state. By eliminating errors in information systems, artificial intelligence reduces the role of a vulnerable human factor in the management decision-making process. The increase in the use of artificial intelligence technologies in industries such as transport, education, healthcare, mining, etc. requires an expansion of the range of technologies used to achieve efficiency indicators.

The accumulated practice of using artificial intelligence has sparked a discussion about the social, legal, and ethical consequences of its use in the public sector. In the coming decades, artificial intelligence will not be able to replace the human mind, solving narrow-profile tasks defined by man. This fundamental contradiction leads to the inability of artificial intelligence to resist manipulation by its creators, which in turn leads to the unreliability of large databases.

Financial risks also appear to be the main reason for refusing to launch artificial intelligence programs. The budgetary possibilities of state programs (strategies) do not provide for the costs of upgrading artificial intelligence technologies, resulting in the unwillingness of public authorities to put the latter into practice.

The low level of digital competencies of specialists and citizens leads to a personnel vacuum in the public sector. At the same time, digital competencies require deepening their specialization within a certain branch of public authority.

Legal conflicts of artificial intelligence management form the prerequisites for the development of special norms controlling its socio-economic impact on society and the state. The practice of international law has a special influence on the resolution of conflicts. The processes of globalization directly affect the formation of national artificial intelligence systems based on differences in the legal systems of individual states.

Finally, the risk of holding an inappropriate subject accountable also appears to be a consequence of the legal uncertainty of the accountability of artificial intelligence technologies. The ethical aspect of accountability is determined by the ability of the human mind to foresee the consequences of using digital technologies. Moral and ethical evaluation criteria turn out to be problematic, since they contradict the nature of artificial intelligence, which does not appeal to categories of the human mind. The problem of the ethical nature of digital technologies goes beyond the development of rules of behavior and covers the systemic issue of the compatibility of artificial technologies and human values. If artificial intelligence goes beyond the task of simulating human behavior, it will become vulnerable in terms of ethical norms and values.

Artificial intelligence technologies are based on the rational principle of reproducing the management decision-making process. However, the algorithm of the management decision may be erroneous due to incorrect databases or initial errors of the creator of the digital technology. Emotional and personal traits of human behavior affect the rational nature of the technologies created, distorting the results obtained, and at the same time, raising doubts about their right to establish rules of ethical behavior of human society.

Realizing the potential of artificial intelligence in the public sector lies in improving the efficiency criteria for the provision of electronic public services, simplifying the procedure for registering the results of intellectual activity and expanding the list of subjects of intellectual activity. This digital technology creates conditions for GDP growth and the inclusion of the Russian economy among the world's leading economies.

Achievements in the field of artificial intelligence demonstrate their enormous potential in the public sector. The presence of risks does not detract from the predictive potential of these technologies, but only if they are combined with the traditional ethical values of the era of pre-digital law. The complexity of the tasks of implementing artificial intelligence in the public sector forces people to use various digital technologies when making management decisions.

REFERENCES

Ukaz Prezidenta Rossijskoj Federacii ot 10 ok-tyabrya 2019 g. № 490 «O razvitii iskusstvennogo intellekta v Rossijskoj Federacii», garant.ru, data obrashcheniya 2023/12/15.

Banerjee, S., Pradeep Kumar, S., Bajpai, J., 2018. A Comparative Study on Decision-making Capability between Human and Artificial Intelligence. – Nature Inspired Computing., 203 – 210.

Boyd, M., Wilson, N., 2017. Rapid Developments in Artificial Intelligence: How Might the New Zealand Government Respond? Policy Quarterly. Vol. 13. Is. 4, 36 – 44.

Gossluzhba, gossluzhba.gov.ru, data obrashcheniya 2024/01/14.

Perspektivy i problemy ispol'zovaniya tekhnolo-gij iskusstvennogo intellekta v regionah Rossijskoj Federacii (aprel' 2022), tse64fmdsetwhhpd6e57a3wjtsud6mdx.pdf (csr.ru), data obrashcheniya 2024/01/10.

Hacker, Ph., 2018. The Ambivalence of Algorithms. Gauging the Legitimacy of Personalized Law. Bakhoum Mor, Conde Gallego Beatriz, Mackenrodt Mark-Oliver, Surblytė-Namavičienė Gintarė (Eds.). Personal Data in Competition, Consumer Protection and Intellectual Property Law. Towards a Holistic Approach? Springer, rp. 85 – 117.

Bure, V.M., Karelin, V.V., Polyakova, L.N., 2016. Veroyatnostnaya model' obsluzhivaniya terminalov. *Vestnik Sankt-Peterburgskogo universiteta. Prikladnaya matematika. Informatika. Processy upravleniya*. 3, 32 – 38.

Gorcev, A.M., Bocharova, M.A., 2022. Analiticheskoe issledovanie odnolinejnoj sistemy massovogo obsluzhivaniya s vhodyashchim sinhronnym potokom sobytij. *Vestnik Tomskogo gosudarstvennogo universiteta. Upravlenie, vychislitel'naya tekhnika i informatika.* 59, 34 – 46.

Kosovskaya, T.M., Petrov, D.A., 2017. Vydelenie naibol'shej obshchej podformuly predikatnyh formul dlya resheniya ryada zadach iskusstvennogo intellekta. *Vestnik Sankt-Peterburgskogo universiteta. Prikladnaya matematika. Informatika. Processy upravleniya.* T. 13. 3, 250 – 263.

Lepihin, A.M., Mahutov, N.A., SHokin, YU.A., YUrchenko, A.A., 2020. Koncepciya risk-analiza tekhniche-skih sistem s ispol'zovanie cifrovyh dvojnikov. *Vychislitel'naya tekhnika.* T. 25. 4, 99 – 113.

Moskvichev, V.V., Nicheporchuk, V.V., Potapov, V.P., Tasejko, O.V., 2021. Cifrovoj pasport bezopasno-sti territorij promyshlennyh aglomeracij i regionov. *Vychislitel'naya tekhnika.* T. 26. 6, 110 – 132.

Sidorov, A.A., Senchenko, P.V., Tarasenko, V.F., 2020. Podhod k ocenke territorial'noj differencia-cii razvitiya cifrovoj ekonomiki. *Vestnik Tom-skogo gosudarstvennogo universiteta. Upravlenie, vychislitel'naya tekhnika i informatika.* 51, 121 – 129.

Suchkov, A.P., 2022. Edinaya model' gosudarstvennyh dannyh: scenarii razvitiya. *Informatika i ee primeneniya.* T. 16. 4, 99 – 105.

About Typical Errors in Representing Big Data and Digital Twins Made when Using Methods Mathematical Modeling

Gulnara Lutfullina[1] and Rafail Tukshaitov[2]
Kazan State Power Engineering University Kazan, Russia
trh_08@mail.ru, gflutfullina@mail.ru

Key words: modeling, data presentation error, methodology error in, overestimation of accuracy, mechanism of error formation.

Abstract: The work examines typical errors in the representation of big data and digital twins, which are made during their mathematical modeling, the structure of the error of mathematical modeling techniques and the mechanism of its formation. Recommendations are given for the presentation of large experimental data based on taking into account the errors of the initial indicators and modeling techniques. Calculating the error in representing big data as a percentage allows the author to quickly identify that it is often, when modeling processes, 1000 and even 100,000 times less than the error of the research methodology. The accuracy of data presentation in some cases can even be an order of magnitude greater than the accuracy of precision instruments used. The error of the modeling results is to a large extent determined by the error of the initial data used for calculations and modeling. A more significant component in the structure of the total error of the research methodology is the error in constructing the mathematical model of big data and digital twins itself, the value of which can range from ±10 to ±50%. Based on the actual permissible error of the measurement technique, recommendations are given on the degree of rounding of experimental data. The inadmissibility of direct readings from the screen of a personal computer is noted. For clarity, a number of examples of big data are provided, borrowed from the literature, in their original published form and after rounding them in accordance with the given recommendations. Keywords: mathematical modeling, error in the representation of big data, error in the modeling methodology, the mechanism of formation of the total error.

1 INTRODUCTION

I would like to begin this paper with the statement made more than 50 years ago by the Irish physicist H. Schenk (Schenk, 1972). I wish to eliminate the reader's doubts regarding the degree of relevance of the issue under consideration: "In many laboratories ... they often conduct experiments with instruments which have a wide range of accuracy... The study of resulting error makes it possible to predict errors for the system as a whole,… it makes possible to detect weaknesses in the performed measurements." One should agree with the author of this statement only on one important issue. At the same time it is necessary to make certain clarifications regarding the share of instrument error in the total error of the big data measurement technique. The material is based on the results we have revealed over decades at Forums at various levels. Most authors in various fields of knowledge think (Schenk, 1972) that the experiment error is determined by the error of the instruments used. This approach is wrong, because during the experiment setup and its implementation, additional errors must be taken into account. Previously, it was repeatedly explained that the total error of an real experiment is determined not so much by the error of the instruments used, but by the error of the experimental technique can differ significantly. This is due to the fact that the total error in the methodology of studying big data usually consists of a number of other methodological errors (Tukshaitov, 2006; Tukshaitov, 2019).

Some issues of optimal presentation of research results, including the presentation of mathematical

[1] https://orcid.org/0009-0004-1936-2658
[2] https://orcid.org/0000-0003-1572-5314

modeling results, are presented in a few sources (Krylov, 1954; Shchigolev, 1962; Seidel, 1985) that are inaccessible but remain little known to readers. This leads to the fact that many numerical data of the results, especially results of mathematical modeling of digital given by the authors are overestimated in the accuracy by as much as 3-5 orders of magnitude. For example, results described by two-digit numbers are given by six-digit and seven-digit numbers even within the same publication. It takes place in some works (Zubov, Mikrin, Ryabchenko, Poklad, 2016; Sybov, 2018; Zhukova, Morozov, 2023; Tukshaitov, 2021).

There are four sources of error in the result.

The error of the mathematical model. If the mathematical model is not chosen carefully enough, then no matter what methods we use for the calculation, all the results will not be reliable enough, and in some cases, completely incorrect.

The error of the initial data accepted for calculation. This is an unavoidable error, but this error is possible and must be assessed to select a calculation algorithm and the accuracy of the calculations.

The method error is based on the discrete nature of any numerical algorithm.

The rounding error is associated with the use in computers of numbers with finite representation accuracy.

Modeling results represented in the literature are highly overestimated in accuracy. This problem prompted us to introduce into practice, along with the term “measurement error,” a new term “representation error” (Tukshaitov, 2006; Tukshaitov, 2021).

What is a typical error in presenting mathematical modeling data?

The authors give significant figures in numbers arbitrarily, relying on the rounding level that is inherent in a given computer. Because of this, there are quite a lot of works where data in tables is given (Sybov, 2018; Elkina, 2005) from four-digit numbers to six (Zubov, Mikrin, Ryabchenko, Poklad, 2016; Elkina, 2005) - and eight-digit (Sybov, 2018). The accuracy of the results should be based on the accuracy of determining the initial indicators of the object included in the mathematical model. Some initial indicators of the sample parameters can be two-digit, others - three-digit, and others four-digit, respectively, with an error of at least 1%, 0.1% and 0.001%. At the same time, the number of significant figures as a result of the calculation should be no more than two. The degree of influence of each indicator on the final result of the calculation should be taken into account. Let us give a number of examples of misunderstanding of the importance of correct presentation of experimental data, identified only in recent years.

2 STATEMENT OF THE BACKGROUND OF THE PROBLEM

By 2002, having already had sufficient experience in processing experimental results presented in a number of publications, we made a report at the Kazan Institute of Physics and Technology named after Zavoisky at a school-seminar organized for physicists of the Middle Volga region. The seminar was then led by the vice-rector of science of Kazan State University (currently Kazan Federal University - KFU), and subsequently by the rector of KFU and the President of the Academy of Sciences of the Republic of Tatarstan M.Kh. Salakhov. To our surprise, the participants did not ask us a single question. Summing up the report, the head of the scientific seminar expressed the following thought: “Colleagues, over the past 25 years we have fallen behind in the processing and presenting experimental data.”

In 2010, we gave a special report to the staff of the Institute of Biophysics and Biochemistry of the Kazan Branch of the Academy of Sciences on the topic “Optimal methods for processing and for presenting experimental data.” The seminar participants listened to the report with approval and noted that they had read something at the university, but unfortunately much had already been forgotten.

Around 2017, at Annual Scientific Conference of the Institute of Energy of the Kazan Center of the Russian Academy of Sciences some speakers were told that the numerical data of mathematical modeling presented by them were overestimated by 3-4 orders of magnitude and their director Professor V.N. Shlyannikov generally agreed with that.

In 2020 we made a scientific report at Republican scientific seminar “Methods of mathematical modeling”, held under the auspices of the Academy of Sciences of the Republic of Tatarstan, dedicated to the same issue. The video of the speech was immediately posted on the Internet on the website of the scientific seminar. During the first year alone, more than 1,600 people read the report. Several well-known scientists of Kazan highly appreciated our understanding of the problem and the work done, for example, such as the head of the Department of

General Physics of KFU, long-term dean of the Faculty of Physics A.V. Aganov; Head of the Department of General Physics, Kazan National Research Technical University - Kazan Aviation Institute (KAI), Professor, Academician of the Academy of Sciences of the Republic of Tatarstan B.A. Timerkaev; Director of the Institute of Mathematics of the Kazan Federal University, Professor, Academician of the Academy of Sciences of the Republic of Tatarstan Nasyrov S.R. and others. At the same time during the meeting Professor B.A. Timerkaev stated that practically many results containing more than three significant figures are obtained with such precision. We fully share this perception of his presentation of the results.

A year later we took part in the same seminar on "Methods of Mathematical Modeling". One of Kazan National Research Technical University professors, the theoretical physicist who had previously participated in many foreign forums in Europe, Israel, Turkey, China and Japan, gave a presentation. His results were given in five-digit numbers. With friendly irony, he was asked the question: "Maybe your results will be more accurate if they are presented not in five-, but in six-digit numbers." The speaker did not begin to polemicize and briefly answered that everything was accurate. True, he later made it clear and said that these were not his data. The data were borrowed from another paper. We replied that it was necessary to borrow numerical data with their preliminary appropriate rounding. His colleague, the recognized scientist at Kazan National Research Technical University, came to the speaker's defense. He began to explain that the numerical data in the work were presented correctly because an analog-to-digital converter with very high accuracy was used. Such a stereotypical view unfortunately is often among many researchers who have a lot of experience in scientific work.

In the fall of 2023 during International Scientific Conference dedicated to the 100th anniversary of Rashid Shakirovich Nigmatullin the former rector of the Kazan Aviation Institute and the radiophysicist, one of the speakers (El-Khazali, 2023), representing the University in Abu Dhabi of the United Arab Emirates, *EL-Khazari Reayrd* was asked the following question regarding the accuracy of his mathematical modeling results: "Your table presents the results of mathematical modeling in five-digit numbers. Data are often presented with such accuracy in our prestigious physics journals. Your data is actually determined with an error of up to 0.0001%. Please tell me what the error was used in the research methodology, which we should focus on." This question puzzled the speaker and he replied: "The error was determined by the error of the mathematical method." Further, continuing the debate, they added that "each mathematical method had its own certain error." The chairman of the meeting suspended our discussion because the speaker was a foreign guest. According to our assessment, the accuracy of data presentation in his work is overestimated by 1000-10000 times relative to the accuracy of the methodology used. With our question, we only wanted to draw the attention of the speaker and of the audience to the inadmissibility of unconfirmed accuracy of calculation results. At this conference, during a break, we briefly met Professor Nikitov S.A., one of the interesting speakers at the Plenary session, who gave me his email address to forward one of our articles.

Somewhat later, with the help of the Internet, it turned out that he was the director of the Institute of Radio Engineering and Electronics and the academician of Russian Academy of Sciences. To explain this problem, we sent him one article (Zhukova, Morozov, 2023). Some time later we sent him another article of a sociological nature (2022), where we proposed our method of determining the rating of scientists which may be of interest to him. Unfortunately, no replies were received. Partly due to his busy schedule and to the fact that these issues seemed not relevant to him, especially in relation to solving problems in radio engineering and electronics. We can only partly agree with this because there are analysis of a number of explanatory examples presented in journals, including "Practical Power Electronics" (Tukshaitov, 2021). I would like to especially note the attitude of the Academician of the Russian Academy of Sciences, the former director of the Military Academy of Shipbuilding, the professor of mechanics and mathematics A.N. Krylov and the author of a series of lectures on approximate calculations (Krylov, 1954) to this problem. He often, as a director, even punished his employees for overestimating the accuracy of calculated data, because the permitted overestimation of data increased demands on the results of calculations of subsequent indicators.

At the end of the scientific conference, the discussion on our remark continued in correspondence with one of the authoritative physicists, who concluded by noting that "the accuracy of the representation did not play a serious role when writing the final result". None of the readers analyze errors in arithmetic operations. This kind of 'enlightenment' has no meaning for the audience." Misunderstanding of the relevance of this problem puzzled and prompted us to once again take up the task of clarifying the issue, especially since my respected opponent recommended “writing a new article and showing when errors become significant.”

Based on the above-mentioned nature of the reaction to our statements regarding mistakes made in presenting experimental data and modeling results, one can judge the insufficient perception of the issues covered by a fairly wide range of researchers.

Numerical explanation of the errors formation mechanim

According to an important provision of metrology, the error in data presentation should not be higher than the error in the measurement technique, since an overestimated representation of the accuracy of the data is often mistakenly perceived as the high accuracy of the research. A typical mistake made by researchers is that in numerical modeling the data is assumed to be fixed without taking into account the error in determining the initial data themselves, which in this case should be perceived as physical “constants”. According to (Seidel, 1985), even physical constants undergo changes over time due to changes in the initial conditions of their determination. For a clear explanation, here are a few elementary examples.

Some authors believe that if only one of the parameters is represented by a three-digit number, then the result of the calculation should also be represented as a three-digit number. The latter, for fear of loss of accuracy the result of the calculation is given as a four-digit number, for example in the form of 3.245, while it is enough to give the result of the calculation only as a two-digit number (in the form of 3.2).

This explanation still remains insufficiently clear to many scientists, and therefore we will explain it in a different way. Suppose in the numerator of the analytical expression the first number is represented by a two-digit number, the second by a three-digit number, and in the denominator by a four-digit number, or in other words, they are presented respectively with an error of 5%, 0.1% and 0.01%. If the error in presenting the result must correspond to the error in the measurement technique (Tukshaitov, 2006), then the calculation result cannot be presented with an error of less than 5%. It follows that the result of the calculation, depending on the absolute value of the number in this example, can be represented as a two-digit number.

To illustrate the overestimation of modeling results allowed in publications, we present a table borrowed from (Tukshaitov, 2021).

Table 1: Power modeling results of control cascade in the Multisim software environment (Tukshaitov, 2021).

Parameters	Uin min and in = 50 A	For For Uin nom and in = 50 A
Input supply voltage (V14)	13.59842	16.99842
Output voltage (V15)	11.99809	12.00001
Emitter voltage VT14 (VT16)	13.43185	13.43384
Voltage on base VT5	3.23106	13.23301
Emitter voltage VT (V22)	2.21896	12.22092

In this table the parameters of the power transistor, usually measured by modern devices with an error of 1-2%, are erroneously shown in seven-digit numbers with an error in their representation of at least 0.00004%.

Perhaps the above explanation of the issue continues to remain not entirely clear to the reader. Therefore, we will explain the mechanism of formation of the error in the result using the following specific examples of numerical modeling.

Example. Let's demonstrate the permissible error using a simple example. Let's say we need to calculate the value of Y based on only three known parameters using the formula Y = (A B)/C. Substituting their conditional values into the formula, we get

$$Y = (13 \bullet 373)/ 22.16=218.82$$

The first number is actually an integer with a margin of error of 3.8%. The second number is with a margin of error of 0.14%. The third number is with an even smaller margin of error of 0.023%. Without taking into account possible deviations of the parameters from the original ones, most authors will give a similar result equal to 218.8. The smaller of them is equal to 218.82 and even 218.824, and practically few - as an integer with additional rounding in the form of 220. Since the actual calculation error is 3.8 %, then the desired value, depending on the level of the greatest error of the entered number, will be reproduced in the range 211 - 228. Based on this, the result of the calculation can be completely written as the number 219, or better yet 220.

If we take into account the probability of an overestimation of two factors only in the numerator, and let’s say the denominator remains unchanged. Then we get another number equal to 219, which naturally fits into the above range of probable values. As the number of factors in the numerator and denominator of the formula increases, the error in determining the result by numerical modeling will only increase. It follows that tenths and hundredths are misrepresented in the calculation and they should therefore be excluded. It is necessary to additionally round whole numbers, giving only the first three significant digits as digits, and the rest as significant zeros.

These recommendations for presenting results are based on taking into account only the error of the initial parameters included in the model. At the same time, specialists in mathematical modeling know that the deviation of modeling results for a number of reasons can actually range from 10 to 50% due to the inadequacy of the model itself. Based on these error levels, we can conclude that the simulation results are often only fair to present as a two-digit number.

The scientific community doesn't accept the need to eliminate errors in processing experimental and calculating data. We have to give a number of more examples in different areas of knowledge in our article. It should be noted that all numbers given in (Kostinsky, 2020) are five- and six-digit, which is as much as 2-3 orders of magnitude higher than the accuracy of the instrument used, which is not acceptable. Conversion frequencies also could not be established experimentally with such high accuracy (0.001%). We propose to consider the same table, but edited in accordance with metrological requirements.

Table 2: Table borrowed from (Kostinsky, 2020).

f, Гц	Converter loading range, %	Interval of changes in THDi values, %		Relative change in THDi, %
		min	*max*	
50	19.947 – 65.038	143.958	106.493	35.231
45	17.611 – 54.318	147.218	112.643	30.703
40	15.120 – 44.359	150.478	119.242	26.290
35	12.951 – 35.593	155.381	121.964	27.397
30	11.145 – 27.781	163.041	131.412	24.132
25	9.487 – 21.040	162.121	140.906	15.031

Table 3: Form of presentation of the table (Kostinsky, 2020) in accordance with metrological requirements.

f, Гц	Converter loading range, %	Interval of changes in THDi values, %		Relative change in THDi, %
		min	*max*	
50	19.9 – 65.0	144	106	35
45	17.6 – 54.3	147	113	31
40	15.1 – 44.3	150	119	26
35	12.9 – 35.5	155,	122	27
30	11.1 – 27.7	163	131	24
25	9.48 – 21.04	162	141	15

The relative values of THDi, expressed as a percentage, can easily be presented as two-digit numbers for the reason that, on the one hand, the accuracy of their representation is overestimated, and on the other hand, this indicator is the final indicator in our research. It is not intended for calculating derivatives indicators. Therefore, it can be represented with slightly less accuracy. Based on the accuracy of the data presented in table 2 we can say that contrary to the authors' statement, the data were obtained not experimentally, but by calculation.

The accuracy of the representation of g-factors when presenting the results of research in the field of Electron Paramagnetic Resonance is not adequate. It remains unclear how some authors give the g-factor as single-digit numbers (Dubiel, Zywczak, Mariarze, 2019; Domracheva, Vorobyova, 2017; Piwowarska, Grutek, Rudowicz, 2019), and others as five-digit (Altshuler, S., 1972; Shakurov, 2019;Tampieri, Tommassini, Agnoli, 2020) and even seven-digit numbers in the form 2.002757±0.000006 (Wertz, Boldton, 1975). In the latter case, along with the g-factor value, the standard deviation is given, which, as a rule, is not indicated by many authors. In addition, in this work, the accuracy of number representation is an order of magnitude which is higher than the accuracy of the relative value of the standard deviation. If we take into account the capabilities of computer technology, then the question arises why many were limited to seven-digit numbers.

In (Chachkov, Mikhailov, 2017), the molecular structures of 14 forms of the Al2Zn3 metal cluster were calculated. At the same time, the authors make a reservation about the approximate nature of the calculations. In table 4 the coordinates of atoms in molecular structures for only two forms are given.

Table 4: Coordinates of metal atoms in molecula (Tampieri, Tommassini, Agnoli, 2020).

Atom	Cartesian coordinates		
	x	y	z
Form 1			
AL1	-0.385668	0.000571	-1.387377
Al2	-0.386316	-0.000851	1.385837
Zn1	1.539499	1.239631	0.000574
Zn2	1.540108	-1.239388	-0.000115
Zn3	-2.745080	-0.000122	0.000209
Form 2			
AL1	0.620927	0.004761	0.550702
Al2	-0.897038	-0.000653	-1.871691
Zn1	-1.602745	1.289997	0.281809
Zn2	-1.596045	1.292645	0.282526
Zn3	3.318438	0.000868	0.008094

Using approximate calculations, the authors present results with an error of 0.00003%. Naturally, no device or technique used will provide such high accuracy. This means that the work contains a significant overestimation of the accuracy of data presentation.

We should also dwell on one typical error, which consists in overestimating the readings of the instruments themselves by 3 or even 10 orders of magnitude (Batalov, Novikov, Faizullin, Kurbatov, Gerasimov, 2023; Savinykh, Garkushin, Ruzorenov, 2023). Thus, when studying the Romanov spectrum of sapphire, the authors give the peak positions in four-digit numbers, with an error of the order of 0.007%. Modern instruments are not capable of measuring the absolute values of the parameter under study. We can only talk about relative shifts of a parameter measured on the same instrument. The accuracy of the instrument readings should be based on the absolute error of the instrument, and not on the digital display data of the instruments, which always provides more accurate readings (several orders of magnitude).

We hope that a careful reading of the content of this work will allow the authors to avoid a number of common mistakes in presenting their data and take a more critical approach to analyzing the reliability of the materials of other researchers.

3 CONCLUSION

1. The error of modern instruments can often constitute only a small fraction of the total error of the mathematical modeling technique. Based on this, when assessing the results of mathematical modeling and numerical calculations of big data and digital twins, one should be guided only by the total methodological error.

2. The modeling error and, accordingly, the level of rounding of its result should be determined based on the error in determining the initial parameters used.

3. The number of significant digits produced by the computer on the display screens and instruments is determined only by their software settings. Therefore, numbers from four to twelve digits displayed on the monitor screen are subject to subsequent rounding, based on the real error of the final result of mathematical modeling.

4. To increase the productivity of processing big data and digital twins in the future, it is necessary to develop and use a tunable program that would allow the researcher to display results on a computer screen, taking into account the methodological error in determining each initial parameter and the methodological error of the mathematical model itself.

REFERENCES

Schenk, K., 1972. Theory of engineering experimen. Moscow: Mir.

Tukshaitov, R., 2006. Fundamentals of optimal presentation of statistical indicators in graphs, diagrams and tables (physics, chemistry, technology, biology and medicine). Ministry of Education and Science of the Russian Federation, Kazan State Energy University, Kazan.

Tukshaitov, R., 2019. System analysis of typical errors made in catalogs of LED lighting devices.To eliminate the fifth typical error," Semiconductor lighting engineering, No. 5 (61), pp. 16-20.

Krylov, A., 1954. Lectures on Approximate Computing. 6th edition. State Technical Publishing House, Collected works, vol. 3, part 1, Publication of the USSR Academy of Sciences.

Shchigolev, B., 1962. Mathematical processing of observations. Moscow: State Publishing House of Physical and Mathematical Literature.

Seidel, A., 1985. Errors in measurements of physical quantities. Edited by Academician Zh.I. Alferova. Leningrad: Nauka.

Zubov, N.E., Mikrin, E.A., Ryabchenko, V.N., Poklad, M.N., 2016. Parameterization of analytical laws for controlling the lateral movement of aircraft. *Bulletin of MSTU im. N.E. Bauman. Series: Instrumentation,* No. 2, pp. 3-17.

Sybov, N.N., 2018. Modeling processes in electrical circuits in problems of intelligent learning systems. *Practical power electronics,* No. 4 (72). pp. 47-56.

Zhukova, D., Morozov, M., 2023. The use of carbon-felt frames as an electrode conductive base for supercapacitors". International scientific conference "Nigmatullin readings – 2023," Collection of reports, October 9 - 12, 2023, Kazan ed. AN RT, pp. 292-295.

Tukshaitov, R., 2021. To eliminate typical errors in the presentation of electrical data allowed in textbooks and scientific periodicals. *Practical power electronics,* No. 1 (81), pp. 50-55.

Elkina, T., 2005. Power supply for industrial enterprises and civil buildings. Laboratory workshop: Textbook. Minsk: UE "Technoprint", pp. 64-71.

El-Khazali, 2023. "Reyad discretization of fractional –order controllers of complex orders," in Proceedings of the International Conference "Nigmatullin,s Readings-2023," Kazan: TAS publishing house, p. 14,

Kostinsky, S., 2020. Review and results of studies of the harmonic composition of the current consumed by low-power frequency converters, as well as methods and devices to reduce their negative impact on power supply systems. News of higher educational institutions. *Energy problems*, vol.. 22, No. 2, pp. 27-42.

Dubiel, K., Zywczak, A., Mariarze, W., 2019. Magnetic phase trasition and exchange bias in Ni45 Co5 Mn35.5 In14.5," Applied Magnetic Resonance, Vol. 50, pp. 809-818.

Domracheva, N.E., Vorobyova, V.E., 2017. Influence of anions on spin-crossover properties, molecular packing and magnetic behavior of dentritomer complexes of Fe (III) of the second generation," in. KIPT im. E.K. Zavoisky 2017. Yearbook, vol. 50, No. 6, pp. 63-70.

Piwowarska, D., Grutek, P., Rudowicz, C., 2019. Origin of ground Kramers Douplets for Co2+(3D17) ions with the effective spin 3/ verbus the fictitions spin1/2. Applied Magnetic Resonance, vol.. 50, pp. 797-808.

Altshuler, S., 1972. B. Kozyrev, Electron paramagnetic resonance of compounds of intermediate groups. M.: Nauka, pp. 265-271.

Shakurov, G.,2019. Tetrahedral centers of Cr4+ ions in a Li2CaSiO4 crystal. in KIPT im. E.K. Zavoisky, Yearbook, 2020, pp. 71-78.

Tampieri, F., Tommassini, M., Agnoli, S., 2020. N-Doped Graphene oxide nanoparticles studied by EPR. Applied Magnetic Resonance, vol. 47, pp. 1481-1489.

Wertz, J., Boldton, J., 1975. Theory and practical proposals of the EPR method. Transl. from English M.: Mir, pp. 367-369.

Chachkov, D.V., Mikhailov, O.V., 2017. Molecular structures of polynuclear metal clusters according to calculations using the DPT method. XVL (heterobi) pentanuclear cluster Al2Zn3,"Bulletin of the Technological University, vol. 20, No. 16, pp. 5-8.

Batalov, R., Novikov, G., Faizullin, D., Kurbatov, N., Gerasimov, K., 2023. Pulsed ion annealing of sapphire single crystals implanted with chromium ions," in KIPT im. E.K. Zavoisky, Yearbook vol. 22, pp. 111-117.

Savinykh, A., Garkushin, G., Ruzorenov, S., 2023. The influence of temperature on the dynamic elastic limit and spall strength of a lead-bismuth alloy at a shock compression pressure of up to 2.4 GPa. *Journal of Technical Physics,* vol. 93, issue 3, pp. 380-386.

Digital Technologies And Automated Information Processing Systems In The Penitentiary System

Aleksey Babkin[1][1], Olga Panfilova[1][2], Aleksandr Koljev[1][3], Oleg Golubev[2][4], Vladimir Testov[2][5]
[1]*Vologda Institute of Law and Economics of the Federal Penitentiary Service of Russia, 2, Shchetinin Str., Vologda, 160002, Russia*
[2]*Vologda State University, 15, Lenin str., Vologda, 160000, Russia*
aleksei_babkin@mail.ru

Keywords: Automation, automation tools, software, digital tools, information technology, penitentiary system, penal enforcement system, online services, ACUS software package, special report, correctional institution, quarantine department.

Abstract: Automated information processing systems for special and general purposes have recently been widely introduced in the domestic penitentiary system. Each of these systems is designed to perform special functions and a specific set of tasks. The scientific article is devoted to the study of issues of automation of the activities of employees of the penitentiary system on the example of the process of processing and recording the results of studying the personality of a newly arrived convict in the quarantine department of a correctional institution for making a decision on his further assignment to a detachment. The authors propose to automate this algorithm through the creation of a special report based on the ACUS software package (automated special contingent accounting file). The functionality and algorithms of working with the ACUS software package for designing and constructing reports are presented. The algorithm for building a special report for the development environment is being analyzed.

1 INTRODUCTION

Carrying out reforms in the legal sphere, including the penitentiary (penal enforcement), requires the development of new methodological approaches to influencing public consciousness in order to form and develop the state's penitentiary policy, correct personality and achieve preventive punishment goals, with their possible implementation through modern digital technologies. One of the main goals of the penal enforcement legislation of the Russian Federation is to correct those sentenced to imprisonment and prevent the commission of new crimes. (Efimenko, Lelik, 2018). However, despite the implementation of the state's policy aimed at reducing the number of people held in a correctional institution, imprisonment remains the most common punishment in modern Russia.

There are three main stages: initial, main and final conditionally includes the process of serving a sentence for convicts. Each of these stages has its own specific tasks, represents the characteristic conditions of serving a sentence by convicts and assumes the specifics of corrective action (Yuzhanin, Gorban, 2018). The admission of convicts to a correctional institution is carried out by the administration of the institution, in accordance with article 79 of the Penal Enforcement Code of the Russian Federation and in accordance with the Internal Regulations. Further, a set of various measures is carried out aimed at adapting the special contingent to the regime rules and requirements (Yuzhanin, 2017).

The process of deploying a special contingent requires the most serious attitude. This applies primarily to employees of penitentiary institutions. The activities of these subjects should be based on

[1] https://orcid.org/0000-0001-8033-1747
[2] https://orcid.org/0000-0003-2540-002x
[3] https://orcid.org/0000-0002-6780-6493
[4] https://orcid.org/0000-0003-2748-0051
[5] https://orcid.org/0000-0002-3573-574X

knowledge of law, pedagogy, psychology and come into contact with the study of the behavior of convicts and their adaptation to conditions of isolation. According to the results of studying the personality of the criminal, it is easier to start educational work, plan the future re-socialization of the convicted person (Bochkarev, 2013).

At the same time, the issues of the possibility of automating the process of processing and recording the results of studying the personality of a newly arrived convict in the quarantine department of a correctional institution remain not fully explored, in order to make a decision on his further assignment to the detachment, which determines the relevance of this work.

2 MATERIALS AND METHODS

The study used general methods of scientific cognition: interdisciplinary analysis and synthesis of the results of scientific research published in scientific and methodological literature, as well as the results of advanced scientific experience; comparative historical methods; methods of empirical research: expertise; software modeling.

3 RESULTS

The author's team was assigned the following task: to explore the possibility of developing a software tool for recording the results of studying the personality of a newly arrived convict in the quarantine department of a correctional institution. For this purpose, a descriptive part of the mechanism (hereinafter referred to as the algorithm) of the actions of correctional facility staff to collect the necessary primary information for making a decision when distributing a convict from the quarantine department to a detachment was provided in the form of the following table (table 1):

Table 1: Data entry table for the newly arrived convict.

1. Special Accounting Department	2. Security Department	3. Operational Department (group)	4. Logistics Department	5. Medical service
6. Psychologist	7. The Center for Labor Adaptation of convicts	8. Accounting	9. Department for educational work with convicts	

For a more detailed understanding of the issue, we have significantly revised the table and converted it into text blocks with detailed explanations for each item of the algorithm for filling in data on convicts, and compiled an analog of the terms of reference.

As an example, let's give the contents of one of the blocks (block 9):

Entering data on a convict who arrived at the quarantine department of a correctional institution:

1. Determination of the conditions of serving a sentence;
2. Level of education, availability of supporting documents;
3. Where he previously served his sentence, how he was released, where he was employed, how he was characterized, whether he participated in educational activities;
4. Attitude to sports, creativity;
5. Circumstances of the committed crime, admission of guilt;
6. The location of the passport;
7. Availability of a profession for employment, propensity for certain types of work;
8. Does he maintain relations with relatives;
9. The existence of grounds for preventive registration;
10. Religion;
11. The possibility of transfer
12. The presence of claims and alimony, the possibility of their payment from personal funds;
13. State of health, availability of supporting documents (disability);
14. The right to a pension, the availability of supporting documents;
15. The presence of a permanent place of residence.

The key task was to explore the possibility of automating this mechanism, to find a programmatic way to implement it.

Under the term "automation", scientists and specialists of various levels currently consider one of the directions of scientific and technological progress, which uses self-regulating technical means and mathematical methods in order to free a person from participation in the processes of obtaining, converting, transferring and using energy, materials, products or information, or significantly reduce the degree of this participation or the complexity of the operations performed (Tsebrenko, 2018; Sergeev, 2023).

Automation systems for both general and special purposes are being put into operation at an increasingly rapid pace in the penitentiary system of the Russian Federation. Various problematic issues of automation of the activities of units of the penal enforcement system are reflected in the works of A.V. Dushkin, E.G. Tsarkova, Yu.N. Dyatlov, A.V. Kalach, D.G. Zybin, V.I. Sumin, O.K. Beskrovnykh, E. B. Lunchenkova, N. V. Goryacheva, A.B. Maslov, L.V. Serik, V.G. Zarubsky et al.

Initially, from our point of view, the following options could be solutions to the task (Fig.1):

- full-fledged development of a new software product using one of the modern programming languages (object-oriented programming environment);
- development of a new software product based on existing online software services (online web services, online designers, etc.);
- development of a new software product using software tools of existing special platforms for the penal enforcement system (AKUS software package, electronic document management system of the penal enforcement system, etc.).

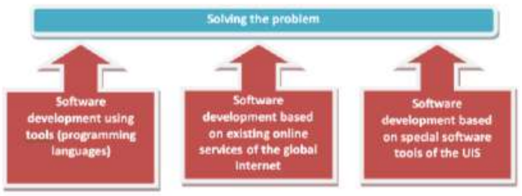


Figure 1: Options for solving a practical problem.

After conducting a detailed study of all areas, we came to the following conclusions, which we offer to your attention:

1. Almost immediately, the option of developing a software tool using high-level programming languages was eliminated. To create and maintain a complex program, it is necessary to have sufficient "knowledge base", which would require contacting third-party organizations or individuals. Such treatment was excluded due to the need to work with information of limited access (personal file, data of a convict admitted to a correctional institution).

2. Various online services, software designers, which can be found in abundance on the worldwide global Internet, including the mobile versions that have been so popular lately, did not suit us as a development tool for similar reasons. First of all, the bulk of these programs have weak free versions that have significant limitations in operation. You can remove them only when switching to the paid versions. In addition, the issue of ensuring the information security of the data of the special contingent when using online services remained open.

3. It was decided to focus on the existing software platforms created earlier for the units of the penitentiary system. From the available programs, our choice was made on the State information System "Software package for automated file registration of special contingent" for correctional colonies (ACUS software package).

The complex is included in the register of programs for electronic computers. The program is designed to automate the work related to the registration of convicts in a correctional institution. The complex accumulates and processes information of various types: from ordinary text information to photographs and fingerprint cards. The ability to generate and execute special requests and reports in a complex allows you to quickly obtain the necessary information, summarize data, statistical summaries, references and other materials (Babkin, Panfilova, 2022; Babkin, Karabanov, 2023).

The following characteristics made it possible to choose ACUS as the main software tool for the implementation of the task:

- the software tool has high technical parameters that allow for the use of subscriber data in real time by most services within the institution;
- the complex is designed in accordance with the internal instructions for maintaining special records;
- has most of the capabilities of information search engines;
- full security of convicts' data when working with the file cabinet (data entry, editing);
- regularly updated and developed in accordance with changes in the legislative framework and the wishes of the users themselves;
- all ACUS users within the institution work with a single database, have access to up-to-date information on convicts within the limits set by their personal profile. The filling capacity of ACUS card files can be several tens of thousands of subscribers.

In addition, among the positive aspects, we will highlight the further prospects for the development of ACUS, which, among other things, influenced our choice:

- bringing the software tools of the ACUS family in line with the changing instructions of the special accounting departments;
- functional development of ACUS family programs;

- development of new subprogram modules;
- improving the protection of personal data in ACUS environments and improving cryptographic protection during data transfer;
- the transition to technologies of distributed databases as part of geographically distributed data transmission networks, management and access should be carried out through a web application;
- improvement of technical support of programs;
- application of remote maintenance methods for software systems;
- application of remote expert assessment methods for filling databases;
- the use of cloud technologies for data storage.

It was decided to implement the algorithm by creating a special report based on the ACUS software package, which in the future we could import and implement into the activities of any correctional colony. We have prepared an approximate scheme for the implementation of not only the algorithm itself, but also options for further implementation of the report into the activities of the correctional institution through the creation of video instructions and practical guidance on integrating the finished report into the ACUS software package (Fig.2).

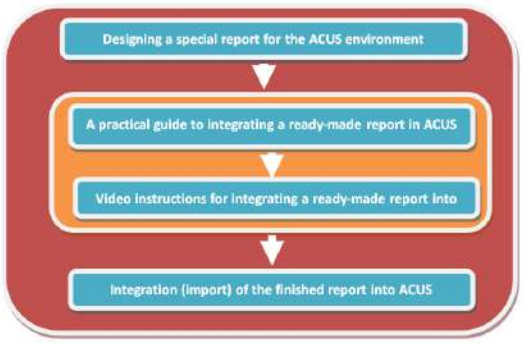


Figure 2: An approximate scheme of the algorithm implementation.

After studying and analyzing the submitted materials and forms of documents, the author's team designed and further constructed a special report in the ACUS environment. Here are the main stages of our work on the report in fragments.

All new reports for the ACUS environment are designed in the program Administration Mode, which contains a larger set of modules that allow you to make a variety of additional settings and select user actions.

The process of constructing a report includes two stages of work.

At the first stage, a new report is created in the Administration Mode in an existing or new section of the program (Fig. 3).

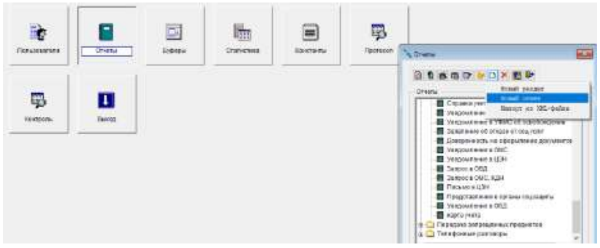


Figure 3: Creating a new report.

Next, work is organized with the Report Designer (Fig. 4), in which fields and forms are formed for subsequent filling in with data about the subscriber of the card file (convicted).

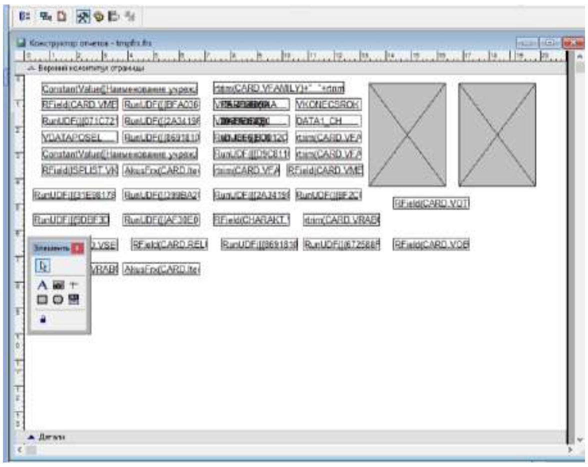


Figure 4: Report Designer.

Each field is created through the ACUS Expression Builder (Fig. 5) or by using a specific programming language.

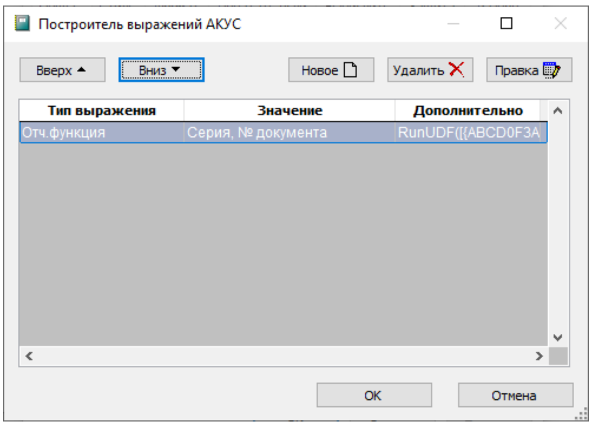


Figure 5: The ACUS Expression Builder.

At this stage of work on the future report, the most time-consuming procedures are the following:

- multiple creation of fields necessary for further automatic filling from the card file through the AKUS Expression Builder, by repeating many complex operations of the same type;
- the need to repeatedly view and edit the created labels, fields and other elements to organize the further output of the finished report (template for the report) on the monitor screen (printer).

After editing and correcting the report created in the Designer, the transition to the second stage of work is carried out – the creation of an MS Word Template (Fig.6) for further output of the finished report on a specific subscriber of the file cabinet (convicted) for printing.

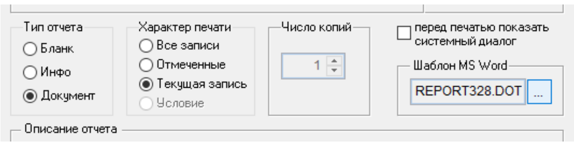


Figure 6: The button for creating an MS Word template for a report.

In general, creating an MS Word Template is a simpler operation compared to preparing a report in the Report Designer.

At the same time, the following nuances must be taken into account: in the process of forming the MS Word Template, the Word element "form" is used - a document with blank areas into which data is entered (text field, list, drop-down list, etc.). In the future, each form created in the MS Word Template should be identified with the same element created in the Report Designer. When identifying, it is necessary not to confuse the numbering of the report elements, which is created by the Report Designer (Fig.7).

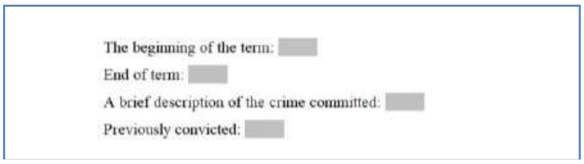


Figure7: MS Word template using forms.

Another possible stage of work, if necessary, is the export-import of the prepared report. Exporting a finished report means saving it as a file and "outputting" it from the ACUS system. Importing a report is adding (embedding) a ready-made (existing) report into the ACUS system (in one of the sections on reports).

4 DISCUSSION

Scientific and technological progress determines the modernization of legal mechanisms, the introduction of modern information technologies and automation and artificial intelligence tools, and orientation to the best practices of foreign countries (Sadykova, 2022; Anisimova, Burdo, Volkova, 2023; Spasennikov, Golodov, 2016). Automation tools and information technologies are actively penetrating into all spheres of public relations, including the activities of correctional institutions and penitentiary system bodies (Lungile, Lungelo, Tlou, 2020).

Recently, the ACUS Software package has become a key software product designed to automate accounting in institutions and bodies executing criminal penalties in the form of imprisonment. Personal and generalized ACUS information is necessary for the services, but can be used by other law enforcement agencies when making government decisions. At the moment, ACUS has the status of a state information system (Babkin, 2020).

As we mentioned earlier, the program is designed to automate the work related to the registration of convicts in correctional institutions and pre-trial detention centers in relation to persons left for household maintenance. Information of various types is accumulated and processed in ACUS: from ordinary text information to photographs and fingerprint cards. The ability to generate and execute special requests and reports in a complex allows you to quickly obtain the necessary information, summarize data, statistical summaries, references and other materials.

An employee of a correctional institution in the course of his official activities has to access the resources of an automated file cabinet on a daily basis. In particular, by the nature of their activities, they often need to use the built-in ACUS module "Reports", since obtaining documents based on data is realized through the use of a reporting system. Reports are data display objects that are used to view and print various information in a pre–prepared form. Most of the reports are based on the instructions for maintaining special records. The developer has already incorporated standard reports for specialists of different levels into the ACUS software environment. But there are situations when there is no ready-made report in the presented "line" and it needs to be created and subsequently integrated into the ACUS environment. Therefore, the implementation of a software solution to automate the process of processing and recording the results of studying the personality of a newly arrived convict in the quarantine department of a correctional institution, in order to make a decision on his further distribution to the squad, through the creation of a special report based on the ACUS software package described by us in this article is of great importance for the penal enforcement system. At the same time, additional conditions are necessary for the further successful development of the complex: the creation of a security system, the development of a significant package of documentation, etc. (Beskrovnykh, Savinova, 2017).

5 CONCLUSION

Of particular importance for the successful implementation of the procedure for the admission of convicts and their further adaptation is not only the competent organization of interaction between the administration of the correctional institution and the investigative and judicial authorities, but also the possibility of promptly recording in electronic form the results of studying the personality of the convict for making a decision on his further assignment to the squad.

Special reports for the ACUS environment greatly facilitate the preparation of materials in various areas of activity. The capabilities of the ACUS allow you to automate the official activities of specialists working with convicts. The data necessary for the departments and services of the institution (correctional colony) become available at any time. The detailed implementation of the algorithm considered by the authors in the form of building a special report to record the results of studying the personality of a newly arrived convict in the quarantine department of a correctional institution based on the ACUS software package will help fully automate the activities of services and departments of institutions and bodies of the penitentiary system, and will also contribute to the observance of the legality of serving a sentence.

REFERENCES

Efimenko, A.A., Lelik, N.B., 2018. On the issue of working with those sentenced to imprisonment in the quarantine department. In: Utkin, V.A. (eds.) ALL-RUSSIAN SCIENTIFIC AND PRACTICAL CONFERENCE 2018, PENAL SYSTEM: PEDAGOGY, PSYCHOLOGY AND LAW, pp. 55–60. Tomsk Institute for Advanced Training of Workers of the Federal Penitentiary Service, Tomsk.

Yuzhanin, V.E., Gorban, D.V., 2018. Initial and final stages of serving imprisonment: problems of conceptual definition. Man: crime and punishment 2, vol. 26, 148–153.

Yuzhanin, V.E., 2017. The initial stage of serving a sentence of imprisonment: problems of conceptual definition. Bulletin of the Institute: crime, punishment, correction 1(37), 4–10.

Bochkarev, V.V., 2013. Preventive measures during the period of convicts' stay in the quarantine department of a correctional institution. Bulletin of the Kuzbass Institute 4(17), 36–39.

Tsebrenko, K.N., 2018. Modeling the electronic environment of an educational organization in accordance with the requirements of federal standards. Information resources of Russia 4, 38–43.

Sergeev, M.K., 2023. Automated systems for information processing and control. Current research 24-1(154), 58–63.

Babkin, A.A., Panfilova, O.A., 2022. Modern means of automating the activities of employees of the penal system: some features of the design and construction of special reports for the environment of the AKUS software complex. Voronezh Institute of the Russian Federal Penitentiary Service 1, 27–34.

Babkin, A.A., Karabanov, R.M., 2023. On the issue of the possibility of developing a special software tool for processing and recording the results of studying the personality of a newly arrived convict in the quarantine department of a correctional institution. Voronezh Institute of the Russian Federal Penitentiary Service 3, 39–45.

Sadykova, R.A., 2022. Experience of foreign countries in the use of artificial intelligence technologies in the penitentiary system. Administrative law and procedure 12, 67-69.

Anisimova, A.M., Burdo, E.P., Volkova, M.A., 2023. Prospects for the use of artificial intelligence in institutions of the penal system. Law and Legislation 11, 187–191.

Spasennikov, B.A., Golodov, P.V., 2016. Foreign experience of penitentiary activities: literature review. On the way to civil society 1(21), 30–34.

Law Enforcement Technology and the Future of Prison Systems, https://www.realtimenetworks.com/blog/law-enforcement-technology-and-the-future-of-prison-systems, last accessed 2024/01/31.

Lungile, P.L., Lungelo, S.M., Tlou, M.M., 2020. Prison breakthrough:use of information systems in correctional facilities. JOURNAL OF SASA, vol. 53.

Babkin, A.A. 2020. Methodology for organizing work with data clipboards in the AKUS software package when training employees of territorial bodies in advanced training courses and professional retraining for heads of correctional institutions. Penitentiary science 14(3), 431–436.

Beskrovnykh, O.K., Savinova,M.O., 2017. Issues of development and implementation of information systems in institutions and bodies of the penitentiary system. In:Collection of scientific works of employees of the FKU NIIIT FSIN of Russia, pp. 53–56.NIIIT FSIN of Russia, Tver.

Algebraic Quasi – fractal Modeling of Complex Systems with Intermittent Links

Natalia A. Serdyukova[1][a], Vladimir I. Serdyukov[2][b]
[1]*Russian Customs Academy, Komsomolsky Prospekt, 4, Lyubertsy, Russia*
[2]*Bauman Moscow State Technical University, 2nd Baumanskaya st., Moscow, Russia*
nsns25@yandex.ru, wis24@yandex.ru

Keywords: Smart systems, algebraic quasi-fractal systems, algebraic quasi-fractal logic, digital transformation, measurement scales, financial security, financial and economic systems, forecasting, structural sustainability

Abstract: Paper contains brief summary of new instruments of description of complex systems based on the works on the theory of algebraic systems by A.I. Maltsev, on the works on of the theory of fractals by Benoit Mandelbrot, the works of A. Tarsky, and the monographs of Serdyukova N.A. and Serdyukov V.I.. A new instrument, algebraic quasi – fractal systems, for investigation of complex systems with intermittent connections are offered on this base.

1 INTRODUCTION. RESEARCH METHODOLOGY

The background for the processes of digital transformation in almost all spheres that ensure and link the functioning of social society were the mathematization of science noted in the work of I.G. Shafarevich (Shafarevich, 1999) and the development of technologies based on the latest achievements of natural sciences. In fact, modern digital transformation is the next stage of the introduction of mathematics into practice, which began with the advent of mathematics. In addition, it should be noted that digital transformation is also the next stage in the implementation of the systematic approach developed in 1937 by Ludwig von Bertalanfi. Algebra and logic are currently key areas in the study of digital transformation, and it can be considered as the most important mechanisms that ensure strategic, fundamental goals and achievements of digital transformation. The role of mathematical methodology and methods underlying the digitalization of complex intelligent systems is increasing. The paper considers, in particular, a brief survey of algebraic methods of digitalization of complex systems, namely, methods of algebraic quasi–fractal logic introduced and developed by the authors, and a new approach to description of systems with intermittent connections.

The concept of a quasi–fractal algebraic system with a countable number of quasi-fractal levels was introduced in (Serdyukova, 2018). The concept of a quasi–fractal algebraic system with the number of levels equal to ω_γ, where ω_γ is an ordinal, and the notion of a quasi – fractal operator QF were introduced in (Serdyukova, Serdyukov, 2021). Among the received practical applications were, for example, the following ones:

- issues of stability of smart systems, in particular, the concept of stability of quasi– fractal algebraic systems, as well as factor –flexible quasi-fractal systems, was introduced and investigated,
- tensor estimation of smart systems satisfying a certain specified property /P – property/ is constructed, (Serdyukova, 2018).

In (Serdyukova, Serdyukov, 2021; Serdyukova, Serdyukov, 2022), based on the concept of quasi – fractal Boolean algebra, an algebraic quasi – fractal logic of the first order is introduced and studied.

In (Serdyukova, Serdyukov, 2019), the connection of quasi – fractal algebraic systems with mathematical logic is considered, in particular, the function of digitalization of the algebra of propositions and the narrow predicate calculus

[a] https://orcid.org/0000-0002-8746-0055
[b] https://orcid.org/0000-0002-0707-7524

(NPC) is constructed, which allows us to build numerical estimates of the truth values of closed formulas of the algebra of propositions and the narrow predicate calculus (NPC).

Analogs of theorems on the properties of a probability measure are obtained for the function of digitalization of the algebra of propositions and the narrow predicate calculus (NPC). As a practical application of the concept of algebraic quasi –fractal logic, an approach is proposed on the basis of which an algorithm for solving the problem of information reliability is developed. In (Serdyukova, Serdyukov, Kusminova, Shishkina, 2024) conditional groups' probability function and conditional digitalization function are introduced. Conditional groups' function of digitalization can be used to clarify the qualitative side of the forecast and its connection with the quantitative characteristics. The definition of a measurement error, connected with conditional digitalization function is given. As a practice application of this notion the explanation of possible causes of forecasting errors in smart systems /in smart university ranking systems, in financial - economic systems are got.

In (Serdyukova, 2018) an algorithm was developed for determining the number of synergistic effects of a system determined by a finite number of factors, and on this basis, measurement scales were constructed to capture the synergistic effects of the system. This allows one to significantly reduce the risks that arise during the operation of the system. In continuation of this, in (Serdyukova, Serdyukov, Kusminova, Kusnetsov, Shishkina, 2022) a risk analysis algorithm for smart planning systems and a risk analysis algorithm for smart control systems were built.

2 RESEARCH RESULTS. DISCUSSION OF THE RESULTS

2.1 Systems with Intermittent Connections Notation trough Bayesian Approach and a Conditional Digitalization Function

Using an algebraic quasi-fractal, one can write down systems with intermittent connections/ links. To do this, we apply a conditional digitalization function using the Bayesian approach, (Serdyukova, Serdyukov, 2021). The defining relations in a group define the connections, and so the Bayesian approach will work. The lack of connection at the upper level of the quasi-fractal weakens the connections at its lower levels, (Serdyukova, Serdyukov, 2021).

The breakdown of the connections of the system in the models of factors defining the system in the form of quasi -fractal groups is associated with the presence of free non-abelian subgroups in these models, i.e. with the amenability property. Breaking the links of the system S modeled by the group of factors

$\boldsymbol{G} = \langle G = \{a_1, \dots, a_n | i \in I\} | \{w_i(a_1, \dots, a_n) = 1, i \in I\rangle$ means that at least one of the defining relations, say $\{w_j(a_1, \dots, a_n) = 1$ falls out, then we get the following model for the system S in the form of a group $\boldsymbol{G_j} = \langle G_j = \{a_1, \dots, a_n | i \in I\} | \{w_i(a_1, \dots, a_n) = 1, i \in I, i \neq j\rangle$. Then $\boldsymbol{G}$ is an epimorphic image of $\boldsymbol{G_j}$. So, $\boldsymbol{G} \cong \boldsymbol{G_j}/\boldsymbol{ker}\,\varphi_j$, here $\varphi_j: \boldsymbol{G_j} \to \boldsymbol{G}$; $Im\varphi_j = G$ **.**

Systems with intermittent connections are useful in studying dynamics of complex systems. So, areas of application of algebraic quasi-fractal dynamics include the following ranges: dynamic planning, that is, decisions are made during system operation based on an analysis of the current situation.

Based on the work of S. McLane (Mac Lane, 1991), an approach that allows to use Category Theory to study temporal logic has been developed. Using this approach, the concept of P −purity, (Serdyukova, 1991), can be defined in the class of algebras of finite signature with equality and finite-ary operations, as well as in categories and in first-order logics. This technique and the fixed - point theorem make it possible to determine the level of sustainability of quasi-fractal logic of the first order.

So, let's define a quasi – fractal category.

Definition 1. A quasi – fractal category is a quasi – fractal monoid for the product in the general sense described in the following way.

A meta quasi – fractal graph $QF^{\alpha}_{k<\omega_\gamma}(\boldsymbol{A^{\alpha}_k} = (\langle A^{\alpha}_k; \Omega_k\rangle, \alpha \in \Lambda_k))$, here ω_γ is an ordinal, consists of objects $\boldsymbol{A^{\alpha}_k} = \mathcal{Ob}^{\alpha}_k = \{a^{\alpha}_k, b^{\alpha}_k, c^{\alpha}_k, \dots, |\alpha \in \Lambda_k\}$, |arrows

$\Omega_k = \mathcal{Ar}^{\alpha}_k = \{f^{\alpha}_k, g^{\alpha}_k, h^{\alpha}_k, \dots, |\alpha \in \Lambda_k\}$, and two operations run as follows:

Domain, which assigns to each arrow f^{α}_k an object $a^{\alpha}_k = dom f^{\alpha}_k$; codomain which assigns to each arrow f^{α}_k an object $b^{\alpha}_k = cod f^{\alpha}_k$. These operations on f^{α}_k are best indicated by displaying f^{α}_k as an actual arrow starting at its domain and ending at its codomain. A meta quasi – fractal category is a meta quasi – fractal graph with two additional operations: quasi – fractal identity, which assigns to each object a^{α}_k an arrow $id_{a^{\alpha}_k} = 1_{a^{\alpha}_k}: a^{\alpha}_k \to a^{\alpha}_k$; composition which assigns to each pair $\langle g_k^\alpha, f_k^\alpha \rangle$ of arrows with $domg_k^\alpha = codf_k^\alpha$ an arrow $g_k^\alpha \circ f_k^\alpha$ called their composite, with $g_k^\alpha \circ f_k^\alpha : domf_k^\alpha \to codg_k^\alpha$. This operation is pictured by the diagram

$$\begin{tikzcd} & b_k^\alpha \arrow[dr, "g_k^\alpha"] & \\ a_k^\alpha \arrow[ur, "f_k^\alpha"] \arrow[rr, "g_k^\alpha \circ f_k^\alpha"] & & c_k^\alpha \end{tikzcd}$$

These operations in a meta category are subjects to the two following axioms:

Associativity. For given objects and arrows in the configuration

$$a_k^\alpha \xrightarrow{f_k^\alpha} b_k^\alpha \xrightarrow{g_k^\alpha} c_k^\alpha \xrightarrow{m_k^\alpha} d_k^\alpha$$

One always has the equality

$$m_k^\alpha \circ (g_k^\alpha \circ f_k^\alpha) = (m_k^\alpha \circ g_k^\alpha) \circ f_k^\alpha \quad (1.1)$$

This equation is represented pictorially by the statement that the following diagram is commutative:

$$\begin{tikzcd} a_k^\alpha \arrow[rr, "m_k^\alpha \circ (g_k^\alpha \circ f_k^\alpha) = (m_k^\alpha \circ g_k^\alpha) \circ f_k^\alpha"] \arrow[d, "f_k^\alpha"'] \arrow[drr, "g_k^\alpha \circ f_k^\alpha"' near start] & & d_k^\alpha \\ b_k^\alpha \arrow[rr, "g_k^\alpha"'] \arrow[urr, "m_k^\alpha \circ g_k^\alpha" near end] & & c_k^\alpha \arrow[u, "m_k^\alpha"'] \end{tikzcd}$$

Unit law. For all arrows $f_k^\alpha a_k^\alpha \to b_k^\alpha$ and $g_k^\alpha : b_k^\alpha \to c_k^\alpha$ composition with the identity arrow $1_{b_k^\alpha}$ gives

$$1_{b_k^\alpha} \circ f_k^\alpha = f_k^\alpha \text{ and } g_k^\alpha \circ 1_{b_k^\alpha} = g_k^\alpha \quad (1.2)$$

This axiom asserts that the identity arrow $1_{b_k^\alpha}$ of each object b_k^α acts as an identity for the operation of composition, whenever it makes sense. The arrows of any metacategory are often called its morphisms.

A quasi – fractal metacategory is to be any interpretation, which satisfies all these axioms.

Examples

1. An example is a quasi – fractal metacategory of quasi – fractal sets, which has objects all sets and quasi – fractal arrows all quasi – fractal functions, with the usual quasi – fractal identity functions and the usual composition of functions. Let's note, that one can consider a quasi – fractal set as a quasi – fractal algebraic system with empty signature, that is $QF_{k<\omega_\gamma}^\alpha(\boldsymbol{A}_k^\alpha = (\langle A_k^\alpha; \Omega_k = \emptyset \rangle, \alpha \in \Lambda_k))$, here ω_γ is an ordinal

$\boldsymbol{A}_k^\alpha = \langle A_k^\alpha; \Omega_k = \emptyset \rangle, \alpha \in \Lambda_k$ is an algebraic system of the level k, $QF_{k<\omega_\gamma}^\alpha(\boldsymbol{A}_k^\alpha = \langle A_k^\alpha; \Omega_k = \emptyset \rangle), \alpha \in \Lambda_k$ is a designation of a quasi-fractal system for the limit ordinal ω_γ, for the ordinal $\omega_\gamma + 1$ we have: $a_\alpha = \boldsymbol{A}_{\omega_\gamma+1}^\alpha = \langle A_{\omega_\gamma+1}^\alpha ; \Omega_{\omega_\gamma+1} = \emptyset \rangle$, $\alpha \in \Lambda_{\omega_\gamma}$ is an algebraic system of the level $\omega_\gamma + 1$, here ω_γ is the limit ordinal.

So, one can consider a quasi – fractal set as a quasi – fractal algebraic system with empty signature, that is $QF_{k<\omega_0}^\alpha(\boldsymbol{A}_k^\alpha = (A_k^\alpha, \alpha \in \Lambda_k)$ or as follows: $QF_{k<\omega_0}^\alpha(\boldsymbol{X}_k^\alpha, \alpha \in \Lambda_k)$ here ω_γ is an ordinal.

2. A quasi – fractal function means a quasi – fractal function with specified domain and specified codomain. A quasi – fractal function $QF_{k<\omega_\gamma}^\alpha(\boldsymbol{f}_k^\alpha : QF_{k<\omega_\gamma}^\alpha(\boldsymbol{X}_k^\alpha, \alpha \in \Lambda_k) \to QF_{k<\omega_\gamma}^\alpha(\boldsymbol{Y}_k^\alpha, \alpha \in \Lambda_k))$ consists of a quasi – fractal set $QF_{k<\omega_0}^\alpha(\boldsymbol{X}_k^\alpha, \alpha \in \Lambda_k)$, its domain, a quasi – fractal set $QF_{k<\omega_\gamma}^\alpha(\boldsymbol{Y}_k^\alpha, \alpha \in \Lambda_k)$ its codomain, and a rule, which assigns to each element $x_k^\alpha \in X_k^\alpha$ an element $f_k^\alpha x_k^\alpha \in Y_k^\alpha$, here ω_γ is an ordinal.

3. A quasi – fractal metacategory of all sets has as quasi – fractal object, all sets, as quasi – fractal arrows, all quasi – fractal functions with the usual composition. The quasi – fractal metacategory of all groups is described in the following way: objects are all quasi – fractal groups, arrows are all quasi – fractal homomorphisms of groups. The quasi – fractal arrows of any quasi – fractal metacategory are called

its quasi – fractal morphisms. Since the quasi – fractal objects of a quasi – fractal metacategory corresponds exactly to its quasi – fractal identity arrows, it is technically possible to dispense altogether with the quasi – fractal objects and deal only with quasi – fractal arrows. The data for quasi – fractal arrows - only quasi – fractal metacategory $QF_{k<\omega_\gamma}^{\alpha}(\boldsymbol{\mathcal{C}} = (A_k^\alpha = \mathcal{Ob}_k^\alpha, \Omega_k = \mathcal{Ar}_k^\alpha, \alpha \in \Lambda_k))$, here ω_γ is an ordinal, consist of quasi – fractal arrows, certain ordered quasi – fractal pairs $\langle g_k^\alpha, f_k^\alpha \rangle$ called the composable pairs of quasi – fractal arrows, and an operation assigning to each composable quasi – fractal pair $\langle g_k^\alpha, f_k^\alpha \rangle$ an arrow $g_k^\alpha \circ f_k^\alpha$ called their composite. With these data one defines an identity of $QF_{k<\omega_\gamma}^{\alpha}(\boldsymbol{\mathcal{C}} = (A_k^\alpha = \mathcal{Ob}_k^\alpha, \Omega_k = \mathcal{Ar}_k^\alpha, \alpha \in \Lambda_k))$, here ω_γ is an ordinal, to be a quasi – fractal arrow u_k^α such that $f_k^\alpha \circ u_k^\alpha = f_k^\alpha$ whenever the composite $f_k^\alpha \circ u_k^\alpha$ is defined and $u_k^\alpha \circ g_k^\alpha = g_k^\alpha$ whenever the composite $u_k^\alpha \circ g_k^\alpha$ is defined.

The concept of a quasi - fractal category allows us to transfer the Erdos- Renyi algorithm and the concept of a giant component to almost any quasi - fractal algebraic systems with varying degrees of error and regardless of the amenability of these systems. If the quasi – fractal system $\mathfrak{A}$ is not an amenable one, then one can apply the Erdos- Renyi algorithm to elementary theory of this quasi - fractal algebraic system $Th(\mathfrak{A})$**,** (Serdyukova, Serdyukov, 2021).

2.2 Risk Systems of the System *S* in accordance with Model *G*. Risk Models Descriptions Using Homological Algebra Method

An important role in the study of the functioning of complex systems belongs to the study of the internal risks of these systems. As a rule, the risk of functioning of a complex system is manifested in the rupture of the connections of this system. Examples of that conclusion can be found in training systems, financial and economic systems, and technical systems. In this regard, we propose the following definition

Definition 2 / Risk systems of the system S in accordance with model G

Let the system S be modeled by a group of factors $\boldsymbol{G} = \langle G = \{a_1, \dots, a_n | i \in I\} | \{w_i(a_1, \dots, a_n) = 1, i \in I\rangle$ with generators $\{a_1, \dots, a_n | i \in I\}$, and defining relations $\{w_i(a_1, \dots, a_n) = 1, i \in I$. Then the system with intermittent connections simulated by the groups $\boldsymbol{G_J}$=$\langle G = \{a_1, \dots, a_n | i \in I\} | \{w_i(a_1, \dots, a_n) = 1, i \in I \backslash J\rangle, J \subseteqq I$ is modeling subsystem risk of the system's model of group $\boldsymbol{G}$ for every $J \subseteqq I$, by a model $\boldsymbol{G}$**.**

In accordance with this definition one can construct the definition of a quasi – fractal risk system's S model

Definition 3 Let the system S be modeled by a quasi – fractal group of factors

$QF_{k<\omega_\gamma}^{\alpha}(\boldsymbol{G}_k^\alpha = (\langle G_k^\alpha; \Omega_k = \langle \cdot, \ ^{-1}, e \rangle \rangle, \alpha \in \Lambda_k))$,

$G_k^\alpha = \langle G_k^\alpha = \{a_{1}{}_k^\alpha, \dots, a_{n}{}_k^\alpha | i \in I\} | \{w_{i}{}_k^\alpha(a_{1}{}_k^\alpha, \dots, a_{n}{}_k^\alpha) = 1, i \in I_k^\alpha\rangle$ with generators $\{a_{1}{}_k^\alpha, \dots, a_{n}{}_k^\alpha | i \in I\}$ and defining relations $\{w_{i}{}_k^\alpha(a_{1}{}_k^\alpha, \dots, a_{n}{}_k^\alpha) = 1, i \in I_k^\alpha;$ here ω_γ is an ordinal.

Then the quasi – fractal system with intermittent connections simulated by the quasi – fractal groups

$QF_{k<\omega_\gamma}^{\alpha}(\boldsymbol{G_J}{}_k^\alpha = (\langle G_J{}_k^\alpha; \Omega_k = \langle \cdot, \ ^{-1}, e \rangle \rangle, \alpha \in \Lambda_k))$,

$G_J{}_k^\alpha = \langle G_J{}_k^\alpha = \{a_{1}{}_k^\alpha, \dots, a_{n}{}_k^\alpha | i \in I\} | \{w_{i}{}_k^\alpha(a_{1}{}_k^\alpha, \dots, a_{n}{}_k^\alpha) = 1, i \in I_k^\alpha \setminus J_k^\alpha\rangle$ with generators $\{a_{1}{}_k^\alpha, \dots, a_{n}{}_k^\alpha | i \in I\}$ and defining relations $\{w_{i}{}_k^\alpha(a_{1}{}_k^\alpha, \dots, a_{n}{}_k^\alpha) = 1, i \in I_k^\alpha \setminus J_k^\alpha$ is modeling subsystem risk of the system's model of group $\boldsymbol{G}$ for every $J \subseteqq I$, here ω_γ is an ordinal. The advantages of the latter definition run as follows. Using quasi – fractal technic one can construct algorithms one can improve a risk analysis algorithm for smart planning systems and a risk analysis algorithm for smart control systems, (Serdyukova, Serdyukov, 2022; Serdyukova, Serdyukov, Kusminova, Kusnetsov, Shishkina, 2022).

2.3 Risk Models Descriptions Using Homological Algebra Methods

Using Homological algebra's methods one can connect the notion of the state of the complex system S modeled by the group of factors $\boldsymbol{G_S}$ and a risks system $\boldsymbol{G_{Sj}}$ of the system S in accordance with the model $\boldsymbol{G_S}$**.**

In (Serdyukov, Serdyukova, Shishkina, 2023) the fisical sense of a group $Hom(G_S, A)$ in accordance with the notion of the state of a system S is considered. In the present section we shall accept the following: $Aut(G_S)$ is a model of the system's S states by a model $\boldsymbol{G_S}$. Using

the universal property of abelianization of a group G which runs as follows:

$$
\begin{tikzcd}
G \arrow[r, "ab"] \arrow[dr, "f"'] & G/[G,G] \arrow[r] \arrow[d, dashed, "F"] & 1 \\
& A &
\end{tikzcd}
$$

here

$$f = F \cdot ab$$
$$(\forall f: G \to A)(\exists F: G/[G,G] \to A)(f = F \cdot ab)$$
$$f = F \cdot ab \qquad (1.3)$$

one gets that any other group with this property is isomorphic to $G/[G,G]$.

This property allows one to establish a one-to-one correspondence between all homomorphisms from the group G to some abelian group A and all homorphisms from abelianization $G/[G,G]$ into group A. It allows us to connect a model of the system's S states by a model $\boldsymbol{G_S}$ and a model of the risks $\boldsymbol{G_{Sj}}$ of the system's S states by a model $\boldsymbol{G_S}$.

In the present section we shall accept the following: $Aut(G_S)$ is a model of the system's S states, $Hom(G_S, A_S)$ is a mapping/≡description of the system's S states through the model A_S, $Hom(G_S, A_R)$ is a mapping /≡description of the system's S states through the model A_R of the system R. We shall connect the homology group with topological distortions of the states of the system S, determined by different models of groups of factors that determine the system. So, from (1) we have

Corollary 4

The description of the system's S states through a model A_S, which is an abelian group

$$Hom(G_S, A_S)$$

coincides with the description of the system's S states through an abelianization $G_S/[G_S, G_S]$ of the group G_S by the model A_S.

Corollary 5

The description of the system's S risks states by a model $\boldsymbol{G_{Sj}}$ through a model A_S, which is an abelian group

$$Hom(\boldsymbol{G_{Sj}}, A_S)$$

coincides with the description of the system's S states through an abelianization $\boldsymbol{G_{Sj}}/[\boldsymbol{G_{Sj}}, \boldsymbol{G_{Sj}}]$ of the group $\boldsymbol{G_{Sj}}$ by the model A_S.

2.4 Closed Associative System's S and Risk Sytem's G_J Synergistic Effects Synchronization in Accordance with Molel of Factors G_S of the system S

Information about the synergistic effects of the system and information about the synergistic effects of the system and its internal risks are of great importance for the smooth functioning of complex systems.

In this section the we shall use the prime number theorem (PNT) to describe the number of synergistic effects of a closed associative system modelled by a finite group. Previously, in [4, Ch 3, Ch 4, Ch 10], we have shown that if system S is modeled by a finite group $\boldsymbol{G_S}$ of factors defining S, then the number of synergetic effects of S is a divisor of $|\boldsymbol{G_S}|$. So, to describe finite system S without synergetic effects, one need the prime number theorem (PNT), as the number of elements of a finite system S without synergetics effects should be prime. So, the model of risks $\boldsymbol{G_{Sj}}$ of a system S in accordance with a group of factors $\boldsymbol{G_S}$ is either unit group or coincides with $\boldsymbol{G_S}$.

The prime number theorem (PNT) describes the asymptotic distribution of the prime numbers among the positive integers. It formalizes the idea that primes become less common as they become larger by precisely quantifying the rate at which this occurs.

It is well known, that the distribution function of primes, is a function equal to the number of primes less than or equal to the real number x.

The distribution of primes is described more precisely by the integral logarithm function. The logarithmic integral function or integral logarithm $li(x) = \int_0^x \frac{dt}{lnt}, x \neq 1,$ is a special function which has number theoretic significance. In particular, according to the prime number theorem, it is a very good approximation to the prime-counting function, which is defined as the number of prime numbers less than or equal to a given value X.

The integral logarithm and the integral exponential function are related by the relation:

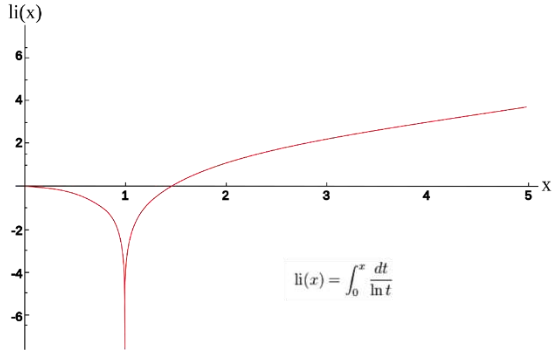


Figure 1: The logarithmic integral function (integral logarithm).

Fig. 1 shows that an increase in the number of factors of a group $\boldsymbol{G_S}$, which models the system S, the number of subsystems of the system S without synergetics effects increases.

So, we have

Theorem 6 (on the distribution of the number of synergetic effects in the systems)

The number of factors $|\boldsymbol{G_S}|$ of a group $\boldsymbol{G_S}$, which models the system S without synergetics effects, yield the prime number theorem (PNT). So, for the model of risks $\boldsymbol{G_{Sj}}$ of a system S in accordance with a group of factors $\boldsymbol{G_S}$ the number of risks' factors $|\boldsymbol{G_{Sj}}|$ increases with the grouth of $|\boldsymbol{G_S}|$, but $\boldsymbol{G_{Sj}}$ has no synergetics effects.

Theorem 7.

The number of subsystems without synergetics effects of a closed system S, modeled by a group $\boldsymbol{G_S}$ of factors defining the system S, increases with the growth the number of factors $|\boldsymbol{G_S}|$, which determine the system S. So, for the model of risks $\boldsymbol{G_{Sj}}$ of a system S in accordance with a group of factors $\boldsymbol{G_S}$ the number of risks' subsystems $\boldsymbol{G_{Sj}}$ increases with the grouth of $|\boldsymbol{G_S}|$, but the model of risks $\boldsymbol{G_{Sj}}$ by the model $\boldsymbol{G_S}$ has no synergetics effects.

3 CONCLUSIONS

Development of a methodology for constructing algebraic quasi-fractal models of smart systems, and, on this basis, the creation of practical applications in the field of digital transformation of the economy and finance, including in the field of taxation is one of the main tasks

The main scientific results in this area run as follows

The concept of algebraic formalization of a smart system was introduced (Serdyukova, 2018).

1. The concept of a presystem was introduced in (Serdyukova, Serdyukov, 2021);
2. The means of quasi-fractal mathematical logic are defined and described, allowing one to compare deterministic and random chaos (Serdyukova, Serdyukov, 2021);
3. Approaches to obtaining results using methods of quasi-fractal mathematical logic have been developed (Serdyukova, 2018; Serdyukova, Serdyukov, 2021; Serdyukova, 2018; Serdyukova, Serdyukov, 2022; Serdyukova, Serdyukov, 2019; Serdyukova, Serdyukov, Kusminova, Shishkina, 2024; Serdyukova, Serdyukov, Kusminova, Kusnetsov, Shishkina, 2022; Serdyukova, 1991; Serdyukov, Serdyukova, Shishkina, 2023);
4. Functions for digitalization of propositional algebra and narrow predicate calculus (UPC) have been developed (Serdyukova, Serdyukov, 2019);
5. Methods for algebraic formalization of smart systems and their algebraic identification have been developed, and their practical applications have been found (Serdyukova, 2018; Serdyukova, 2018; Serdyukova, Serdyukov, 2022; Serdyukova, Serdyukov, 2019; Serdyukova, Serdyukov, Kusminova, Shishkina, 2024; Serdyukova, Serdyukov, Kusminova, Kusnetsov, Shishkina, 2022; Serdyukova, 1991; Serdyukov, Serdyukova, Shishkina, 2023).

REFERENCES

Shafarevich, I.R., 1999. *Basic concepts of algebra*. - Izhevsk: Izhevsk Republican Printing House,.

Serdyukova, N., 2018. *Algebraic Identification of Smart Systems. Theory and Practice/* N. Serdyukova, V. Serdyukov, Intelligent Systems Reference Library, 191.

Serdyukova, N.A., Serdyukov, V.I., 2021. *Algebraic Quasi – fractal Logic*, in print.

Serdyukova, N., 2018. *Algebraic Formalization of Smart Systems. Theory and Practice*/ N. Serdyukova, V. Serdyukov. Smart Innovation, Systems and Technologies, Volume 91, - Switzerland, Springer Nature.

Serdyukova, N. A., Serdyukov, V. I., 2022. Mechanisms of Temporal Quasi - Fractal Logic in Smart Systems, in *Smart Education and e-Learning - Smart Pedagogy*, edited by Vladimir L. Uskov, Robert J. Howlett, Lakhmi C. Jain, volume 305, pp 456.

Serdyukova, N.A., Serdyukov, V.I., 2019. Digitalization of Propositional Algebra and NPC, *Procedia Computer Science* 00.

Serdyukova, N.A., Serdyukov, V. I., Kusminova, O.A., Shishkina, S.I., 2024. The Chaotic Presystem's Digital Management, in print.

Serdyukova, N.A., Serdyukov, V.I., Kusminova, O. A., Kusnetsov, A.N., Shishkina, S.I., 2022. Temporal Logic Usage in Control and Planning Models of Smart Systems, in *Smart Education and e-Learning - Smart Pedagogy*, edited by Vladimir L. Uskov, Robert J. Howlett, Lakhmi C. Jain, volume 305, pp 427 – 435.

Mac Lane, S., 1991. *Categories for the working mathematician*, - New York, Berlin, Heidelberg, Springer – Verlag.

Serdyukova, N.A., 1991. On generalizations of purities, *Algebra & Logic*, 30, № 4, 432 - 456.

Serdyukov, V.I., Serdyukova, N.A., Shishkina, S.I., 2023. Modeling of smart system states using homological algebra methods, Academy of Sciences of Armenia, Institute of Mechanics, Actual Problems of Continuum Mechanics, *Proceedings of the VIII International Conference*, October 01-05, 2023, Tsakhkadzor, Armenia, Yerevan, pp. 252-256 A 437 Actual problems of continuum mechanics. - Yerevan; Gitutyun, 362 s.

https://en.wikipedia.org/wiki/Logarithmic_integral_function#/media/File:Logarithmic_integral_function.svg.

Methods for Analyzing the Content of Petroleum Products in Soil

M. A. Kovaleva[1][a], T. N. Vinichenko[1][b], V. G. Shram[1][c], T. A. Luneva[2][d],
D. N. Britskaya[1][e] and T. Y. Matkerimov[3][f]
[1]Siberian Federal University, 660041, 82/6 Svobodny pr., Krasnoyarsk, Russia
[2]Reshetnev Siberian State University of Science and Technology, 660037, 31 pr. im. gazeta Krasnoyarsk worker, Krasnoyarsk, Russia
[3]Kyrgyz State Technical University, 720044, 66 Mira Avenu, Bishkek, Kyrgyzstan
Lera0727@yandex.ru

Keywords: Methods of analysis, petroleum products.

Abstract: The article discusses the methods that are most often used to determine and control the level of oil and petroleum products in the soil. Their comparative analysis is carried out. The data obtained from the study of soils contaminated with petroleum products by fluorimetric and gravimetric analysis, as well as IR spectroscopy, are analyzed. The indicators obtained during the study using IR spectroscopy are higher than when using the fluorimetric and gravimetric methods, one of the reasons for this, in our opinion, is the different nature of extractants.

1 INTRODUCTION

Today, oil and petroleum products are recognized as one of the main pollutants of the environment. Pollution by oil-like compounds is a powerful technogenic factor that negatively affects many natural processes and relationships (Yakovlev, Savenok, 2017).

Figure 1 shows the dynamics of several years of accidents at hazardous production facilities, which are subject to Federal State supervision.

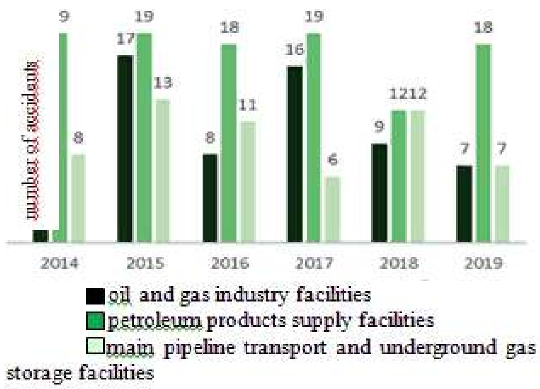


Figure 1: Dynamics of accident rates at hazardous production facilities in the oil and gas industry of the Russian Federation.

For local emergency spills, it is not possible to maintain such statistics, since often the point supply of petroleum products remains unaccounted for.

Soil pollution with petroleum products affects all physical and biological properties that determine the

[a] https://orcid.org/0009-0006-8313-8380
[b] https://orcid.org/0000-0002-1815-0360
[c] https://orcid.org/0000-0002-1415-1737
[d] https://orcid.org/0000-0001-5681-3658
[e] https://orcid.org/0009-0007-3164-8837
[f] https://orcid.org/0009-0007-9942-0839

fertility and ecological functions of the soil. Under the influence of petroleum products, soil particles aggregate and their ability to retain moisture is lost. A change in the physical properties of the soil leads to the displacement of air by oil products, disruption of the supply of water and nutrients, which leads to a slowdown in plant growth and their death. Even slight soil contamination with petroleum products helps to reduce the number of soil microorganisms. The gradual accumulation of difficult to decompose hydrocarbons, such as cyclic and aromatic hydrocarbons, resins and asphaltenes, leads to sealing of soil pores (Trofimov, Amosova, Orlov, 2008; Kovaleva, Slashchinin, 2023).

2 RESULTS AND DISCUSSION

Today, to assess the level of soil contamination with petroleum products in the Russian Federation, the following threshold concentration levels of petroleum products are recommended:

• less than 1000 mg/kg: acceptable level;
• from 1000 to 2000 mg/kg: low level of contamination;
• from 2001 to 3000 mg/kg: average level of contamination;
• from 3001 to 5000 mg/kg: high level of contamination;
• more than 5000 mg/kg: very high level of contamination

Oil industry organizations are increasingly relying on the recommendations of the Ministry of Natural Resources of the Russian Federation dated September 12, 2002, when determining the permissible residual oil content in the soil (RAC). The disadvantage of this document and similar regulations is the inconsistency of the determination methods used for assessment and, as a result, different interpretation of the results (Braginsky, 2009). Thus, it is proposed to assess the degree of contamination based on migration indicators, toxicological and phytoproductive testing. The proposed methods cannot fully reflect the real picture of pollution, since they do not take into account the migration of oil components and petroleum products.

Crude oil contains tens of thousands of individual compounds. Even the most advanced methods for analyzing mixtures of organic compounds do not provide complete separation of all components of such a complex system.

Thus, the issue of analysis and control of soil contamination with oil and petroleum products is relevant.

The main methods of quantitative chemical analysis for the determination of petroleum products in soils at the moment are IR spectrometric, chromatographic, fluorimetric and gravimetric methods. The purpose of the work is to consider the advantages and disadvantages of analysis methods, as well as the possibility of comparing the results obtained by different methods.

The IR spectrometric method is based on measuring the effect of infrared radiation on a soil sample. At the moment, this method is widely used for the analysis of oil and petroleum products. Using IR spectroscopy, it is possible to determine the content of hydrocarbon compounds and identify functional groups. The method allows you to obtain the most accurate results in a short period of time; it shows even an insignificant content of oil and petroleum products. IR spectrometry also has its disadvantages. The installations do not recognize all types of oil; if there are different components in the soil, they can block oil particles during radiation, which makes it difficult to more accurately determine the oil content. To properly test the results, it is necessary to calibrate and correct the data (Simion, Găman, Lăutaru, 2022; Safieva, Kosheleva, Ivanova 2008).

The chromatographic method for studying the oil content in soil is based on separating the components of the mixture according to their chemical properties in the stationary and mobile phases. Gas or liquid chromatography is most often used. Chromatography, as applied to the study of oil composition, helps determine the individual composition of light, high-boiling oil products; complex hydrocarbons, group composition of oil fractions and products of its processing. The chromatographic method allows the identification of various components of oil, and is therefore applicable to a wide range of petroleum products. One of the disadvantages of gas chromatographic analysis at constant temperature and carrier gas velocity is that, for an analyzed mixture of components that differ greatly in retention characteristics, it is difficult to select the optimal column temperature and carrier gas velocity (Nekhoroshev, Turov, Nekhoroshev, Golovko, 2006; Havenga , Rohwer, 1999).

The chromatography method requires the use of complex specialized and expensive equipment; only qualified employees are allowed to work on such installations.

Another common method for studying petroleum products is the fluorimetric method, the essence of which is to measure the fluorescent glow that occurs when a sample of oil-contaminated soil is irradiated with ultraviolet light.

This method allows you to determine the oil content in the soil based on the intensity and wavelength of fluorescence. Petroleum products contain many fluorescent components, so fluorescence spectroscopy is a highly sensitive and specific method for detecting oil spills.

Using the fluorescence spectroscopy method, it is possible to identify oil and oil products with samples from the proposed source of pollution in case of comparison with a specific oil product (Safieva, Kosheleva, Ivanova 2008).

In this case, there is a strong dependence of the fluorescence intensity on the type of petroleum product, which is caused by the different content of aromatic hydrocarbons, and the problem of calibrating the device using a standard solution also arises, which is necessary to obtain reliable data.

The gravimetric method of analysis is also very common. It is based on the principle of determining the mass of a soil sample before and after oil removal. This method allows you to determine the oil content by changing the mass of the sample. Weighing samples on analytical balances makes it possible to determine the oil content in the soil with high accuracy. The method is also very simple to implement and requires minimal costs. You should not exclude the possibility of errors when using this method, since the result may not be accurate due to the density, humidity and other parameters of the samples. When weighing, as a rule, it is impossible to determine the content of individual components of oil and petroleum products (Sukhoverkhov, Logvinova, 2019; Kovaleva, Ganzha, 2020).

Each of the considered methods is complete for studying the content of petroleum products in soil and soils. But the problem is that despite many years of practice in their use, it is only possible to analyze and compare data within one specific method. Since the results of different research methods are practically not comparable.

We examined soil samples for the content of petroleum products using IR spectroscopy, fluorimetric and gravimetric methods of analysis, the results of the obtained studies are presented in tables 1-3.

Table 1: Results of determining the content of petroleum products in soil using IR spectroscopy.

№ samples	Results (mg/g)	Error	Soil types
1	89,0	± 22,0	Organo-mineral
2	259,0	± 65,0	Organo-mineral
3	34,0	± 9,0	Organo-mineral
4	122,0	± 30,0	Organo-mineral
5	0,8	± 0,2	Mineral

Table 2: Results of determining the content of petroleum products in soil using the fluorimetric method.

№ samples	Results (mg/g)	Error	Soil types
1	41,9	± 14,7	Organo-mineral
2	134,0	±47,0	Organo-mineral
3	20,1	± 7,0	Organo-mineral
4	26,5	± 8,3	Organo-mineral
5	0,12	± 0,05	Mineral

Table 3: Results of determining the content of petroleum products in soil by the gravimetric method.

№ samples	Results (mg/g)	Error	Soil types
1	52,6	± 16,6	Organo-mineral
2	184,0	±47,1	Organo-mineral
3	24,7	± 8,0	Organo-mineral
4	82,51	± 15,6	Organo-mineral
5	0,31	± 0,07	Mineral

e strongly encourage authors to use this document for the preparation of the camera-ready. Please follow the instructions closely in order to make the volume look as uniform as possible (Moore and Lopes, 1999).

3 CONCLUSIONS

The significant difference between the results obtained is due to the fact that the methods for determining petroleum products are fundamentally different. The data obtained as a result of IR spectroscopy is higher than that obtained with fluorimetric and gravimetric research methods. In our opinion, one of the reasons may also be the different nature of the extractants.

When conducting analysis using the fluorimetric method, the lowest readings were obtained. In this case, hexane is used as an extractant, which extracts the most soluble organic compounds, therefore this method is the most objective when analyzing the content of light fractions in soils that are in a highly mobile state.

Obtaining values during the gravimetric analysis method involves extraction with chloroform, which is capable of extracting aromatic hydrocarbons to a greater extent than hexane.

The highest values for petroleum products were obtained using IR spectroscopy and using carbon tetrachloride as a solvent. This indicates a more complete extraction of hydrocarbons, both light and heavy fractions.

Thus, after analyzing the advantages and disadvantages of the above methods and conducting a comparative analysis of the data obtained, we can conclude that when monitoring the content of oil and petroleum products in the soil, the most accurate result can be obtained using IR spectroscopy. IR spectroscopy allows, along with structural group analysis of the hydrocarbon part of oil and petroleum products, to characterize heteroatom-containing compounds.

Promising from the point of view of organizing express control are portable spectrometric instruments and methods based on the analysis of infrared spectra, in particular in the near-infrared region.

REFERENCES

Yakovlev, A. L., Savenok, O.V., 2017. Violations of environmental safety during the intensification of oil production in the fields of the Krasnodar Territory, *Environmental protection in the oil and gas complex*.

Trofimov, S.Ya.,. Amosova Ya. M., Orlov D.S., 2008. The influence of oil, soil cover and the problem of creating a regulatory framework for the influence of oil pollution on soils *Soil science*.

Kovaleva, M. A.,. Slashchinin, D. G., 2023. Physico-chemical analysis of oil emulsions *II International Conference on Environmental Technologies and Engineering for Sustainable Development*

Braginsky, O. B., 2009. *The book*, The publishing company. Academia.

Simion, A. F., Găman, A.N., Lăutaru, V.A., 2022. Analysis of total content of petroleum products in water by using ftir spectroscopy, *MATEC Web of Conferences.*

Safieva, R.. Z., Kosheleva, V. N., Ivanova L. V., 2008. IR spectroscopy in the analysis of oil and petroleum products, *Bulletin of Bashkir University.*

Nekhoroshev, S.V., Turov, Yu..P., Nekhoroshev, V.P., Golovko, A.K., 2006. Revealing the common sources of commercial explosive-containing articles, *Russian Journal of Applied Chemistry.*

Havenga ,W.J., Rohwer, E.R., 1999. Chemical characterization and screening of hydrocarbon pollution in industrial soils by headspace solid-phase microextraction, *Journal of Chromatography A.*

Sukhoverkhov, S.V., Logvinova, V.B., 2019. Express methods for determining the content of paraffins in oil, petroleum products and oily deposits, *Chemical technology.*

Kovaleva, M. A., Ganzha, V. A., 2020. Environmental problems of gasoline and diesel fuel use in Russia, *IOP Conference Series: Journal of Physics.*

Machine for Seedbed Preparation for Sorghum Sowing In Burundi

Tarasenko Boris Fedorovich[a], Drobot Viktor Alexandrovich[b],
Valery Viktorovich Tsybulevsky[c], Eric Hawyarimana[d], Svetlana Olegovna Chernyaeva[e]
FSBEI HE "Kuban State Agrarian University named after I.T. Trubilin"
viktor.drobot.85@mail.ru

Key words: Burundi country, power tiller, combined aggregate, milling machine, disk working tools, harrow, adapter.

Abstract: The analysis of sorghum cultivation technology in Burundi has shown a low level of mechanization of the soil preparation process due, first of all, to small forms of farming (up to 0.5 ha per family farm). The conducted theoretical studies allow us to justify the expediency of reducing labor costs for the most labor-intensive operations through the use of small-scale mechanization. The aggregate considered in the article is a machine for performing combined operations of soil preparation. The development of the machine was accompanied by the analysis of drawbacks of existing combined tillage machines taking into account small areas of arable land. The results of calculations of traction resistance of the combined tillage machine on the basis of a motorized block are given. The obtained mathematical dependence of the soil cultivation process and its graphical interpretation show the dependence of energy consumption on various factors.

1 INTRODUCTION

The Republic of Burundi is a small country located in East Africa with a high population density (more than 300 people per square kilometer). The most common type of activity is agriculture, which employs more than 80% of the country's population. At the same time, the development of this sector is at a low level due to the significant use of manual labor. This factor may be the result of small farms (on average up to 0.5 hectares of agricultural land per family farm), which does not make it unprofitable to purchase and use expensive agricultural machinery and power tools.

Burundi's climatic conditions determine the main direction of agricultural activity. The most common export crops include tea, coffee, and cotton. Most of the food crops are beans, rice, potatoes, maize, and bananas. One of the first cereal crops to be cultivated in Burundi was sorghum, a crop used both for human nutrition and animal feed (Khavyarimana, Tarasenko, Karpenko, Drobot, 2023).

Due to the peculiarities of its root system, sorghum is a drought-resistant crop, uses nutrients from the soil rationally, but requires a well-tilled seedbed.

Sorghum is the fifth largest crop in the world, behind maize, rice, wheat and barley.

As with other crops, high yields in sorghum cultivation depend on site selection and the preceding crop. Rational system of soil tillage, including the technology of preservation and accumulation of moisture in the soil, optimal timing of its implementation can not but affect the yield of the crop under consideration.

Any soil tillage technology is based on the primary requirements that reflect the optimal parameters of thermal and water-air regimes, provide a reduction in the risk of disease infection of the seed layer, destruction of weed vegetation (Drobot, Brusentsov, 2021).

The introduction of modern technologies provides for the use of various kinds of technical means. To reduce the negative impact of their drivers on the soil, it is proposed to reduce the number of passes of machinery on the sowing area through the use of combined aggregates that allow combining several

[a] https://orcid.org/0000-0001-9957-5979
[b] https://orcid.org/0000-0002-3136-6481
[c] https://orcid.org/0000-0003-4246-6899
[d] https://orcid.org/0009-0008-3746-8359
[e] https://orcid.org/0009-0002-9245-882X

operations in one pass of the aggregate (Tarasenko, Orlenko, Dmitriev, Khavyarimana, 2006).

Taking into account the low level of economy we propose the use of low-powered power means like motor-blocks, thus allowing to mechanize agricultural processes and reduce the use of manual labor.

According to the technology of soil treatment in sorghum cultivation in Burundi after harvesting, the complex includes milling operations and additional crumbling of the layer and crushing of the root part of weed organics by means of disk working tools (Tarasenko, Khav'yarimana, Drobot, Rudnev, 2023).

2 RESEARCH METHODOLOGY

The proposed unit for soil preparation (Figure 1) for sorghum sowing in Burundi includes a power sub-motor frame with an engine from a motorcycle Voskhod-3M, ignition system from a scooter Vyatka, fuel tank, forced cooling system fan, a rod made of steel wire to shift gears, the gear lever of the gearbox of the motorcycle engine, muffler, transmission, working shaft, steering wheel with clutch lever and throttle control handle, bracket for connection with a vehicle, wheels, operator's seat, milling working bodies (Tarasenko, Niyomuvunyi, Drobot, Rudnev, Blinova, 2023), whereby according to the utility model, as a vehicle is used a trailer (Figure 2) equipped with wheels with the ability to adjust their height of installation depending on the depth of soil cultivation and mounted behind it removable working bodies in the form of a disk battery. Detachable wheels for power tillers or detachable milling attachments are mounted on the working shaft of the power unit.

The essence of the proposed aggregate for soil preparation for sorghum sowing in Burundi is presented in Figures 1 - 5.

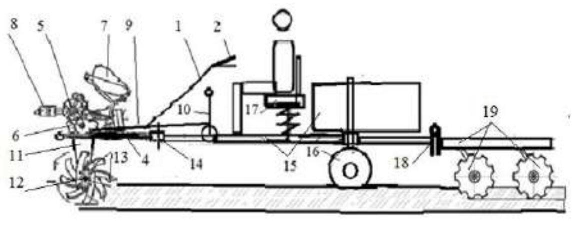


Figure 1: Side view of machine with cutter bar and disk battery.

The machine for soil preparation for sorghum planting in Burundi, includes a power unit containing a steering wheel 1 with a clutch lever 2 and a handle 3 for throttle control and a sub-motor frame 4. Submotor frame 4 is equipped with engine 5 from motorcycle Voskhod-3M with gearbox 6. Engine 5 is equipped with ignition system from scooter Vyatka, forced cooling fan, fuel tank 7, muffler 8. The gearshift box 6 of the motorcycle engine 5 is connected by a rod 9 made of steel wire with a lever 10 to change gears, and through the transmission 11 is connected to the working shaft 12, on which are mounted removable milling work tools 13. The power plant through the sub-motor frame 4 by means of a bracket 14 is coupled with a vehicle, as which is used a trailer 15 with wheels 16 and spring-loaded operator's seat 17. The wheels 16 of the trailer have the possibility of adjusting their mounting height depending on the depth of tillage. At the rear, the trailer 15 is equipped with brackets 18, with the help of which removable disk batteries 19 are attached or hitched (shown conventionally in the diagrams of block attachment). At the same time, removable wheels for power tillers 20 or removable milling working tools 13 are mounted on the working shaft 12 of the power unit.

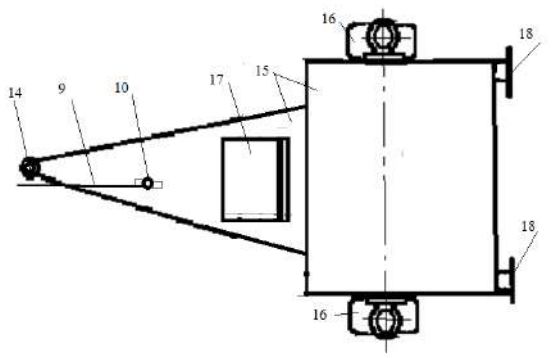


Figure 2: Trailer.

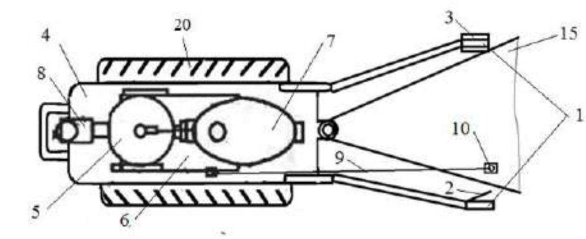


Figure 3: Top view of power unit with wheels for power tillers.

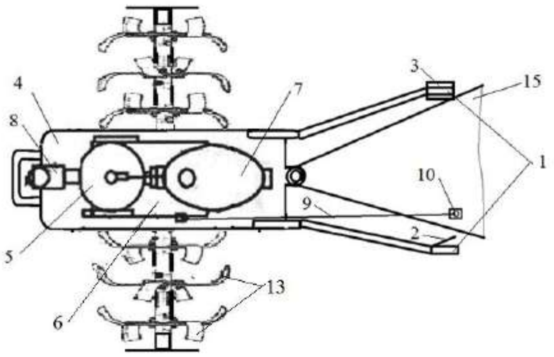


Figure 4: Top view of power unit with milling machine.

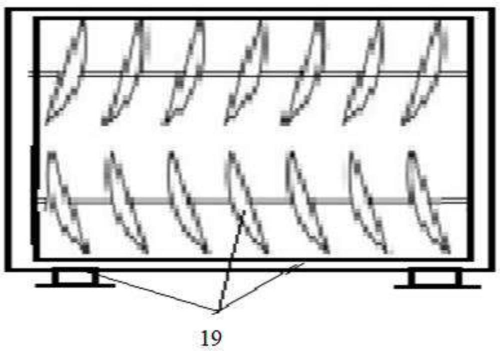


Figure 5: Top view of the disk battery.

The machine operation consists of the following operations.

After harvesting the preceding crops, milling and cultivation with disk cutters is performed. For this purpose the detachable wheels for power tillers on the machine are removed, and instead of them milling working tools are mounted. Then the trailer wheels are fixed at a height according to the depth of processing with disks attached to the brackets of the disk battery. Then the clutch lever is squeezed out on the handlebar and fixed in this position by a latch, the motorcycle engine placed on the under-motor frame with ignition system from Vyatka scooter, with a fan of forced cooling system is started. The engine is checked at idle speed. Then turn on the first gear and removing the latch unlock the clutch lever, after which from the gearbox through the transmission is transferred rotation to the working shaft with fixed on it soil-turning milling cutters, by means of which the soil is milled, providing intensive loosening and subsequent mixing of the fertile layer. When rotating, the cutters enable the machine to move together with the trailer and the disk unit. batteries. The disks additionally cut and shred the root part of weed organics (Primakov, Nikolenko, 2022; Nikolenko, Drobot, 2023).

The use of this aggregate for soil preparation for sorghum sowing in the conditions of agricultural production in Burundi, will provide the expansion of functional capabilities and improve the quality of soil tillage.

In the practice of using feather working tools, milling cutters with horizontal axis of rotation are the most widespread. The possibility of rotation of working bodies from the drive mechanism, gives us the right to consider them as active rotary working bodies.

In our proposed unit, cutting of soil chips by the cutter blade starts from the field surface, which corresponds to the direct rotation of the rotor.

Taking into account the level of development and socio-economic condition of Burundi, an important issue in the cultivation of any crop is the issue of energy intensity. For a more rational use of rotary working tools, it is necessary to identify analytical dependencies of the required power, analyzing the parameters affecting the energy intensity of processes.

3 RESULTS OF THE STUDY

According to the researches conducted by Dr. F.M. Kanaryov, the power of milling machine can be determined by the expression:

$$N = N_n + N_p + N_o, \qquad (1)$$

Where Nn – power spent on overcoming constant resistances;

Np – power used in the process of cutting off soil chips;

No – power spent on throwing away soil particles.

According to the research conducted, a formula for determining the power required by the cutter was derived:

$$N = N_n + \frac{v_n \cdot l_p \cdot n \cdot [k_л \cdot (\delta_c + l_{к.л}) + k_o \cdot S_{к.с}]}{S} + 0{,}5 \cdot \rho_n \cdot B \cdot h \cdot K_{om} \cdot v_n^3 (\lambda - 1)^2, \qquad (2)$$

Where N_n– power spent on overcoming constant resistances, as which we take power losses in the drive system of the rotating mechanism ($N_n =$ 3,01 кВт);

v_n – speed of translational motion of the milling machine. It is accepted equal from 0.83 to 1.4 m/s (3...5km/h), which is conditioned by physiological features of the operator of manual motorized equipment;

l_p– – length of the cutting arc, depending on the kinematic parameters of the cutter, the angle of cutting start and the height of the ridge in the transverse plane. For the milling cutters with saber-shaped blades, we assume the following ($l_p = 0{,}18$ m);

n – number of milling cutters in standard version (n=8);

$k_л$ – soil resistivity, $k_л = 1{,}1\frac{кН}{m}$;

δ_c – soil chip thickness ($\delta_c = 0{,}06$ m);

$l_{к.л}$ – blade length of the knife wing ($l_{к.л} = 0{,}06 \ldots 0{,}07$m);

k_o– specific resistance of soil to deformation ($k_o = 120$ кPa);

$S_{к.с}$ – projection of the knife blade on the frontal plane ($S_{к.с} = 0{,}001183$ m^2);

S – the distance traveled by the cutter from the moment the first blade of the cutter disk starts cutting to the moment the second blade starts cutting ($S = 0{,}08$ м);

p_n – density of the cultivated soil layer ($p_n = 11300$ Н/m^3);

B – rotor working width (B = 0,25 m);

h – working depth (0,06, 0,09, 0,12 m);

k_{om} – soil rejection factor ($k_{om} = 0{,}7$);

λ – rotor kinematic parameter (λ = 4).

On the basis of the obtained theoretical dependence of power on the speed of the machine at different depths of cultivation, we construct the graph shown in Figure 6.

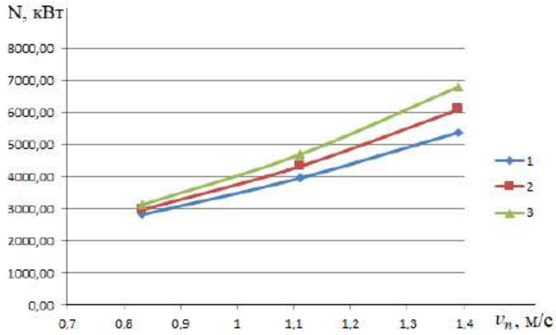


Figure 6: Dependence of power on the speed of machine movement at different working depths: 1 - at a working depth of 0.06 m; 2 - at a working depth of 0.09 m; 3- at a working depth of 0.12 m.

Soil reaction to the machine rotor (P_f,N) taking into account the total power is determined by the expression:

$$P_ф = \frac{N \cdot S}{v_n \cdot l_p}. \quad (3)$$

Dependence of cutter force on machine speed and working depth is shown on the graph (Figure 7).

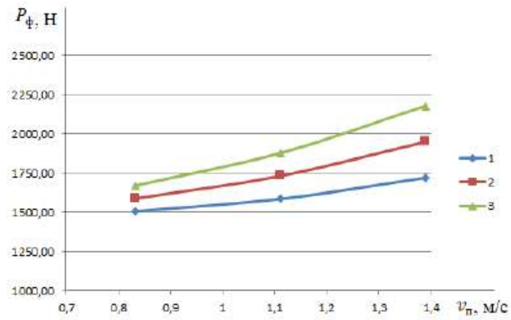


Figure 7: Soil response to the rotor (cutter) of the machine at different speeds and at different tillage depths: 1 - at a tillage depth of 0.06 m; 2 - at a tillage depth of 0.09 m; 3- at a tillage depth of 0.12 m.

For a more detailed representation of the response surface from two factors (speed and depth of machining) we obtained a model with real coefficients (second degree polynomial):

$$P_ф = 2{,}033 \cdot 10^3 - 339{,}583 \cdot X_1 - 4{,}678 \cdot 10^3 \cdot X_2 + 2{,}442 \cdot 10^3 \cdot X_1 \cdot X_2 + 37{,}5 \cdot X_1 \cdot X_1 + 2{,}744 \cdot 10^{-7} \cdot X_2 \cdot X_2, \quad (4)$$

где X_1 – forward speed of milling machine, km/h;

X_2 – working depth, m.

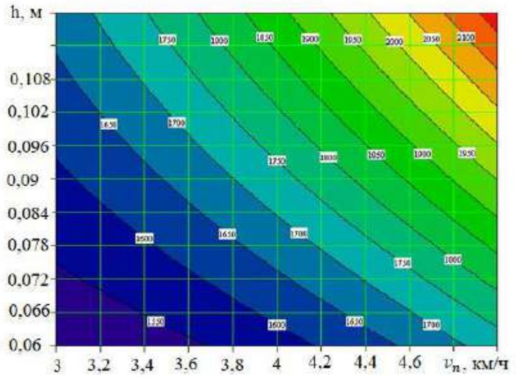


Figure 8: Surface of dependence of soil reaction to the rotor (cutter) of the machine on the speed of movement and depth of cultivation.

Parameters of disk working tools and the soil layer cut off by them have a direct impact on the quality and energy parameters of soil tillage. It is necessary to achieve optimal values of parameters, which will contribute to the reduction of energy consumption to the minimum level (Medovnik, Maslov, Tarasenko, Chebotaryov, Bugayev, Drobot, 2006).

Unfortunately, the mechanics of soil tillage is insufficiently studied, and the significant variation of physical and mechanical properties of soil during tillage prevents the creation of an accurate mathematical model for determining the optimal parameters. It is necessary to resort to a large number of different assumptions (Tarasenko, Tverdokhlebov, Bogatyrev, Medovnik, Gorovoy, Drobot, Poplavkov, Tsybulevsky, 2021).

Analysis of scientific and technical literature allows us to consider the soil reaction to the disk using an analytical expression that establishes the relationship between the horizontal component of the traction resistance of the disk tillage implement and its geometric parameters (Drobot, Tsybulevskiy, 2010):

$$P_д = \lambda \cdot G_м \cdot \frac{sin\varepsilon_3 \cdot sin\gamma + f \cdot (cos^2\gamma + cos\varepsilon_3 \cdot sin^2\gamma)}{cos\varepsilon_3 - f \cdot sin\gamma \cdot sin\varepsilon_3} + a \cdot b \cdot [k + \varepsilon \cdot v_п^2] +$$
$$+ a \cdot b \cdot l \cdot \gamma_{об} \cdot \frac{sin\beta + f \cdot (cos\gamma \cdot ctg\gamma + sin\gamma \cdot cos\beta)}{cos\beta - f \cdot sin\gamma \cdot sin\beta} + \frac{a \cdot b \cdot \gamma_{об} \cdot v_п^2 \cdot sin^2\gamma \cdot [sin\beta + f \cdot sin\gamma \cdot (ctg^2\gamma + cos\beta)]}{g \cdot (ctg\beta - f \cdot sin\gamma)}, \quad (5)$$

where λ – coefficient, the value of which may not exceed 0,3-0,4;

$G_б$ – disk harrow weight ($G_б = 120$ H);

ε_3 – rear cutting angle (ε_3=10^0 – 12^0);

γ – blade bevel angle formed by the blade line with the direction of travel, γ=4 hail;

f – coefficient of friction ($f = 0{,}6$);

a – formation thickness (depth of treatment) ($a =$ 0,06 m);

b – layer width ($b = 0{,}3$ m);

k – coefficient taking into account soil properties (σ – temporary soil tensile strength and φ – friction angle) and geometric shape of the wedge (crumbling angle β); the value of this coefficient should be determined experimentally (k=1,9…2,2 кН/m);

ε – speed resistance coefficient, depending on soil properties and parameters (geometric shape) of working surfaces of organs ($\varepsilon = 0{,}05$);

$v_п$ – translational speed (от 0,83 до 1,4 m/s);

l – formation length ($l = 0{,}45$ m);

$\gamma_{об}$ – soil volume weight ($\gamma_{об} = 14500$ H/m^3);

β – crumbling angle ($\beta = 5$ hail);

g – free fall acceleration (g =9,8 m/s^2).

Soil reaction to the disk implement is determined at different speeds at a constant depth equal to the sorghum sowing depth (0.06 m) according to formula (5). The resulting graph is shown in Figure 10.

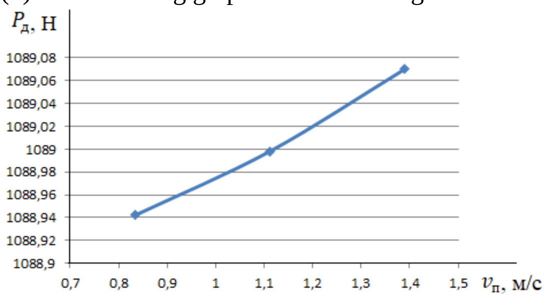


Figure 10: Soil response to disc implements at different travel speeds and constant tillage depths.

Traction resistance of the machine (P) (Nikolenko, 2023) determine by the expression:

$$P = P_ф + P_д + f \cdot G_а, \quad (6)$$

where $G_а$ – unit weight ($G_а = 1670$ H).

The dependence of traction resistance of the machine on the variation factors, taking into account its weight, is determined by formula 6 and presented in the form of a graph in Figure 11.

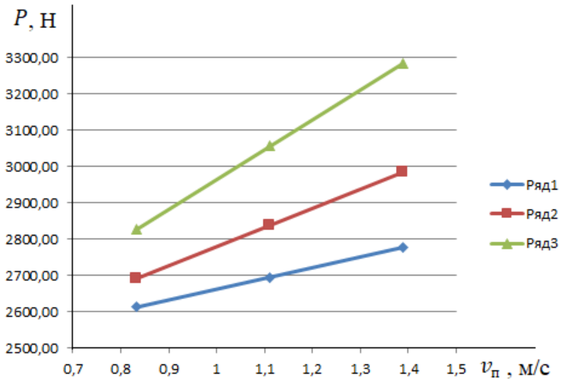


Figure 11: Dependence of traction resistance on the speed of machine movement at different working depths: 1 - at a working depth of 0.06 m; 2 - at a working depth of 0.09 m; 3- at a working depth of 0.12 m.

The response surface of the traction resistance of the machine from the travel speed is considered using a mathematical model (second degree polynomial with real coefficients).

$$P = 3{,}138 \cdot 10^3 - 338{,}083 \cdot X_1 - 4{,}744 \cdot 10^3 \cdot X_2 + 2{,}442 \cdot 10^3 \cdot X_1 \cdot X_2 + \\ +37{,}333 \cdot X_1 \cdot X_1 + 370{,}37 \cdot X_2 \cdot X_2, \quad (7)$$

where X_1 – orward speed of milling machine, km/h;

X_2 – working depth, m.

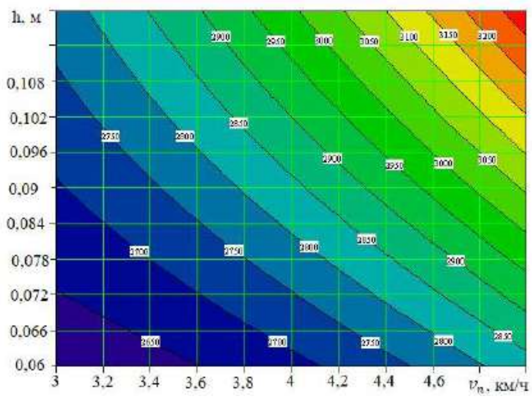


Figure 12: Surface of dependence of machine traction resistance on travel speed and working depth.

4 CONCLUSIONS

According to the received dependencies, on which the graphs are constructed (Figure 8, 12) it is possible to determine the required power of a motorized block on soil cultivation at various variants of a complete set of the unit.

REFERENCES

Khavyarimana, E., Tarasenko, B. F., Karpenko, V. D., Drobot, V. A., 2023. State of Burundi's agricultural sector and research tasks. *Polythematic network electronic scientific journal of Kuban State Agrarian University*. № 192. C. 194-219.

Drobot, V. A., Brusentsov, A. S., 2021. Agromeliorative methods of surface soil tillage. Year of Science and Technology 2021. Collection of abstracts on the materials of the All-Russian scientific-practical conference. A.G. Koschayev. Krasnodar. C. 252.

Tarasenko, B.F., Orlenko, S.Y., Dmitriev, D.A., Khavyarimana, E., 2006. Patent for utility model RU 206 472, A01B 3/36 (2006.01), A01B 3/40 (2006.01), A01B 49/02 (2006.01). Mounted disco-chisel harrow /: FGBOU VO "Kuban State Agrarian University named after I.T. Trubilin". - Published: 13.09.20212. Bulletin No. 26.

Tarasenko, F. F., Khav'yarimana, E., Drobot, V. A., Rudnev, S. G., 2023. Field testing of a disk-chisel harrow. *Tractors and Agricultural.* 90(3). C. 225-232.

Tarasenko, B. F., Niyomuvunyi, A., Drobot, V. A., Rudnev, S. G., Blinova, A. I., 2023. Soil cultivating with a tiller with V-shaped knives. *Tractors and Agricultural Machinery*. 90(4). 307-314.

Primakov, N. V., Nikolenko, A. Y., 2022. Energy-saving technology of soil preparation for fruit orchard establishment. *Polythematic network electronic scientific journal of Kuban State Agrarian University.* № 183. 234-242.

Nikolenko, A. Yu., Drobot, V. A., 2023. Energy-saving technologies of soil cultivation in the conditions of agricultural production of Krasnodar region. Scientific support of agroindustrial complex. Collection of articles on the materials of the 78th scientific-practical conference of students on the results of research and development for 2022. In 3 parts. Responsible for the issue A.G. Koschayev. Krasnodar. 308-311.

Medovnik, A. N., Maslov, G. G., Tarasenko, B. F., Chebotaryov, M. I., Bugayev, S. V., Drobot, V. A., 2006. Patent RU 2275782 C1, A01C 7/00, A01B 49/06 Device for sowing seeds of grain crops /: FGBOU VO "Kuban State Agrarian University named after I.T. Trubilin". - Published: 10.05.2006. Bulletin. No. 13.

Tarasenko, B. F., Tverdokhlebov, S. A., Bogatyrev, N. I., Medovnik, A. N., Gorovoy, S. A., Drobot, V. A., Poplavkov, P. S., Tsybulevsky, V. V., 2021. Patent RU 2436270 C1 A01B 63/112, G01L 5/13 Field installation for testing tillage working bodies /: FGBOU VO "Kuban State Agrarian University named after I.T. Trubilin". - Published: 20.12.2021. Bulletin No. 35.

Drobot, V. A., Tsybulevskiy, V. V., 2010. Optimization of parameters of the process of surface soil cultivation by horizontally located disc working bodies. Proceedings of the Kuban State Agrarian University. № 23. C. 181-186.

Nikolenko, A. Yu., 2023. Energy analysis of the working process of the rotary plow. Energy-resource saving and energy efficiency: current issues, achievements and innovations. Collection of scientific papers of the II International Scientific and Practical Conference. Nalchik. 212-215.

Digital and Reading Literacy of Schoolchildren in Teaching Physics

Nadezhda Antonova [1][a]
[1]*South Ural State Humanitarian and Pedagogical University, Lenin Avenue 69, Chelyabinsk, Russia*
in-nadya@mail.ru

Keywords: schoolchildren, literacy, physics education, digital literacy, reading literacy

Abstract: Against the background of a request for the use of SMART technologies and Internet capabilities in teaching and in everyday life, the possibility of forming digital and reader literacy in teaching physics by means of an electronic textbook form, augmented reality, a digital laboratory, a technopark of universal pedagogical competencies, mobile search, digital educational resources is presented. The analysis of identifying the role of digital literacy of students in teaching physics is presented. The relevance of the problem of the formation of reading literacy of schoolchildren is due to the fact that the ability to work with information is one of the main basic competencies necessary for any graduate of a primary school, regardless of the further educational trajectory chosen by him, when teaching physics, the formation of reading literacy is associated with working with texts of physical content and assignments to it.

1 INTRODUCTION

Today, the issue of increasing the digital literacy of the population is being actively raised. This is especially true for students who have the highest demand for using SMART technologies and Internet capabilities in education and in everyday life (Lebedeva, Shefer, Nosova, Ruzakov, 2020). In terms of the skills of safe work on the Internet and taking responsibility for committed actions, the «digital gap» between students and adults should be recognized as quite large (Peshkova, Samarina, 2018). Digital literacy occupies a priority place in the list of basic skills in demand in the 21st century in almost any position. Digital literacy is as much in demand as the ability to write and read. Students who develop digital literacy as an integral part of their education are more effective in their studies, more in demand in employment, and teachers who possess digital information freely combine innovative pedagogical practices such as inverted learning, digital curation, mobile learning technologies, and use open educational resources with maximum benefit (Connolly, McGuinness, 2018; Emejulu, Mcgregor, 2019; Hobbs, Coiro 2019).

2 METHODOLOGY

The problem of research is addressed in the following works:

– STEM education (N. A. Moiseenko (Moiseenko, Temirova, Mataev, 2023), O. T. Slanov (Slanov, Dzitsoev, 2023), M. A. Chervonny (Chervonny, Shvaleva, Vlasova, 2020), O.R. Shefer (Lebedeva, Shefer, Nosova, Ruzakov, 2020; Shefer, Nosova, Lebedeva, 2018), etc.);

- digital literacy of schoolchildren (S.M. Avdeeva (Avdeeva, Tarasova, 2023), T.A. Boronenko (Avdeeva, Tarasova, 2023; Boronenko, Kaisina, Fedotova, 2019; Boronenko, Kaisina, Fedotova 2021), S.N. Kostina (Kostina, Novikova, 2023), Yu.V. Kuzmina (Kuzmina, Avdeeva, Tarasova, 2023), A.V. Filkina (Filkina, Kamneva, 2023), etc.);

– digital competencies and digital literacy (A.V. Pesha (Pesha, 2022), E. V. Popov (Popov, 2023), etc.); media literacy students of a pedagogical university (S. R. Musifullin (Musifullin, 2023), etc.); digital literacy of a future teacher (S.A. Rogozin (Popov, 2023), etc.)

Digital literacy also includes reading literacy in teaching physics – proficiency in:

– reading, perceiving, finding, analyzing, comprehending, evaluating and summarizing various types of physical information presented in educational, popular science literature, popular

[a] https://orcid.org/0000-0002-3823-270X

science periodicals, other sources, including the media and Internet sites;

– to extract the necessary physical information for its integration, interpretation, transformation in accordance with the task;

– navigate through the received physical information in life and professional situations (Antonova, 2023).

We see the formation of digital and reader literacy in teaching physics in the following:

1. Using the electronic textbook form (EFU). Electronic textbooks are included in the list recommended by the Ministry of Education of the Russian Federation, developed by the publishing house «Bustard», «Russian textbook», «Enlightenment», «Exam», «Exam-Media», meet new educational standards and, moreover, are a good addition to paper-based textbooks, expanding the possibilities of didactic manuals. In our opinion, the most convenient and modern is the EFU in physics from the UMK of A.V. Peryshkin (Peryshkin, 2019), analyzing it we come to the following conclusions:

– in all paragraphs of the EFU in physics there are interactive tabs with tasks and a large amount of additional information;

– texts – contain brief information about outstanding physicists and their scientific activities, portraits of scientists, tasks for project activities, descriptions of devices and technical devices, materials for additional reading;

– images – show devices and universal installations, their principles of operation, schemes;

– video demonstration experiments, virtual laboratory work – allow you to study all the experiments of the course, even if the physics room is not well equipped;

– final papers – prepare for tests and help summarize the material covered, which include matching tasks and questions with an answer input, experiments – complement the «Tasks and exercises» section in printed textbooks, can be used for group surveys (if there is an interactive whiteboard) and for self-checking of students.

2. Augmented reality is the result of introducing any sensory data into the field of perception in order to supplement information about the environment and improve the perception of information.

At the moment, there are two main approaches to the formation of virtual reality systems. Firstly, it is a virtual room, and secondly, wearable virtual reality devices. In the first case, a special room is built, surrounded by stereoscopic screens, on which the image of the virtual world is broadcast. A person is placed in a kind of analogue of a circular stereoscopic cinema hall, outside of which the virtual world is located.

The main advantage of such a system is the possibility of finding and interacting with a group of people in one virtual world. All wearable virtual reality devices lack this advantage. In addition, the absence of an additional device on the head and the unlimited field of view of a person in a virtual space are undeniable advantages of virtual room systems. The implicit advantage of such systems is the ability to connect significant computing resources to such systems and, consequently, the ability to synthesize images of the virtual world with a greater degree of realism, which ultimately increases the naturalness of perception of virtual reality (Grigoriev, 2020). An example of augmented reality is a textbook by the author V.V. Belaga.

3. Digital physics laboratory from the company «Scientific Entertainment». It includes the following digital sensors: a position sensor (fixing four body positions); a force sensor; an absolute pressure sensor; an angular velocity sensor; an acceleration sensor; a temperature sensor; a humidity sensor; a voltage sensor; a current sensor; an oscillography voltage sensor with two measuring channels (Gigolov, Povalyaev, 2020).

4. Sets of equipment «GIA-LABORATORY» or «FGOS-LABORATORY». In the control and measuring materials of the OGE, task No. 17 is an experimental task performed by students using real laboratory equipment. An indication of the need to use it is given in the instructions before the text of the task. Each student is given a set of equipment, which is based on standard sets for front-end work in physics, as well as on the basis of sets of equipment «GIA-LABORATORY» or «FGOS-LABORATORY», where all necessary and sufficient devices and materials for the task are collected.

5. The possibilities of the technopark of universal pedagogical competencies.

Pedagogical technoparks, or technoparks of universal pedagogical competencies, are educational spaces that are equipped with high–tech equipment from the best Russian and world manufacturers. A technopark of universal pedagogical competencies has been created on the basis of the Federal State Budgetary Educational Institution of Higher Education in Chelyabinsk, which has the following laboratories: «Analytical Chemistry», «Robotic Systems and Virtual Reality», «Genetics. Optics. Physiology», «Fundamental Physics», «Radiography», «Alternative energy».

When carrying out practical work in the conditions of the technopark, we propose the following plan:

I. Theoretical part. Get acquainted with the installation, describe it according to the plan.

Instrument study plan

1) Purpose of the device.

2) The principle of operation of the device (what phenomenon or law underlies the operation of the device).

3) The scheme of the device (its main parts, their purpose).

4) Rules of use of the device.

5) Scope of the device.

Practical part. Description of the experiment, results, conclusions.

II. The professional training of future teachers by means of the technopark and its capabilities are described in more detail in our article (Antonova, 2023; Antonova, Shefer, Kochetkova, Lebedeva, Erenraut, Akhkamova, 2023).

6. Mobile search. The necessary technical conditions for the implementation of admission: the availability of mobile devices with Internet access for students.

When using the mobile search method at the preparatory stage, the teacher prepares problematic educational situations in which students need to search for additional information using the Internet. Using mobile devices, students can access various phone modules: a microphone (for voice search or melody search), an integrated camera (for image search), and a software keyboard (for text search).

The advantages of using the mobile search method in comparison with traditional search via personal computers:

– this method allows you to indirectly explore various methods of searching for information using a mobile device while directly studying any educational topic;

– in addition to using search technologies, students develop the skill of working with various information input modules built into mobile devices.

Example 1. To expand the understanding of the concept under study, students can be offered, based on the methodological technique «Mobile Search», to find information on the Internet, for example, about the manifestation in nature of the phenomenon of mirror reflection or the harmful effects of the phenomenon of refraction of light on humans and the environment. The «Mobile search» technique forms students' skills to independently search, analyse and use information, according to the task assigned to them.

Example 2. Search for information from popular science publications.

Prepare a report on the topic «Eye and vision» based on the publication in the magazine «Quantum» (website of the magazine «Quantum»: http://kvant.mccme.ru/rub/8D.htm), using an information retrieval algorithm.

An algorithm for searching for information in a popular science periodical:

1. Take the latest issue of the magazine for the current year.

2. Review it. Let's assume that it has an article related to your topic.

3. Make an annotation card for this article: author; title; number, year, pages; link; what is the article about; the main facts and important thoughts; quotes.

4. Take the following issues of magazines and follow the steps described in paragraphs 2 and 3, if there is an article suitable for the subject. You will get a set of annotation cards.

5. Guided by this set, review the selected articles again and draw up a speech plan based on them. Do not include repetitive, insignificant and incomprehensible information in it.

6. Write your message text, implementing the plan you have drawn up. Insert important quotes and facts you like into it.

This work develops the skills to conduct analysis, briefly formulate facts and thoughts, make a work plan based on the information extracted, which contributes to the formation of reading and digital literacy.

3 RESULTS

In the course of our research, to identify the role of digital literacy of students in teaching physics, we conducted a survey of schoolchildren (grades 8-11, 118 people).

Analysing the survey data of students, we came to the following conclusions:

– the main Internet sources for homework preparation are Wikipedia (57%), video tutorials (50%), the site «Knowledge» (53.3%), the solution of the VPR, OGE, USE (53.3%);

– the main sources of information during distance learning are «Ya klass» (46.7%), Video tutorials on the YouTube channel (66.6%), Google tests (46.7%), Russian electronic school (60%), ZOOM (40%);

– for schoolchildren and students, the computer is a source of information (73.3%), communicating with loved ones or strangers (53.3%), listening to radio and music, watching videos and TV shows (50%);

– students spend more than 3 hours a day working with the Internet (70%);

– mobile applications for studying Photomath (Mathematics) – 60%, Google translator – 70%, calculator – 70%;

– students have basic computer skills, such as typing (92%), inserting pictures into text (88%), searching for information on the Internet (88%), social communication. social networks – (92%), watching movies for entertainment, games (92%); the development of digital literacy has a positive effect on student academic performance, using the electronic form of a textbook for practical work on the subject of Physics (86%).

4 CONCLUSIONS

Summarizing the results of the study, we came to the following conclusions:

1. We have defined digital literacy as a set of knowledge, skills and abilities that are necessary for life in the modern world, for the safe and effective use of digital technologies and Internet resources.

2. Developing digital literacy, we also form reading literacy in teaching physics, as the ability to read, perceive, find, analyse, comprehend, evaluate and summarize various types of physical information presented on electronic resources and Internet sites; extract the necessary physical information for its integration, interpretation, transformation in accordance with the task; navigate with the help of the received physical information in life and professional situations.

3. The formation of digital and reader literacy has a positive effect on student academic performance (86%). For this, we suggest using: augmented reality, a digital physics laboratory from the company «Scientific Entertainment», «GIA LABORATORY» or «FGOS LABORATORY», electronic textbooks, in our opinion, the most convenient and modern is EFU in physics from UMK A.V. Peryshkin publishing house «Exam», educational sites such as cool physics, media didactics, video lessons, solve VPR, OGE, USE, scientific journals «Quantum», «Science and Life».

4. Modern practical work should be carried out in the technopark of universal pedagogical competencies, where students get acquainted and describe installations, conduct an experiment, therefore, this contributes to the formation of experimental skills.

ACKNOWLEDGEMENTS

The research was carried out with the financial support of the Mordovian State Pedagogical University named after M.E. Evseviev as part of the scientific project "Pedagogical support of research activities of future physics teachers in the process of methodological training" contract No. 16-665 dated 01.07.2024.

REFERENCES

Antonova, N. A., 2023. Professional training of future teachers by means of technopark. *Vocational education in Russia and abroad.* No. 3 (51). pp. 94-100.

Antonova, N., Shefer, O., Kochetkova, G., Lebedeva, T., Erenraut, E., Akhkamova, Y., 2023. Psychological and social adaptive orientation in the teaching of first-year students. *E3S Web of Conferences : EBWFF 2023 - International Scientific Conference Ecological and Biological Well-Being of Flora and Fauna (Part 1)*. Vol. 420. P. 06044. Blagoveschensk, Amur region, Russia: EDP Sciences.

Antonova, N.A., 2023. The formation of reader's literacy as a pedagogical problem. *Innovations in education*. No. 2. pp. 12-27.

Avdeeva, S. M., Tarasova, K. V., 2023. On the assessment of digital literacy: methodology, conceptual model and measurement tool. *Education issues*. No. 2. pp. 8-32.

Boronenko, T. A., Kaisina, A.V., Fedotova V. S., 2019. Development of digital literacy of schoolchildren in the conditions of creating a digital educational environment. *Prospects of science and education*. No. 2(38). pp. 167-193.

Boronenko, T. A., Kaisina, A.V., Fedotova V. S., 2021. Characteristics and level assessment of digital literacy of schoolchildren. *Prospects of science and education*. No. 2(50). pp. 256-277.

Chervonny, M. A., Shvaleva, T. V., Vlasova, A. A., 2020. A study of the readiness of physics teachers to implement STEM education. *Russian Journal of Education and Psychology*. Vol. 11, No. 5. pp. 93-108.

Connolly, N., McGuinness, C., 2018. Towards digital literacy for the active participation and engagement of young people in a digital world. *Young people in a digitalised world*. Vol. 4. P. 77.

Kuzmina, Yu. V., Avdeeva, S. M., Tarasova, K. V., 2023. Digital literacy, cognitive control and the use of digital devices by children. *Psychological science and education*. Vol. 28, No. 4. pp. 81-97.

Emejulu, A., Mcgregor, C., 2019. Towards a radical digital citizenship in digital education. *Critical Studies in Education*. Vol. 60. No 1. pp. 131-147.

Filkina, A.V., Kamneva, O. S., 2023. Profiles of digital literacy of schoolchildren. *Bulletin of Tomsk State University. Philosophy. Sociology. Political science.* No. 71. pp. 204-214.

Gigolov, A.I., Povalyaev, O.A., 2020. The possibilities of evaluating experimental skills in physics using digital technologies. *Pedagogical measurements*. No. 2. pp. 102-108.

Grigoriev, A.S., 2020. Augmented reality. *Actual problems of development of secondary and higher education: mezhvuz. sb. scientific tr*. Issue XVI. Chelyabinsk: «Edge of Ra».pp. 127- 133.

Hobbs, R., Coiro J., 2019. Design features of a professional development program in digital literacy. *Journal of Adolescent and Adult Literacy*. Vol. 62(4). pp. 401-409.

Kostina, S. N., Novikova, O. N., 2023. How do older teenagers assess the impact of digital technologies on educational activities? *Bulletin of Tomsk State University. Philosophy. Sociology. Political science*. No. 74. pp. 190-205.

Lebedeva, T.N., Shefer, O.R., Nosova, L.S., Ruzakov, A.A., 2020. Pedagogical aspects of the formation of professional competence of future teachers in a SMART society: monograph. – Chelyabinsk: South Ural Scientific Center of the Russian Academy of Sciences. 351 p.

Moiseenko, N. A., Temirova, A. B., Mataev, S. E., 2023. Professional development of a teacher in the context of the introduction of STEM education and prerequisites for the creation of a STEM laboratory. *Vestnik GGNTU. Humanities and socio-economic sciences.* Vol. 19, No. 3(33). pp. 78-85.

Musifullin, S. R., 2023. Formation of media literacy of pedagogical university students in the conditions of transformation of the educational process. *Science for Education Today*. Vol. 13, No. 1. pp. 7-27.

Peryshkin, A.V., 2019. Physics. 8th grade: textbook [Electronic resource]. – M.: Publishing house «Exam». 271 p.

Pesha, A.V., 2022. The development of digital competencies and digital literacy in the XXI century: a review of research. *Education and self-development*. Vol. 17, No. 1. pp. 201-220.

Peshkova, G.Yu., Samarina, A.Yu., 2018. Digital economy and human resources potential: strategic interconnection and prospects. *Education and Science*. Vol. 20. No. 10. pp. 50-75.

Popov, E. V., 2023. Features of measuring digital literacy in Russia. *Sociological research*. No. 11. pp. 51-61.

Rogozin, S. A., Kudinov, V. V., Meshkov, V. D., Senkin, M. E., 2023. Development of digital literacy of a future teacher during the first year of study at the university. *Prospects of science and education*. No. 6(66). pp. 67-88.

Shefer, O.R., Nosova, L.S., Lebedeva, T.N., 2018. Modern methodology of studying programming at a university. *Scientific and technical information. Ser.1. Organization and methodology of information work*. No.5. pp. 6-12.

Slanov, O. T., Dzitsoev, D. O., 2023. The main advantages and disadvantages of implementing a STEM education system. *Economics and management: problems, solutions*. Vol. 2, No. 9(139). pp. 10-15.

Implementation of Virtual PHET Medium in Explaining Kepler's Laws

Tulkun Nasirov[1][a], Chori Toshpo'latov[2][b] Farid Ruziyev[3][c] and Xulkar Hudoyeva[2][d]
[1]*University of geological sciences, 60, Olimlar Street, Tashkent, Uzbekistan*
[2]*Tashkent brach of Samarqand university of veterinary medicine and biotechnologies, 35A, Al-Xorezmi Street, Tashkent, Uzbekistan*
[3]*Institute of ionic-plasma and laser technologies of Uzbekistan academy of sciences, 33, Do'rmon yo'li Street, Tashkent, Uzbekistan*
[4]*School 201, 6A, Shosh Street, Tashkent, Uzbekistan*
tulkunnasirov@yandex.ru

Keywords: virtual PHET medium, Kepler's laws, mastery of lesson.

Abstract: The analysis of experiences carried out on revealing the advantages using integrated PHET medium during the lesson on Kepler's laws on astronomy has been presented. It has been shown, that using this medium allows us to increase mastery by pupils to 1.5 times in comparison of the traditional teaching using the usual blackboard. It has been revealed that teacher during the lesson can take a passive rather than active role leaving it to the students themselves to carry experiments in accelerated and decreased (to million times) formats of motion of Solar system space bodies. Then the pupil's quantities with excellent and good knowledge have been increased to 21 and 19 %, correspondingly, as the same time ones with the satisfactory and unsatisfactory grades, contra versa, have been decreased to 17 and 16 %, correspondingly.

1 INTRODUCTION

Your paper will be part of the conference proceedings therefore we ask that authors follow the guidelines explained in this example and in the file «FormatContentsForAuthors.pdf» also on the zip file, in order to achieve the highest quality possible (Smith, 1998).

Be advised that papers in a technically unsuitable form will be returned for retyping. After returned the manuscript must be appropriately modified.

The information technologies become an integral part of lessons on physics and astronomy. Here virtual laboratory works have the important role. Therefore, in the recent time often the investigations in which aspects using such virtual works are being appeared. Let us review the latest papers where information technologies on physics and astronomy lessons had been used.

For example, in paper (Mugutullina, 2020) having laboratory works had been analyzed, tasks of creation of computer models of physical processes, development comfort user interface, method of carried out laboratory works using interactive laboratory complex had been discussed. Totally, the necessity of using virtual laboratory works in physics teaching, knowing methodic materials and also efficiency of all teaching process had been justified.

In paper (Dmitriyev, 2023) the possibility increasing efficiency of educational process through the implementation information technologies had been considered. There the methodic aspects for creating and using virtual laboratory works intended for organization self-study by students of different sections of physics had been discussed. Analysis of experiences and their application in high educational schools had been presented in which screening form of different virtual laboratory works for carrying

[a] https://orcid.org/0000-0003-3813-1252
[b] https://orcid.org/0009-0006-0996-5513
[c] https://orcid.org/0009-0009-8842-5161
[d] https://orcid.org/0009-0002-1713-9669

online experiments, allowing to students prepare for their implementation had been demonstrated clearly.

The possibilities using virtual laboratory works on physics had been studied in paper (Akmatbekova, 2023) as one of containing elements of self-training of students for carry out real laboratory works. There the method for carrying out virtual laboratory works had been developed, preparation and conducting experiential learning had been described and its quantitative and qualitative results had been analyzed. It had been shown that using virtual laboratory works on physics allows show to students the studying efficiency, speed and high accuracy of obtained results, which confirms efficiency proposed method. Thus, students can form independently the practical skills and abilities in convenient for their time, without limiting the time themselves and territorial remoteness from the educational organization. There had been noted that teaching based on the virtual laboratory creates conditions for effective manifestation of intellection fundamental laws, promotes for development and activation of student's creativity and optimizes cognitive process of students teaching.

In paper (Zlobina, 2022) the necessity of virtual laboratory works on the astronomy lessons for observing space objects and creating cognitive interest for subject had been considered. There a sample of virtual laboratory work using Stellarium medium had been proposed. This task also deals with that in recent period calculations carried out then by Kepler using new information technologies are being clarified.

In paper (Yalovenko, 2022a) inconsistencies in Mercury planet orbital rotation had been considered and methods for their elimination had been proposed. And in other paper (Yalovenko, 2022b) extension of first Kepler's law in the new text: "Each planet of Solar system rotates by irregular ellipse and Solar situated in the shortest focus". Solar in such presentation has priority and our representations on the environment space are being expanded. In other paper of same author (Yalovenko, 2020) expansion of motion momentum conservation laws for obtaining gravitation theory and Kepler's laws had been considered.

The wave function of electron in the hydrogen type atom in analogy with the Kepler's task had been chosen which satisfactory Whittaker's equation in any kinematics and any spin (Granovskii, 2021). Then electron being as the pure quantum mechanical object in point of view classic mechanics had been considered which simplifies representation nature of atomic scale.

In paper (Abubekerov, 2020) the algorithm for numerical solution of Kepler's equation with machine accuracy had been represented. The convergence of the iteration sequence of Newton's method on the known initial approach had been proven. The task of finding the numerical solution of Kepler's law as the floating point numbers had been constructed. The aspects conditioned by calculations near machine zero had been taken into account. The accuracy of possible result had been analyzed. The task arising by striving for the highest possible accuracy had been revealed and its solution had been proposed. The estimation of machine time required for solution Kepler's equation using this method had been estimated.

The generalized Kepler's task in the spherical coordinates had been considered (Petrosyan, 2022). The explicit form of the additional motion integral of generalized Kepler's task in the spherical coordinates, wave function of which is spheroidal basis had been given and three-term recurrent representations to which expansion coefficients of spheroidal basis on the spherical and parabolic bases satisfy had been derived.

In all mentioned above papers although aspects for effective using some virtual laboratory works had been considered but in them questions studying pupil's consequence of stages of execution of works and also observing processes in Kepler's laws in the chronological order not yet clearly had been defined.

2 METHOD OF INVESTIGATIONS

In the present paper the analysis of carried out experiments on astronomy lessons has been considered, in which Kepler's laws using virtual integrated PHET medium are explaining. Wherein for clear demonstrating advantages of using virtual medium we held lessons in two classes (11^A and 11^B) on the same title: "Kepler's laws". In 11^A class teacher used PHET medium and during on the lesson he chose a passive role giving pupils themselves conduct experiments with planets (see, Figures 1-3). At the same time in 11^B class teacher conducted lesson without such integrated medium, that is in which he chose active and pupils take passive positions.

Figure 1: Fixation a moment of the astronomy lesson for studying Kepler's first law.

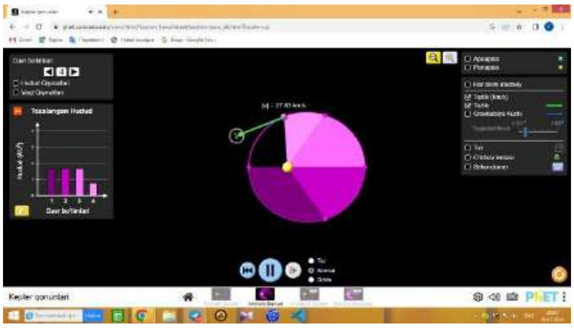


Figure 2: Fixation a moment of the astronomy lesson for studying Kepler's second law.

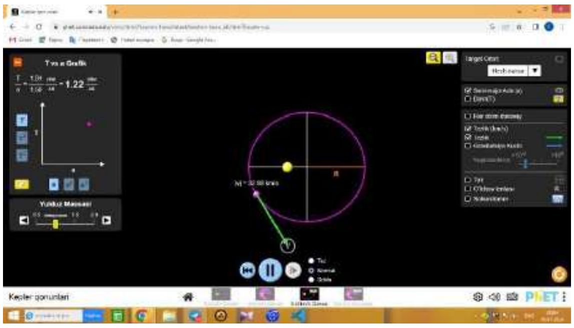


Figure 3: Fixation a moment of the astronomy lesson for studying Kepler's third law.

It should be noted that lately in our previous investigations (Nasirov, 2023) pupils could get acquainted with the picture of the physical world in small (10^{-10} *meter*) distances, now in the present investigations the advantages of integrated PHET medium, controversy, for explaining essential big distances have been shown, for observing which by naked eyes several ten years and working contribution of many researchers would be required.

3 EXPERIMENTAL RESULTS

Before ending each lesson, teacher required fill out Table: "I know & I don't know & I found out", consisting 10 questions dealing with Kepler's laws (Table 1).

Table 1: questions on revealing the pupil mastery of Kepler's laws.

№	**Questions**	**I know**	**I don't know**	**I found out**
1	The meaning of the word "Planet"			
2	The essence of Kepler's first law			
3	The essence of Kepler's second law			
4	The essence of Kepler's third law			
5	Half shaft			
6	Focus			
7	The planet velocity			
8	The planet period			
9	Aphelion			
10	Perihelium			

Pupils mastery have been estimated by criterium: selecting the "I know" in 9-10 cells are 5 (perfectly); in 6-8 cells are 4 (good); in 3-5 cells are 3 (satisfactory) and less than 2 cells are 2 (unsatisfactory). Results of for each class have been presented on Table 2. Here *pupil's mastery* we have calculated by representation:

$$pupil's\ mastery = \frac{perfectly + good + satisfactory}{all\ pupils} \cdot 100\%$$

Here *perfectly*, *good* and *satisfactory* are the pupil's quantity, received 5 (perfectly), 4 (good) and 3 (satisfactory) grades, correspondingly.

Table 2: pupils mastery of Kepler's laws.

№	**Pupils grades**	**In 11^A class**		**In 11^B class**	
		Quantity of pupils	Fraction to all pupil's quantity (%)	Quantity of pupils	Fraction to all pupil's quantity (%)
1	5 (perfectly)	10	38	4	15
2	4 (good)	12	42	6	23

3	3 (satisfactory)	4	14	8	31
4	2 (unsatisfactory)	2	7	6	23
5	*Pupils mastery*	26	93	20	69

As we can see from Table that *pupil's mastery* of 11^A class more to 1,5 times approximately than one of 11^B class. As to the pupil's grades comparison, then pupils with perfectly grades in 11^A class more to 21 % in comparison of 11^B class, pupils with good grades in 11^A class more to 19 % in comparison of 11^B class. At the same time pupils with grades satisfactory and unsatisfactory, then contra versa, in 11^A class less to 17 % (satisfactory) and 16 % (unsatisfactory) in comparison of 11^B class, correspondingly.

4 CONCLUSIONS

Thus, based on the analysis of experiments carried out on revealing advantages of using integrated PHET medium in lesson entitled "Kepler's laws" on astronomy we can conclude that:

the first, using such medium allows us increase pupil's mastery to 1,5 times in comparison of the traditional lessons using usual blackboard;

the second, teacher during the lesson can take a passive role leaving it to pupils themselves conduct experiments in the accelerated and decreased (to million times) scales of motion of space bodies of Solar system.

REFERENCES

Mugutullina I.A., Usenko N.Yu., 2020. Using virtual laboratory works for physics lesson. *Science prospects.* 11(134). P. 128-131.

Dmitriyev O.S., Osipova I.A., Isayeva O.V., 2023. Experience of using virtual laboratory works on physics. *Voprisi sovremennoy nauki I praktiki*. Universitet im. V.I. Vernadskogo. 3(89). P. 144-152.

Akmatbekova A.J., Mambetakunov E., 2023. Virtual laboratory works on physics as optimization form of independent work of students. *Vestnik Oshskogo gosudarstvennogo universiteta. Pedagogika, psixologiya.* № 1(2). P. 6-17.

Zlobina S.P., 2022. Virtual laboratory works on astronomy lessons. *Nauchniy aspekt.* V. 1. № 5. P. 110-113.

Yalovenko S.N., 2022. Cause of precession of Mercury and ither planets. Updated first Kepler's law. *Simvol nauki.* № 1-1. P. 7-13.

Yalovenko S.N., 2021. About the orbit of Mercury. Extension of Kepler's first law. *German International Journal of Modern Science.* №22 P. 67-70. DOI: 10.24412/2701-8369-2021-22-67-70

Yalovenko S.N., 2020. Kepler's laws. *Colloquium-Journal*. № 5-2 (57). P. 12-24.

Granovskii Ya.I., 2021. Conform symmetry of Kepler' problem. *Vestnik Novgorodskogo gosudarstvennogo universiteta.* №4 (125). P. 114-116.

Abubekerov M.K., Gostev N.Yu., 2020. Solution of Kepler's equation wich machine accuracy. *Astronomicheskii jurnal.* V. 97, № 12, P. 1022–1029.

Petrosyan M.G., Avanesyan E.V., 2022. Spheroidal basis of the generalized MIK-Kepler problem. Izvestiya visokix texnologii. 3(22). P. 24-33.

Nasirov, T., Xudoyeva, H., 2023. E3S Web of Conferences **458**, 06002. P. 1-5.

Models for the Future Technological Development of Fire Safety in the Russian Federation

Valeriy A. Yakovlev[a]
Department of Technosphere Safety, North-Eastern Federal University, 58 Belinsky Street, Yakutsk, Republic of Sakha (Yakutia) 677000, Russia
febra.t@yandex.ru

Keywords: fires, fire safety, fire protection measures, fire fighting, ignition, forest fires.

Abstract: The topic of this work is relevant, because the field of fire safety suffers enormous material damage and in some cases is accompanied by loss of life. As an object of study, a potential model for the development of fire equipment and fire safety in the Russian Federation as a whole was chosen. It is believed that this study is justified, since it traces the goal of maintaining a high level of fire safety in the country in cities, towns, places of concentration of material assets and at national economy facilities, by bringing them to an exemplary fire-fighting condition. The article is devoted to familiarization with the issues of fire safety, the organization of fire protection, it also provides a literature review of previously conducted similar studies. The result of the study is an announcement and a proposal for the use of modern fire extinguishing equipment, as well as tools using geographic information systems. Ultimately, the use of the proposed means of fire protection and prevention can be a key factor in their reduction, including the reduction of casualties and property damage.

1 INTRODUCTION

The Russian Federation has a system of fire safety, which is a combination of forces and means, as well as measures of a legal, organisational, economic, social, scientific, and technical nature, aimed at combating fires.

One of the main elements of the Federal Fire Service is the State Fire Supervision in the Russian Federation. It is carried out by officials of the state fire supervision bodies under the jurisdiction of the federal executive body authorized to solve problems in the field of fire safety.

Scientists Sh.Sh. Dagirov and M.V. Aleshkov argues that the technology for creating modern models of equipment consists of several stages. At the initial stage, the need for the developed type of technology is established. For this, statistical data on fires and emergencies are analyzed and summarized, in which it became necessary to attract equipment with the required new tactical and technical indicators. Then, an assessment is made of world practice in the manufacture and use of such equipment. After completing these tasks, the customer forms a technical assignment for the manufacturer or design bureau for a detailed study of possible options for technical solutions for a new model of fire and rescue equipment

S.G. Aksenov in his research notes that when developing a modern fire truck, one must clearly take into account the technological complex, which includes all the characteristics that must correspond to the solution of functional problems of fire equipment. Light aluminum, titanium alloys, adhesive technologies for joining body elements should be used in car structures. Manufacturers of fire equipment pay serious attention to the design of the car, its ergonomics are also taken into account when creating new models. The direction of development of fire engineering is also determined by the situation that develops during the extinguishing and elimination of disasters and fires.

Scientist V.A. Dragin argues that the development and mastering of the production of fire and rescue equipment and fire-technical products by Russian enterprises made it possible, in general, to solve the problem of providing fire departments with fire-and-rescue equipment, fire-technical equipment and fire extinguishing agents. Currently, fire equipment covers a large arsenal of various means: primary fire

[a] https://orcid.org/0000-0002-3765-5292

extinguishing equipment, fire engines, fire extinguishing installations and communications equipment. At the same time, in order to improve the quality and reliability of fire and rescue equipment, work is being done to develop new technologies in the organization of domestic production. A variety of fires and fire fighting conditions, as well as the work performed during the hostilities, required the creation of fire trucks for various purposes.

Today, digital technologies are increasingly being used in the field of occupational, environmental and fire safety. In this paper, we would like to draw attention to how modern technology is already helping firefighters to deal with fire outbreaks and how it may help in the future.

The purpose of this work is to study the impact of digital technologies on the efficiency of the work of the State Fire Supervision in the Russian Federation. The paper discusses the main areas of application of modern technologies, such as video surveillance systems, automatic fire alarms, unmanned aerial vehicles and others, as well as their practical application in the work of firefighters.

During the study, we will analyze various aspects of the use of digital technologies in fire safety, including their effectiveness, ease of use, opportunities for expansion and improvement. We will also consider examples of the practical application of modern technologies in fire safety on the territory of the Russian Federation and beyond.

The study of this topic is relevant and important, given the growing number of fires and the need to improve the efficiency of fire services. The results obtained can be useful for determining the optimal strategies for the use of digital technologies in fire safety and for improving the efficiency of the work of the State Fire Supervision in the Russian Federation.

2 THE FIRE SAFETY SITUATION IN RUSSIA

Ensuring comprehensive safety is one of the most important functions of the state. Considering the dynamics of fires and the number of people killed in fires, this is one of the priority tasks of the Russian Federation. The Russian State Fire Service assesses the situation with fires as extremely difficult (Figure 1). Thousands of people die in Russia every year because of them (Fig. 2) and entrepreneurs lose their business. Unequivocally, fires have a negative impact on the social, man-made and economic infrastructure of the country.

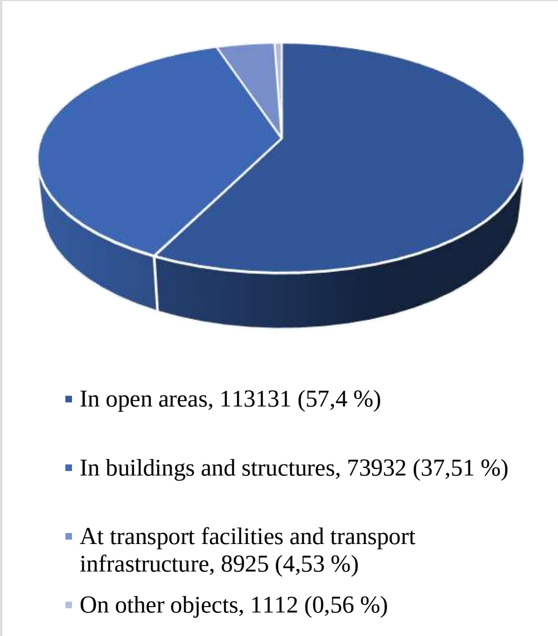


Figure 1: Fire situation by facility group.

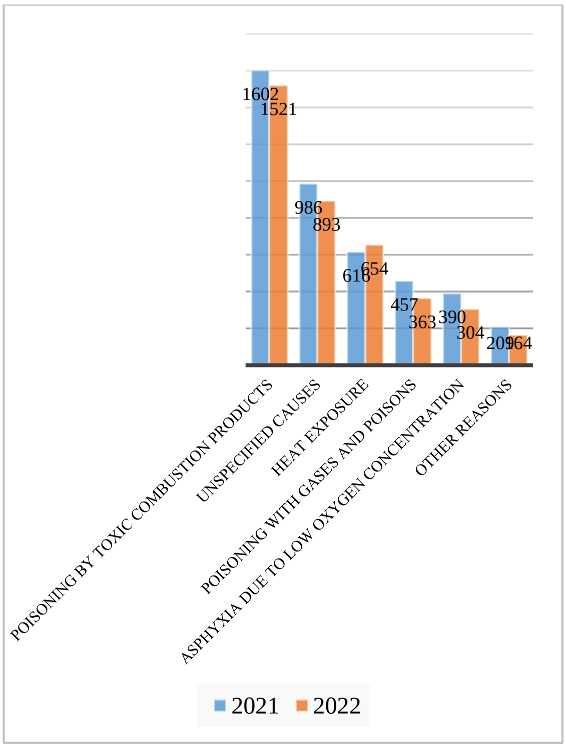


Figure 2: Number of people killed in fires in 2021 and 2022.

There are now several centres in Russia that deal with innovative technologies, develop fire prevention measures, evaluate and develop models of robotic and fire-rescue equipment. The tasks of the structural subdivisions of the Research Institute are to carry out fundamental and applied work and to develop design and technological solutions that would ensure the fire safety of people, facilities and equipment. Experimental research is carried out in the subdivisions which carry out evaluation and improvement of emergency rescue equipment, development of measures to prevent and eliminate consequences of emergencies. Separate tasks are assigned to testing centres, which carry out testing of equipment, materials, and means preventing and eliminating fires, including automatic equipment. Polygon tests of equipment, technical means and materials are carried out in conditions as close as possible to the natural conditions in which they will be operated or used.

3 MODERN FIRE SAFETY EQUIPMENT

Extinguishing media is improved every year because there is a constant need to preserve health and lives and to minimise losses from fires. Novec1230 is one such fire extinguishing agent (Fig. 3). It can be said to be the "panacea" of 2021. This modern, new-generation agent is highly effective and has excellent environmental credentials. Its molecular formula consists of 12 fluorine atoms. Its action consists in removing heat as a component of the combustion chain reaction by 70% and delaying the combustion reaction (inhibition) by 30%. The colourless and odourless refrigerant is intended for automatic fire-fighting systems. It doesn't conduct an electric current, doesn't decrease concentration of oxygen, doesn't harm a human body (safety factor - 2, 38) and the ozone layer. These distinctive qualities make it possible to quickly extinguish a fire, reduce the high temperature inside the room and gain extra time for evacuation.

Technical characteristics of the innovative Novec unit:

The operating temperature of the unit is from 0 °C to +50 °C.

Atmospheric preservation time - up to 5 days.

Operating pressure - 2.5 to 4.2 MPa.

Type of start-up - manual, solenoid, pneumatic.

Figure 3: Novec gas fire extinguishing system.

Novec 1230 is often called "dry water" because it is very similar in appearance to water. The substance is chemically inert and does not react with structural alloys, metals, plastics, sealing materials. This means that after extinguishing a fire, equipment, documents, machines will remain in working order. In accordance with international certifications, Novec 1230 gas extinguishing agent can extinguish fires of solid combustible materials. The agent is already in use in oil companies, oil refineries, flight control centres and situation centres. In Russia, Novec1230 refrigerant fire extinguishing systems have been installed at more than 15 types of facilities. Among the first were the media centre of the Olympic Games in Sochi, the Russian State Library of Art.

Microcapsules with dispersion of 50 ... 200 microns have also been noted as extinguishing agents. They have found their application in the field of fire protection as:

Thermo-activatable gaseous extinguishing agents (stickers). Stickers are composite plates which are mainly used for extinguishing fires in electrical panels up to a volume of 60 litres. They are glued inside the equipment using a self-adhesive base plate. The actuation temperature is 100-120 °C.

Powder extinguishing agents. Powders are used in modular extinguishing systems. The dispersion of the powder capsules is 150...200 microns.

Heat-activated microencapsulated cloths. They are classified as primary fire fighting equipment, including for extinguishing human clothing. The principle of action of the extinguishing cloths is identical to that of stickers. The microencapsulated cloths are applied to a specific fabric.

Microencapsulated extinguishing paints. Paint with refrigerants and microcapsules is used to protect steel structures and buildings made of combustible materials.

Extinguishing powders with the addition of thermo-activated microencapsules of 10...15% by mass. The powders themselves have no extinguishing effect on smouldering materials. However, at the department of fire safety of protection facilities of

Ivanovo Fire and Rescue Academy of the State Fire Service Ministry of Emergency Situations of Russia conducted a study concerning fire-extinguishing powder and additives of heat-activated capsules with chladones. During industrial tests, it was found that the addition of microcapsules with a refrigerant to the fire extinguishing powder "Volgalit-ABC" increases the fire extinguishing efficiency of the powder when extinguishing a model burning stack of wood. It should be said that powder mixtures can be widely used as an extinguishing compound for extinguishing objects with valuable equipment, items of historical value.

According to the results of the research at the Fire Safety Department of the Ivanovo Fire and Rescue Academy of the State Fire Service Ministry of Emergency Situations of Russia, promising uses of microcapsules with refrigerants as additives for fire extinguishing powders have been established.

The Russian Emergencies Ministry's own staff are thinking about how to prevent fires and extinguish them. In 2020, FGBU IAC EMERCOM of Russia successfully developed a subsystem for data collection and analysis, Thermal Points, using machine learning technology and presented it at the WILDFIRE AI open hackathon. It is part of the Hazard and Risk Atlas information system. Its operating principle is as follows:

1. The system receives data from agencies within the RCHS.

2. The algorithm processes data from all satellites (AQUA, TERRA, NOAA) around the clock.

3. After processing the information from artificial intelligence models goes to web-portal of thermal points of MES, mobile application as a map of object or list.

Each thermal point outputs data on the risk of fire (e.g. in a peatland, industrial site or bog), as well as sound and text alerts. All users of the subsystem, including regional and municipal authorities and the RF Ministry of Emergency Situations, have access to the information. The operational data is enriched with information on the RF subject, area and nearest settlements, weather forecast on the area, fire danger category. Based on this data, the ML model automatically determines one of 11 types of burning.

"Thermo-points" have been launched all over Russia. With their help: firefighting costs have been reduced, and regional services react 3 times faster to forest fires and eliminate hotspots in time to prevent the fire from reaching populated areas.

Unmanned aerial vehicles (UAVs) have also found their place in the field of fire safety. Drones (Fig. 4) are specialised and remotely controlled by humans. They are equipped with a camera and can navigate on water.

Figure 4: Fire-fighting quadcopter.

Drones can solve several problems at once:

1. Instantly assess a fire in an urban environment. Drones are manoeuvrable, so they can easily avoid obstacles, fly over buildings, and see all details through smoke. Drones with a thermal imaging camera can locate fires (Fig. 5) and find people in poor visibility conditions.

2. Patrol problematic forest areas from the ground. Due to difficult terrain or poor road infrastructure, it is difficult for ground-based EMERCOM teams to patrol forested areas. Drones, however, can do it. They help to explore the forest, determine scales, fire cut-off lines (Fig. 6) and correctly allocate extinguishing tactics and resources. They are much more advantageous than conventional aviation.

3. Carry out search and rescue operations. In hard-to-reach and dangerous areas, drones can become the "eyes and ears" of rescuers. The use of drones aids in correcting evacuations, assessing the scale of impact and predicting the further outcome of events. During disasters, such as an earthquake, they can fly over fallen structures, locate people and identify dangerous spills.

Figure 5: Shooting with a thermal imaging camera.

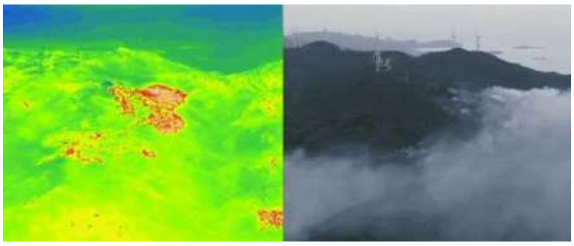


Figure 6: Monitoring a forest fire hotspot from a quadcopter.

Some UAV models are equipped with water hoses and firefighting equipment, but only a limited number of companies use them. Drones are currently being actively implemented and used in emergency services in most of the developed world. For example, drones have been used in Switzerland (2019) to deliver medical supplies and in Ghana (2019) to combat COVID-19. This technique has shown high results during the extinguishing of forest fires in California, South America. The Russian Federation is not far behind. In the summer of 2021, EMERCOM officials used drones to monitor the fire situation in the Moscow region.

Lightning detection technology contributes to fire protection (Fig. 7). They locate lightning strikes with special devices, especially in areas without cellular communication. Their mechanism is simple: the systems record electromagnetic impulses of lightning strikes and send the information to a server. After the data is processed, the location of the lightning strike is shown on a map. This technology helps to prevent fires.

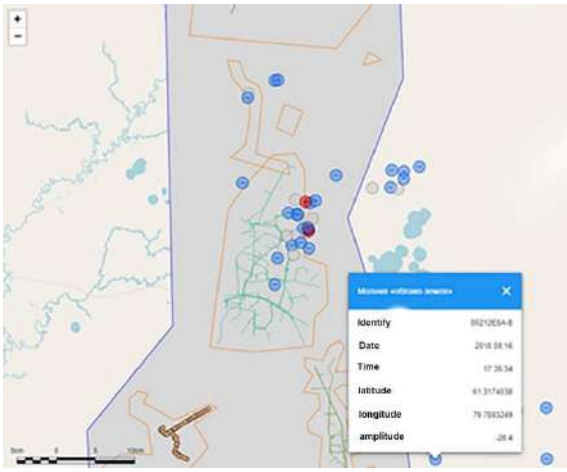


Figure 7: A lightning guidance system using the example of the GIS "Thunderstorm".

The most difficult fire-fighting conditions occur at facilities such as: thermal power plants, nuclear power plants and oil refineries. Fire spreads quickly, visibility is reduced and the room begins to fill with toxic substances and smoke. There is also the possibility of an explosion and an increase in radiation levels. Forest fires are also a difficult situation as they can spread at 30km/h. In order to prevent possible disasters and avoid human casualties, robotic technology has been developed. The MRC (Figure 8) is controlled remotely. The uncrewed, tracked combat unit has increased cross-country mobility. The first robotic fire-fighting units with baton trunks were installed at LNPP and Russian thermal power plants. They were suitable for water spraying of roof structures in engine rooms. However, the robotic complexes are equipped with fire detection, heat and video surveillance and even a self-testing programme. They have successfully coped with:

- reconnaissance of a fire in conditions of radiation, chemical contamination, and fragmentation contamination;

- firefighting;
- emergency rescue operations.

The designs are not afraid of high temperatures, so are able to work where a rescuer cannot.

Figure 8: A firefighter robot created by Tensosensor engineers.

It must be recognised that artificial rainfall can save the forest fire situation. The artificial natural phenomenon is completely environmentally friendly. The method consists of spraying silver iodide into the sky. This method is already used for fire prevention and extinguishing. Special planes with pyropatrons are used for precipitation control. They demonstrated their effect in Yakutia (in 2022), when they extinguished 152 forest fires in 10 days. It is worth adding that the pyropatrons for them are produced in Russia - at the Research Institute of Applied Chemistry, part of Rostec State Corporation.

The need for innovations in fire extinguishing is because standalone systems are not able to meet all current fire protection requirements. Some of them use extinguishing agents that can cause significant damage to the property and equipment in the room. In addition, there are no feedback devices on such systems, so a fire is only reported some time later, when some property may have already been damaged.

4 CONCLUSIONS

It has become apparent that in 2022 the approach to fire safety regulations and control and supervision activities has gradually begun to change due to the transition to risk-based inspections. The Russian EMERCOM is working to improve the responsiveness of fire departments, expanding the conditions for compliance of protection facilities with fire safety requirements. Rescue services are introducing new prevention mechanisms in the area of fire safety, investing in the development of firefighting technologies and techniques and a bias towards various robotics, unmanned aerial systems and modern domestic monitoring equipment.

Pozhtekhnika Group of Companies plays a major role in the development of fire safety in Russia. It is a leading manufacturer of integrated fire safety systems and automation systems for facilities of any level of complexity. Pozhtekhnika's products equip more than 10,000 facilities throughout Russia and the CIS countries.

There are several centres now operating in Russia that deal with innovative technologies used in fire and rescue teams, develop measures to prevent fires, evaluate and develop models of robotic and fire and rescue equipment. The tasks of structural divisions of Research Institute are: carrying out fundamental and applied works and development of design-technological solutions, which would provide fire safety of people, objects, equipment. Thus, there is no doubt - the future of the fire industry is highly promising.

In conclusion, it can be noted that fire safety issues are relevant and will always remain in the first place in the list of priorities of any society. Modern technologies already today help firefighters to cope with challenges and improve the quality of their work, as well as prevent fires preventively. At the same time, innovations and the latest technologies are needed to effectively fight fires and improve fire safety.

The Pozhtekhnika company and research institutes are an example of the successful application of technologies and innovations in the field of fire safety. Leading experts in the field of safety and risk management believe that the use of modern technologies and innovations can significantly improve the level of fire safety in the world.

Thus, we can conclude that the introduction of innovative technologies in the fire industry in Russia and the world is a necessity and a promising direction of development, which will help reduce the number of fires and improve the quality of fire services.

REFERENCES

Zhang, X., Wua, X., Park, Y., Zhang, T., Huang, X., Xiao, F., Usmani, A., 2021. Perspectives of big experimental database and artificial intelligence in tunnel fire research. Tunn. Undergr. Space Technol., 108.Article 103691.

Ingason, H., 2008. State of the art of tunnel fire research. Fire Saf. Sci., 9, pp. 33-48.

Drysdale, D., 2011. An Introduction to Fire Dynamics. (third ed.), 9781119975465.

Lemaire, T., Kenyon, Y., 2006. Large scale fire tests in the second Benelux tunnel. Fire Technol., 42, pp. 329-350.

Fletcher, I., Welch, S., Torero, J.L., Carvel, R.O., Usmani, A., 2007. The behaviour of concrete structures in fire. Therm. Sci., 11 (2), pp. 37-52.

Lai, H., Wang, S., Xie, Y., 2016. Study on the fire damage characteristics of the new Qidaoliang Highway tunnel: field investigation with computational fluid dynamics (CFD) back analysis. Int. J. Environ. Res. Publ. Health, 13, 1014.

Lesnikowski, A., Ford, J.D., Biesbroek, R., Berrang-Ford, L. 2019. A policy mixes approach to conceptualizing and measuring climate change adaptation policy, Climatic Change, 156 (4).

Survey of the Water Distribution Network Operation Using a Hydraulic Electronic Model

Primin Oleg Grigor'evich[1,2][a], Gromov Grigorii Nikolaevich[3][b]

[1]*Doctor of Engineering, Chief Researcher, Research Institute of Building Physics of the Russian Academy of Architecture and Construction Sciences, 21 Lokomotivnyi Passway, Moscow, Russia*

[2]*professor National Research Moscow State University of Civil Engineering, 26 Yaroslavskoe Hwy., Moscow, 129337, Russia*

[3]*Ph.D. (Engineering), Associate Professor, National Research Moscow State University of Civil Engineering. 26 Yaroslavskoe Hwy., Moscow, Russia*

tepper2007@yandex.ru, gromovgn@mgsu.ru

Key words: System, water distribution network, pipelines, simulation, information, calibration.

Abstract: The integrity and safety of public water supply are among the main requirements for these systems - the most important component of public health and one of the main priorities of the federal social policy (Primin, Gromov, 2021; Primin, Pupyrev, 2012). The development of water industry and engineering infrastructure in Russian cities must be carried out in accordance with the projects of the water supply and wastewater disposal schemes. The water distribution network is one of the most cost-expensive and at the same time vulnerable elements of the municipal water supply system. The significant amount of statistical and operational information, complex configuration and structure of the municipal water supply systems, uncertainty of water demand required the use of information technologies to study the functioning of the municipal water distribution network. The paper describes the implementation of the project based on the use of a hydraulic electronic model of a water distribution network

1 INTRODUCTION

Estimation of the condition, water supply continuity, development of engineering and technical solutions aimed at developing and upgrading the system, assessment of the required capital investments are the main objectives while examining the efficiency of the water distribution network of a public water supply system (Chupin, Melekhov, 2020; Hayworth, 2009).

Currently, more than 18 billion cubic meters of water are supplied annually to the water networks in the Russian Federation; however, 30.5 million people, or 22% of the population, are not provided with public water supply services so far. There is no public water supply in 12% of cities and 68% of rural settlements. Water losses in the water distribution networks average 19% of the total volume supplied. The condition of water-transportation conduits is worrying. In terms of the length of underground pipelines, Russia ranks second in the world, and in terms of deterioration of pipes, Russia is among the leaders; hence resulting in a high failure rate of pipelines, losses of drinking water and wastewater leaks (Primin, Pupyrev, 2012). According to the data of the RF Ministry of Construction the vast majority of water and wastewater pipelines in the Russian cities (more than 60%) today have been worn out and need to be reconstructed.

This situation causes serious harm to the life and health of the Russian citizens, damage to the environment and the state's economy; and entails an increase in water tariffs.

As regards the organizational policies, currently, with the development of the economy, market consolidation, and improvement of the regulatory framework in terms of design and construction of water supply systems in Russian cities, a real opportunity has emerged for a large-scale

[a] https://orcid.org/0000-0002-9641-8545

[b] https://orcid.org/0000-0002-3655-4000

reconstruction of public water supply systems in Russia.

This is one of the main targets of the Federal Project “Clean Water” developed within the framework of the national project “Ecology” in accordance with Decree of the President of the Russian Federation dated May 7, 2018 No. 204 “On the national objectives and strategic missions of the development of the Russian Federation for the period up to 2024."

In operating practice, the general requirements to the technical inspection of public water supply systems are given in Article 37 of the Federal Law of the Russian Federation dated December 7, 2011 No. 416-FL “On Water Supply and Wastewater Disposal” and determined by Order of the Ministry of Construction of the Russian Federation dated August 5, 2014 No. 437 “On approval of the Requirements to the technical inspection of public hot water supply, cold water supply and (or) wastewater disposal systems.”

However, the analysis of these documents showed the lack of recommendations during the survey for the use of advanced information technologies, software products for estimating the operation and condition of the water distribution network, obtaining and using the initial data needed for the development and upgrade of water supply systems of the cities and communities in Russia, and plans of action to improve the reliability of water supply in accordance with the established requirements, based on their technical condition and actual operating conditions.

The research carried out in NRU MSUCE proved the efficiency of using hydraulic electronic models in the furtherance of these goals (Gromov, 2018).

2 SURVEY METHOD

The electronic model of a water supply system is an information system consisting of databases, technical support and software designed for the storage, monitoring and updating the information on the engineering and technical condition of public water supply systems; implementing the mechanism of the supervisory control in the system, and carrying out hydraulic calculations. Herewith, the electronic model of a water supply system is an integral part of the water supply scheme being, at the same time, a powerful tool for estimating, as part of a technical survey, the measures on upgrading the system, such as: searching for and eliminating latent water losses, optimizing the water distribution network, identifying emergency areas, selecting the locations for installing dictating points and pressure regulators.

The electronic model of a water distribution network consists of two parts: a database and software. The database contains the information that describes the operational characteristics of the water distribution network, such as: the diameter, material of the pipelines, diameter of the valves, water abstraction amount, characteristics of the pumping equipment, and much more. The topographic framework of the hydraulic electronic model of the water supply is the Master Plan of the city and water pipeline routing in the format of the geographic information system (GIS) (Gromov, 2018).

The electronic model software package provides for solving continuity and energy balance equations in order to determine pressure losses in the water distribution network and allocation of costs. Continuity equations ensure compliance with the mass conservation law. Energy equations ensure compliance with the energy conservation law with account of the pressure losses along the length of pipelines and local pressure losses. The global energy balance round each closed loop in the system must be equal to zero.

The requirements to the software of the electronic model of the municipal water supply system in Russia are regulated by the Decree of the RF Government of September 5, 2013 No. 782 “On the water supply and wastewater disposal schemes.” In accordance with it, the software of the hydraulic electronic model shall provide for the storage and possible update of the following information on the water supply and distribution system:

-graphic display of the water supply facilities with reference to the topographic basis of the municipal unit;

- description of the main facilities of the water supply systems;

- description of the actual characteristics of the operating modes of the water supply system and its separate elements;

-simulation of all types of switches over carried out in the network;

- measurement of the water consumption and calculation of pressure losses in the sections of the water distribution network;

-calculation of changes in the characteristics of the water supply facilities in order to simulate various scheme options;

-estimation of the implementation of scenarios for the perspective development of the water supply system in terms of ensuring water supply modes.

Currently, various software packages can be used for the practical implementation of the hydraulic electronic models (Bentley, MIKE URBAN, ZuLu, ISIGR, Citi Com, etc.. In the Russian Federation, domestic software products are most popular, this is largely due to the low price compared to the considered software packages and a sufficient set of functions.

One of the main software products developed by Polyterm Russian company is ZuluHydro computer-aided calculation package for the survey and analysis of water supply networks in large cities.

ZuLuHydro software package provides for completing the following tasks: conducting a scheduled annual analysis of the condition and operation efficiency of the network; identifying overloaded sections of the network and equipment that limit the conveying capacity; performing hydraulic calculations and analysis of the possible consequences of the scheduled switches over in the water mains; revealing the areas with increased hydraulic resistance and latent leaks by comparing the calculation results with the data of the manometric survey of the network; simulating emergency situations in the network and justifying the measures to minimize the consequences of the failures; simulating the consequences of major water abstractions associated with big leaks in case their urgent localization is not possible; looking up for the gate valves to isolate the failed section of the water distribution network; estimating the hydraulic pattern of the consumer activities and the impact of cutoffs in the water distribution network.

It should be noted that ZuLuHydro software package provides for developing independently plugs-in while installing ZuluNetTools and ZuluXTools components. Besides, this software product has a reference book and a support system in Russian.

An analysis of the ZuLuHydro capabilities shows that this package does not provide for estimating the convergence of the model with respect to the operation of a real water supply system.

Since 1990 **Potok** data processing center has been developing and implementing information systems for the utility operators. One of the products of this company is IGS package. The developer of the software product presents the following characteristics:

-Hydraulic calculations of water distribution networks of arbitrary complexity with an unlimited number of sources and pumping stations operating for the common network, situational simulation and analysis of the water supply modes.

-Simulation of switches over and their arbitrary combinations.

-Optimization of operating modes for pumping stations; drawing up hourly process flow diagrams and schedules of clean water tanks filling.

- Simulation of emergency situations, drawing up recommendations for the localization of failures with the generation of comprehensive reports on the zone of emergency shutdown.

-Simulation of water consumption objects and networks of perspective development, drawing up technical specifications for the connection of consumers.

-Building piezometric graphs including comparative ones for different day hours and water consumption patterns.

-Keeping and analyzing the logs of the network failure rates.

-Keeping switch over logs and retrospective analysis of the modes according to the log data.

-Keeping the logs of applications for scheduled and emergency repairs and rehabilitation works; logs of the vehicles and machinery use; drawing up work orders for the maneuver brigades.

- Analysis of the performance indicators of the water supply system.

- Drawing up preventive maintenance schedules.

-Full capacity of the GIS geographic information system and certification of networks and equipment for the water supply system.

The characteristics of CityCom-GroGraf software fully meet the requirements set by the Decree of the RF Government No. 782 of September 5, 2013; however, this software does not provide for estimating the model convergence, and lacks the functions of automatic model calibration.

ISIGR software package was developed by the Institute of Energy Systems named after L.A. Melent'ev of the Siberian Branch of the Russian Academy of Sciences. A distinctive feature of ISIGR software package is that it is implemented as an Internet system that provides for the connection to make hydraulic calculations from anywhere in the world provided a computer and Internet are available.

The functionality and capabilities of the domestic products are lower compared to Bentley WaterGEMS and Mike Urban software packages based on EPANET standard. Nevertheless, it can be said with full confidence that the presented domestic software packages are capable of completing the main tasks of the hydraulic survey of the municipal water distribution network while providing for a large amount of reporting information.

In terms of the cost-benefit analysis, energy and water quality calculations, the Russian software packages are somewhat retarded compared to Bentley WaterGEMS and Mike Urban software. Therefore, while choosing a software product for developing an electronic model, one must be sure that either now or in future the operator of the water distribution network will not face the tasks that the Russian software packages cannot complete. A significant disadvantage of the Russian software packages is that they do not provide for a complete design solution in terms of the system energy efficiency and water quality. It should be noted that the Russian software packages are not based on a common standard; thus, it is not inconceivable that certain problems can arise while transferring the data from one software package to another.

Building a hydraulic electronic model involves the following steps:

1. Building a design scheme of the model.
2. Developing the balance characteristics of the model.
3. Carrying out preliminary calculations of the system.
4. Calibrating the hydraulic model.

Building a design scheme consists in choosing the type of the design scheme (scaled-up or detailed); it is based on a geophysical basis on a scale of M 1:500. To link the water supply network diagram to the local plan, one has to use the functions of modern software systems and load additionally topographic tablets, geophysical basis or other necessary graphic information in the format of ca geographic information system (GIS) into the program.

Developing the balance characteristics of the model consists in the development of a balance scheme in accordance with the adopted type of the design scheme. During this stage, an analysis of the balances of the water consumption in the city is carried out. This stage provides for indicating certain consumption values for each consumer included in the model.

Carrying out preliminary calculations of the system consists in correcting errors and inaccuracies in the electronic model. The purpose of this stage is launching hydraulic calculation in the software package.

Calibration of the hydraulic model consists in making various changes to the model in order to accurately match the model to the operation of the system based on a series of measurements in the network.

To build a hydraulic model the following information is required:

1. Characteristics of the elements of the water distribution network (pipelines, pumping units, tanks, control valves).
2. Water consumption of consumers assigned to the corresponding network nodes.
3. Topographic information (geodesic marks in the network nodes, coordinates).
4. Information about the system control (for example, pump operating mode).

It is recommended to use design schemes of two types: detailed and scaled-up. A detailed design scheme of the network includes all the elements (pipeline routing, information on the system consumer flow rates, schemes of pumping stations, central heating stations, etc.).

Figure 1 shows an example of a part of the detailed hydraulic electronic model of a city in GIS format.

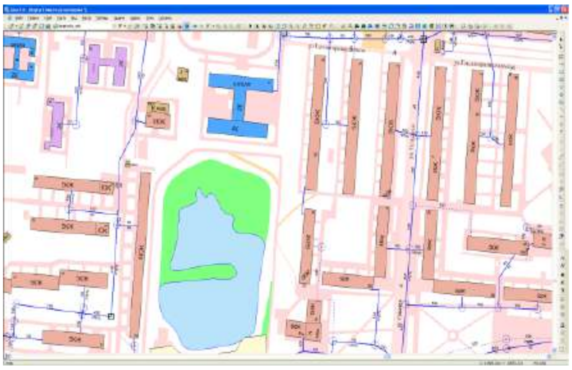


Figure 1: Example of a part of the detailed hydraulic electronic model.

In case a water utility operator does not have a developed water supply model while conducting a survey of the water distribution network, the decision to build a scaled-up network model as a first stage of the detailed model implementation is made.

The scaled-up model provides for analyzing the operation of the major water mains and pumping stations, as well as estimating possible passing of the required flow while connecting large water consumers. Once the design scheme of the selected type has been built, the flow characteristic of the model is determined that is based on the analysis of the operational data and actual supply of the booster pumping stations. Based on the analysis, the maximum day and maximum hour of water delivery is determined. Next, a balance diagram of the system is made that includes zones, as well as subzones of the water supply system.

Based on the balance scheme, either the hydraulic calculation of the water distribution network can be performed for the estimated hour; or 24-hour system simulation can be executed.

Choosing the type of the design scheme of the electronic model should be based on the simulation objectives, amount of available initial data, as well as on the time required for the implementation of the model.

3 SURVEY RESULTS

Fundamentally, all the software packages for the hydraulic calculation of the water distribution network have been designed to solve a system of equations that satisfy Kirchhoff's I and II laws.

In the process of mathematical simulation of water supply systems, the design network scheme is presented in the form of an oriented graph where elements of the water distribution network such as pipelines are usually presented in the form of edges (branches) with account of the water flow direction. The key elements of the hydraulic electronic model are system consumers, pumping equipment, hydrants, etc.

Herewith, the hydraulic calculation methods require an unambiguous specification of initial data, which in turn is characterized by significant uncertainty. It should be noted here that while calculating the designed network, the resistances of its elements, i.e. pipeline sections, are known and can be taken from reference books (11).

Studies in real networks have shown that while calculating an existing network, the resistance of sections may differ from the tabular values. In this regard, it should be noted that about 70% of pipelines in Russia are made of steel. Without adequate protection steel pipelines are most vulnerable to the internal and external corrosion. In turn, the internal corrosion is the main reason for changes in the hydraulic resistance of steel pipelines.

Studies have shown that a fairly large number of factors can influence the discrepancy between the electronic model of the system and the actual data on the network operation:

- incorrectly entered network topology;
- incorrect display of the boundaries of water supply zones in the model;
- adopted simplifications and assumptions in the development of the model;
- errors while entering the information on the system structures (for example: ground elevations, lengths and diameters of the pipelines, characteristics of control valving);
- incorrectly entered level in the regulating tanks;
- indication of incorrect data on the operation of pressure regulators;
- indication of incorrect operating characteristics of pumping units;
- changes in the hydraulic characteristics of the network elements with time (increase in the pipeline resistance, changes in the *Q*-*H* characteristics of the pumps, changes in the amount of water abstraction);
- incorrect distribution of water flows in the system in relation to the actual water consumption;
- errors in elevation marks while allowing for the data of the pressure sensors;
- latent leaks in the network.

The main objective of calibrating an electronic model of a water distribution network is to ensure the model keeping the measured characteristics of a real water supply system (Vassiljev, 2009). From a mathematical standpoint, the process of a hydraulic model calibration consists in minimizing target *E* function:

:

$$E = \sum_{j=1}^{P} w_h\,(h_j^m - h_j)^2 + \sum_{i=1}^{Q} w_q\,(q_i^m - q_i)^2 \quad (1)$$

where *P* and *Q* are the measurable values of pressure and flow rate; h_i^m - measurable head in assembly *j*; h_j - design head in an assembly *j;* q_i^m- measurable flow rate in pipe *i*; q_i - design flow rate in pipe *I*; w_h and w_q are dimensional weighting factors for the pressure and flow measurements, respectively.

In fact, *E* function is the sum of the quadratic differences between the actual network operation data and simulated flow and free head data. Therefore, this function reflects the convergence of the model with the operation of a real network. Accordingly, the objective of the calibration is to minimize this function. As part of the development of a method for calibrating an electronic model of a water distribution network, macro- and micro-calibration is proposed. Macro-calibration focuses on the convergence of the entire water supply network model. In this case, the material of the pipeline is taken into account while estimating the roughness value of a particular pipeline in accordance with the following equation:

$$\varepsilon_i = \varepsilon_{max} - (\varepsilon_{max} - \varepsilon_{min})\left[{(age_{max} - age_i)}\Big/{(age_{max} - age_{min})}\right]^b, \quad (2)$$

where ε_i – roughness of pipe *i*, mm; ε_{max} и ε_{min} – maximum and minimum roughness values corresponding to age_{max} and age_{min} – maximum and minimum time for pipeline laying. The degree b in equation (2) provides for accounting additionally for the power dependence of the distribution of equivalent roughness relative to the pipeline laying time. The value of the degree b is refined during the model calibration process.

4 DISCUSSION OF THE RESULTS

The analysis of Russian software products showed the lack of the algorithm-driven calibration function. In this regard, an algorithm for automatic calibration of the electronic model for "Zulu" Russian software was developed based on the genetic algorithm (Primin, Gromov, 2018).

The calibration algorithm is implemented in Visual Basic for Application (VBA) language using Excel spreadsheets and ActiveX library of ZuLuNetTools components.

The structure of the algorithm action includes:

1. Acquiring from the electronic model database the data on the material and year of the pipeline construction.

2. Based on the values of the specified range of roughness as a result of calculation using formula (2), the algorithm determines the values of the equivalent roughness of each pipeline.

3. The equivalent roughness values obtained as a result of the calculation are exported to the electronic model database, whereafter a hydraulic calculation of the network is carried out.

4. After performing the hydraulic calculation, the macro calibration algorithm calculates the value of the function *E* using formula (1). Based on the obtained values, a surface is formed that reflects the dependence of the objective function *E* on the maximum values of the roughness of pipelines made of various materials. Next, the minimum value of the function *E* and the corresponding maximum values of the equivalent roughness of steel and cast iron pipelines are selected.

The developed calibration algorithm was evaluated while building a real electronic model of the water distribution network of one of the Russian cities (Primin, Gromov, Stepanov, Kozlova, 2018).

5 CONCLUSIONS

1. One of the important steps in the use of information technology in the survey of the operation of a water distribution network is the use of hydraulic electronic models.

2. Electronic models are tools for evaluating the current state of the water supply system, and allow modeling its prospective development.

3. Based on the experience of implementing electronic models in a number of Russian cities, a technique for building electronic models, and algorithms applicable to the Russian software "ZuLuHydro" and needed for building and calibrating models were developed.

4. So that the electronic model corresponded to the real characteristics of the system, carrying out a calibration stage is required. From a mathematical standpoint, calibration involves minimizing the function that reflects the quadratic difference between the measured characteristics of the system and the values obtained as a result of the simulation.

REFERENCES

Primin, O.G., Gromov, G.N., 2021. Reliability and environmental safety of water and sewer pipelines. E3S Web of Conferences 263, 04002. FORM-2021.

Primin, O.G., Pupyrev, E.I., 2012. Problems of the current state of water supply and sanitation systems in Russia. *Chistaia Voda: Problemy i Resheniia,* 3-4;40-48.

Chupin, R.V., Melekhov, E.S., 2020. Justification of the parameters of developing water supply and sanitation systems based on their electronic models. *IOP Conference Series: Materials Science and Engineering, 2020.*

Hayworth, G. I., 2009. Reliability engineering advan-ces. New York; Nova Science Publishers, Inc.

Gromov, G.N., 2018. Improving the hydraulic calculations of water supply systems using hydraulic models. *International Journal of Civil and Structural Analysis.* 2; 141-148.

ZuLu" Software official website 2018. URL: https:// www.politerm.com/(accessed date: 01.06.2018)

"City Com" Software official website URL: http:// citycom.ru/citycom/hydrograph/ (accessed date: 01.06.2018)

"ISIGR" Software official website URL: http:// 51.isem.irk.ru/ (accessed date: 01.06.2018).

Bentley Systems, Incorporated. 2011;28-37.

DHI. MIKE URBAN. 2016; 145-150.

Shevelev, F.A., 2013. Tables for hydraulic calculations. Moscow, Kniga po Trebovaniiu.

Vassiljev, K. A., 2009.Calibration of a model of an operational water distribution system containing pipes of different age. *Advances in Engineering Software*. 40; 659-664.

Primin, O.G., Gromov, G.N., 2018. Use of genetic algorithms for calibration of hydraulic models of water supply systems. IOP Conference Series Materials Science and Engineering; 456(1):012108/.

Primin, O.G., Gromov, G.N., Stepanov, D.L., Kozlova, O.V., 2018. Calibration of an electronic model if a water supply system (through the example of the water distribution network of Salavata city). Vodosnabzhenie i Sanitarnaia Tekhnika. 9;4-12.

Impact of COVID-19 on the Russian Agricultural Sector

T. E. Marinchenko[a]
Russian Research Institute of Information and Feasibility Study on Engineering Support of Agribusiness, the Federal State Budgetary Scientific Institution (Rosinformagrotekh FSBSI), 60, Lesnaya Str., Pravdinsky Township, 141261 Moscow Region, the Russian Federation
9419428@mail.ru

Keywords: COVID-19, agricultural sector, impact, activity, digitalization.

Abstract: From the very beginning of the COVID-19 pandemic, proactive measures were needed to maintain open intra-regional and international trade, expand the scope of social protection programs, preserve agricultural food chains and support agricultural production. Russian agriculture was not officially recognized as affected by the COVID-19 pandemic, but many sub-sectors felt the negative consequences. In particular, the meat and dairy sub-sectors, as well as producers of organic products, suffered to a greater extent than crop production. The pandemic has impacted those involved in the processing, shipping and distribution, and those involved in the food service sectors. Small and medium-sized agricultural enterprises suffered the most, especially producers of perishable products, seedlings and flowers. However, the pandemic also had positive consequences, in particular, attention increased to such parameters of food security as import independence, and the processes of automation and digitalization accelerated. The main negative and positive consequences of COVID-19 on Russian agriculture are discussed.

1 INTRODUCTION

FAO research has shown that the COVID-19 pandemic has threatened not only lives, but also livelihoods that provide food. Soaring unemployment, loss of income and rising food prices have threatened access to food in both developed and developing countries. Global food markets are not protected from negative developments (NovelCoronavirus (COVID-19), 2019). However, they have been less affected compared to other sectors that are more dependent on logistics disruptions and weakening demand (Market Monitor, AMIS, 2020). FAO research showed that small farmers experienced the most difficulties, while finding it difficult to purchase seeds and fertilizers due to rising prices and declining incomes. They were experiencing the consequences of destroyed logistics schemes and a lack of labor. Closed borders required agricultural enterprises to resolve issues of storing and transporting products, as well as processing them to minimize losses. Closed restaurants and retail outlets led to a temporary oversaturation of the market and a reduction in production volumes (COVID-19), 2019;Belaya, 2020).

One of the global trends during the pandemic has been the digitalization of economic sectors and social security of the world's population. In 2019–2021, the average global growth rate of the fleet of industrial robots and the Internetization of the population has reached, according to expert estimates, 10–12%. The share of Internet coverage of the world population has grown to almost three quarters (The pandemic has accelerated, 2021).

An important conclusion of the pandemic is that most agricultural enterprises have not been ready to work in these difficult conditions. For example, illness among workers at pig slaughter plants in Germany led to serious supply disruptions (Hogan, Hunt, 2020). Advances in digitalization in countries around the world before the pandemic made it easier to function during lockdowns (Sedova, Nazarenko, 2022).

Russian agricultural production suffered less than other sectors of the economy. A serious challenge was the breaks in agricultural food chains, the depreciation of the ruble, the fall in household

[a] https://orcid.org/0000-0003-3721-112X

incomes, which had led to a decrease in demand and a change in its structure, a reduction in the volume of interregional and international trade, a lack of seasonal workers, etc. (Kolomeitseva,Glotova, 2023). The pandemic marked the deglobalization of the Russian economy, regionalization and renationalization of domestic and foreign policy. The role of the state as a guarantor of food security and a regulator of the development of the agricultural sector has increased (How has Russia's economy, 2021). An analysis of the negative and positive consequences of the pandemic on the Russian agribusiness is provided.

2 MATERIALS AND METHODS

In the process of analyzing the indicators of the agribusiness for the first half of 2020, the development trends of the program for digitalization of the agricultural sector and the development of proposals to reduce risks in the agricultural food sector, methods of monographic, comparative and other types of analysis were used. The research process used official data from FAO, AMIS, the Russian Federal State Statistics Service, the Ministry of Agriculture of Russia, as well as scientific research by Russian and foreign scientists.

3 RESULTS AND DISCUSSION

Although the Russian agricultural sector was not recognized as affected by the COVID-19 pandemic, many sub-sectors felt the negative consequences. The volume of agricultural production in the first six months of 2020 increased by 3%, while for basic types of economic activity it decreased by 4.1% (Rosstat - Wholesale trade, 2021). However, this increase was achieved mainly due to crop production. The meat and dairy sub-sectors, aquaculture, and organic producers were hit more than crop production.

The most serious challenge was transport restrictions, both within the country (problems with obtaining work permits and transporting food and equipment), and at the intercountry level (difficulties with importing day-old chicks, seeds, vitamins, plant protection products and food ingredients) (Dmitrieva, 2023;Ryazantsev,Vazirov,Khramova, Smirnov, 2020).

In the context of ruble devaluation, agricultural production dependent on imported inputs faced increased production costs. Thus, at the beginning of 2020, prices for vitamins and feed amino acids, which were not produced in the country, increased by 30-50%. This affected the cost of feed, the share of which in the cost of milk and meat was up to 75%. The costs fell on all sectors of livestock farming, and ultimately on the consumer. According to the Russian Federal State Statistics Service average retail prices for milk and dairy products increased by 5.4% in annual terms over the six months of 2020 (Fig. 1) (Rosstat - Wholesale trade, 2021).

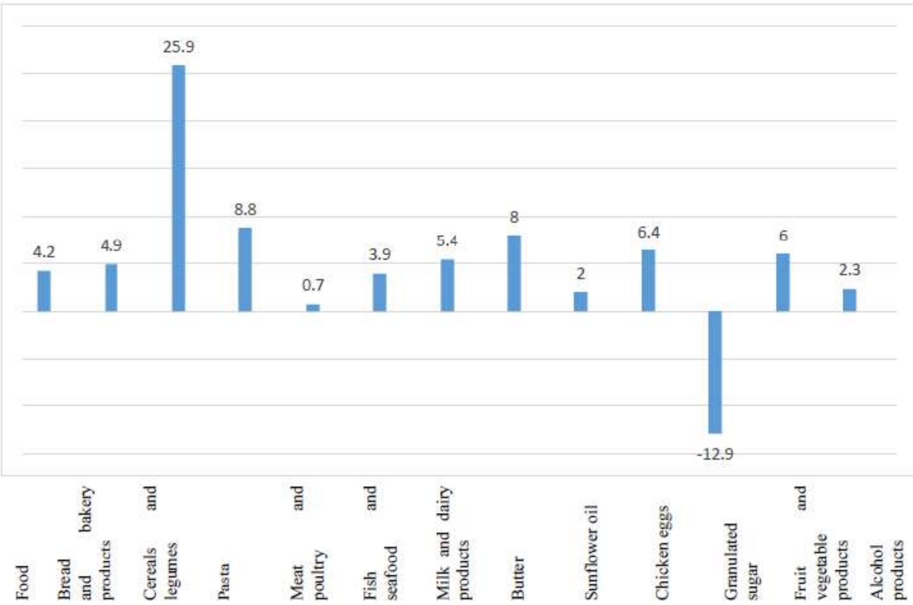


Figure 1: Dynamics of average retail prices of food products by category January-June 2020. Source: Russian Federal State Statistics Service.

In the meat industry, there has been a shift in demand from highly processed products to cheaper cut meat. With the increase in feed costs, there was a decrease in meat prices. In the poultry industry, for example, against the backdrop of declining wholesale prices, low demand and increased pork production, wholesale prices for poultry meat fell below cost levels in May 2020. At the same time, the cost has increased and the supply of imported hatching eggs has decreased, which initiated projects to build our own production facilities (Rosstat - Wholesale trade, 2021, Marinchenko, 2023). Beef consumption also declined amid growth in pork and chicken meat.

The dairy market is largely domestic. Falling incomes and the self-isolation regime have reduced the consumption of dairy products. Milk is a product of inelastic demand, but dairy products have lost in consumption volumes, in addition, the volume of government purchases has decreased due to the closure of child care institutions (Burdenko,Bykasova, 2021).

A serious negative effect of COVID-19 was a drop in household incomes, which resulted in a reduction in demand for more expensive categories of products, including organic products. Large food manufacturers, for example, the Cherkizovo Group and Miratorg Agricultural Holding, were forced to optimize the range of meat products. During a period of uncertainty and restrictions on freedom of movement, the population tended to purchase products with long shelf life, which led to an increase in demand and a subsequent rise in prices for cereals and legumes (Fig. 1). The population is more conservative in its choice and prefer to eat at home (Ukolova, 2021).

With a general decline in income, average food expenses increased. If, on average, 31.7% of a family's income was allocated for food in May 2019, then it was already 41.5% in May 2020, while income decreased by 13.5% (Fig. 1) (Rosstat - Wholesale trade, 2021)

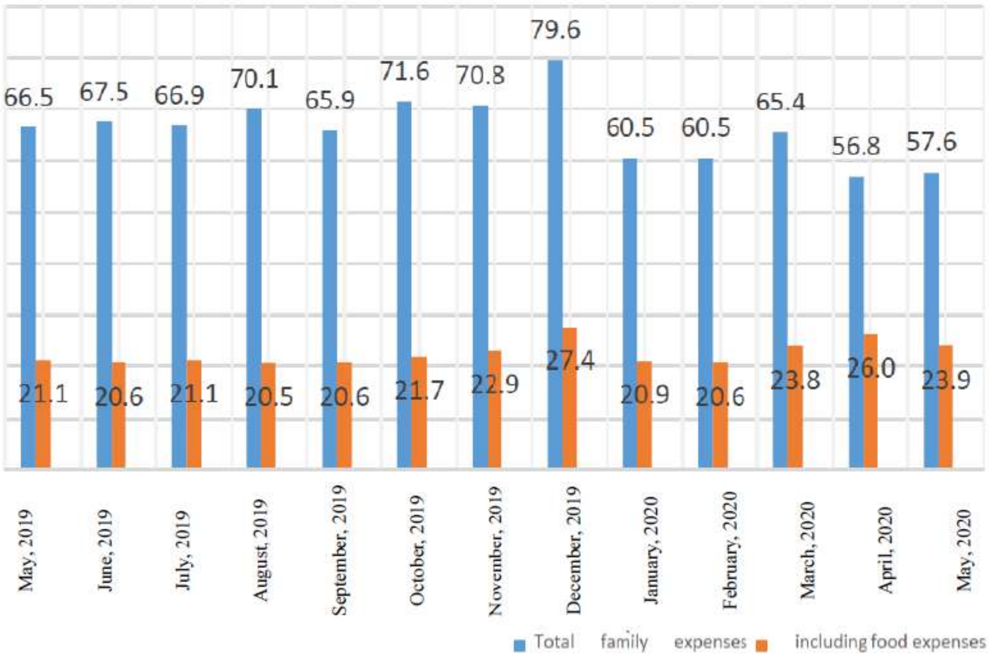


Figure 2: Dynamics of total expenses and food expenses.
Source: Russian Federal State Statistics Service.

Another example is the losses of producers of perishable products associated with the severance of logistics connections and the closure of regional and municipal borders (How has Russia's economy, 2021). The profitability of the greenhouse business, for example, has decreased from 15-20% to just above zero. On average, retail prices for cucumbers in Russia fell by 15% and by 23% for tomatoes from May to June, while the demand for fresh produce decreased by 30% during self-isolation. The industry's losses amounted to at least 6.2 billion rubles (Rosstat - Wholesale trade, 2021).

Small farms selling products at fairs and markets that were closed during the self-isolation period suffered more. The farmers who specialized in growing spring flowers and seedlings in greenhouses suffered the most. They were forced to dispose of their products. Local authorities also joined in the sale of products in “manual control” mode (Ukolova,2021).

During the COVID-19 pandemic, Russian agricultural exports have changed. There has been a reduction in sales channels. The share of raw materials with low added value increased, which was the result of a decrease in global effective demand and increased competition, while in monetary terms the volumes increased. In the first 6 months of 2020, Russia exported food worth $11.9 billion, which was 14% more than that in 2019 (Rosstat - Wholesale trade, 2021).

At the same time, the pandemic also had a positive impact. Thus, the investment agenda has changed. Food security as a state priority raising the issue of import substitution influenced decisions on investing in projects in the field of import substitution (Marinchenko,2023). The emphasis has changed from the question of whether the product will be cheaper than an imported one to the factor of import substitution.

The next effect was the acceleration of automation and robotization of agricultural production. Agricultural enterprises with the capacity to process perishable products were able to obtain value-added products instead of their losses. Experts suggest, and the author supports this proposal, to return to the practice of minimum balances, in which products are procured with a small reserve, which makes it possible not to disrupt the supply of products if it is necessary to ensure quarantine measures (Ukolova,2021).

The change in the structure and format of consumption led to the development of new forms of doing business, and those companies that were able to quickly adapt received advantages, were able to expand their markets and change their position in value chains. Digitalization processes have intensified. For example, retail trade has become a driver of digital transformation, an important sales channel and a source of demand for human capital efficient in the digital economy (Sedova,Nazarenko, 2022). During quarantine restrictions, its online sales tripled (Ukolova,2021).

The state’s priorities in the field of digitalization of the agricultural sector are outlined in the departmental project titled “Digital Agriculture”. The evolution of the project’s development is indicative.

The project purpose was the digital transformation of agricultural enterprises through the introduction of digital technologies and platform solutions to ensure a technological breakthrough in the agribusiness and achieve a 2-fold increase in productivity in “digital” agricultural enterprises by 2024.

The project included activities for the implementation, among others, the national platform for digital public management of agricultural enterprises called “Digital Agriculture”, for identifying and analyzing problems and conditions hindering the digitalization of the agricultural sector, identifying the most promising digital technologies, accumulating data on agricultural land, creating an information base for market participants, and ensuring control over the quantity and quality, processing, transportation and sale of products (Marinchenko,2021).

The national platform with the Agrosolutionssubplatform should ensure a 2-fold increase in labor productivity per employee, a 1.5-fold reduction in unit costs for business administration and a reduction in the share of material costs in the cost of a unit of agricultural products (fuels, fertilizers, electricity, planting material, feed, etc.) by 20% or more.

The concept of the 2020 “Digital Agriculture” national platform already planned to include more than 50 services for managing the agribusiness and six subplatforms for land use and land management, product traceability, agrometeorological forecasting, and collection of industry data, information support and provision of services and storage and distribution of information materials (Marinchenko, 2021. Digital technology).

The departmental digital transformation program for 2021-2023 of the Russian Ministry of Agriculture provides for the interaction between participants in the agribusiness in electronic form, and increasing the transparency and predictability of processes for market participants and financial institutions that finance targeted industry programs.

The unified digital platform for agriculture in 2022 has already united all industry information systems. Information is collected and processed within the framework of the Single Window information system. It is planned to create a unique digital ecosystem around the agribusiness uniting multi-level management systems of the agricultural sector, related industries and departments (The Ministry of Agriculture, 2021). Thus, the state vision of the functionality of the digital ecosystem of the agribusiness has come a long way since the beginning of the pandemic.

4 CONCLUSIONS

The COVID-19 pandemic has had enormous consequences for the global economy, in addition to threatening life, and has revealed the risks of insufficient food supply for the population of many countries around the world.

The Russian economy features deglobalization, regionalization and renationalization of politics, growing state influence on the agricultural sector. The priority of investments in import-substituting projects has increased.

The main negative consequences of the COVID-19 pandemic, which led to losses for agricultural farms and farmers, were restrictions on the import of means of production, a decrease, and in some cases, the cessation of sales of goods, a shortage of labor, loss of markets, a decrease in household incomes, a reduction in demand and a change in its structures, etc.

A feature of these consequences was the multidirectionality of influences at the level of sub-sectors, when some of them increased production, while others experienced a crisis. It is advisable for enterprises to organize the practice of minimum balances, which will allow the formation of a stock of products at agricultural enterprises.

In addition, long-term consequences emerged, in particular, the pandemic accelerated the modernization and digitalization of the agricultural sector and contributed to the diversification of agricultural production. Thus, in particular, the program for digitalization of agriculture has changed. From a national platform aimed at increasing the efficiency of agricultural production, it has become more complex to a concept to an ecosystem for managing the agribusiness. Experience in online sales of agricultural products has been formed.

REFERENCES

Belaya, A., 2020. High alert mode. What problems of agriculture did the coronavirus reveal? In *Agroinvestor*https://www.agroinvestor.ru/analytics/article/34152-rezhim-povyshennoy-negotovnosti-kakie-problemy-selskogo-khozyaystva-vyyavil-koronavirus/.

Burdenko, E.V., Bykasova, E.V., 2021. Positive approaches and practices for sustainable SME development in the COVID-19 context. In *Handbook of Research on Strategies and Interventions to Mitigate COVID-19 Impact on SMEs*, pp. 403-429.

Dmitrieva, E., 2023. New Socio-economic Picture of the World: Consequences and Challenges of Coronavirus. In *COVID-19: Implementation of the Sustainable Development Goals, RTCOV*, ISBN 978-989-758-617-0, SciTePress, pp. 373-379.

Hogan, M., Hunt, N., 2020. Pig pandemic adds to German pork sector pain as exports banned https://finance.yahoo.com/news/pig-pandemic-adds-german-pork-021819586.html.

How has Russia's economy fared in the pandemic era? Retrieved in https://www.worldbank.org/en/news/opinion/2021/06/08/how-has-russia-s-economy-fared-in-the-pandemic-era.

Kolomeitseva, N., Glotova, I., 2023. How Has the Pandemic Changed the AgroindustrialComplex.In *"COVID-19: Implementation of the Sustainable Development Goals" - RTCOV*; ISBN 978-989-758-617-0, SciTePress, pp. 299-304.

Marinchenko, T., 2023. Development of meat poultry farming in Russia within the framework of state programs. In *E3S Web of Conferences. International Scientific Conference*, p. 371.03033.

Marinchenko, T., 2021. Digital technology in agricultural sector. In *IOP Conf. Ser.: Earth Environ. Sci*, p. 666.032024.

Marinchenko,T.E., 2021. Digital transformations in agriculture. In *Studies in Systems, Decision and Control*, vol. 283, pp. 409-418.

Market Monitor, AMIS, 2020, No. 76 – March. Retrieved in https://www.amis-outlook.org/fileadmin/user_upload/amis/docs/Market_monitor/AMIS_Market_Monitor_Issue_76.pdf.

Novel Coronavirus (COVID-19). Retrieved in https://www.fao.org/2019-ncov/q-and-a/impact-on-food-and-agriculture/en.

Rosstat - Wholesale trade and commodity markets (rosstat.gov.ru). Retrieved in https://rosstat.gov.ru/statistics/opttorg.

Ryazantsev, S., Vazirov, Z., Khramova, M., Smirnov, A., 2020. The impact of the COVID-19 pandemic on the position of labor migrants from Central Asia in Russia. In *Central Asia and the Caucasus*, vol. 21, 3, pp 58-70.

Sedova, N.V., Nazarenko A.A., 2022. Impact Analysis of COVID-19 Pandemic on Digital Technologies Spread in Corporate Sector of the Russian Federation. In *Regional Economy. South of Russia*, vol. 10, 3, pp. 28-35.

The pandemic has accelerated digitalization and deglobalization: what does this mean for Russia? Retrieved in https://www.hse.ru/news/expertise/531116306.html.

Ukolova, N.V. et al., 2021. Development of technology transfer in agriculture during the COVID-19 pandemic in Russia. In *Bioscience Biotechnology Research Communications*, vol. 14, 4, pp. 1544-1549.

The Ministry of Agriculture is creating a national platform for digital agriculture. Retrieved inhttps://tass.ru/ekonomika/11416853.

Marinchenko, T., 2023. Improving the infrastructure for the transfer of innovations in the agribusiness. In *E3S Web of Conferences*, vol. 371, p. 03001.

Marinchenko, T.E., 2021. Automation of dairy cattle breeding. In *IOP Conf. Ser.: Earth Environ. Sci*., vol. 624(1), p. 012080.
Marinchenko, T.E., 2021. Digital Technology in Agricultural Sector. In *IOP Conf. Ser.: Earth Environ. Sci*., vol. 666(3), p. 032024.
Marinchenko, T.E., 2021. Digital Transformations in Agriculture Studies in Systems. In *Decision and Control*, vol. 283, pp. 409-418.
Marinchenko, T.E., 2022. Regional Activity in Agriculture Digitalization. In *IOP Conf. Ser.: Earth Environ. Sci*., vol. 988(3), p. 03007.
Marinchenko, T.E., 2022. Support for Innovative Activities in the Russian Agricultural Sector. In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 1069(1), p. 012034.
Marinchenko, T.E., 2022. Transformation of the Service Sector as Part of the Agribusiness Digitalization. In *IOP Conf. Ser.: Earth Environ. Sci*., vol. 988(4), p. 042007.
Milking robots. Statistics and forecasts around the world. Retrieved in https://robotrends.ru/robopedia/doilnye-roboty.-statistika-i-prognozy-po-miru (accessed on 12.10.2023).
Nemenushchaya, L.A., Bolotina, M.N., 2021. Innovations for milk production. In *Equipment and technologies in animal husbandry*, vol. 3 (43), pp. 43-47.
Radun, V. et al., 2021. Implementing artificial intelligence as a part of precision dairy farming for enabling sustainable dairy farming. In *ЕкономикаПољопривреде*, vol. 68(4), pp. 869-880.
Russian IT companies will provide farmers with "smart" technologies. Retrieved in https://www.croc.ru/press_releases/rossijskie-it-kompanii-obespechat-agrariev-umnymi-tekhnologiyami (accessed on 12.10.2023).
Sandu, I., et al., 2019. Scientific basis for forecasting the innovative development of the agricultural sector of the region’s economy. In *Perm region IOP Conf. Ser.: Earth Environ. Sci.*, vol. 274, p. 012016.
Shahinfar, S. et al., 2012. Weigel Prediction of Breeding Values for Dairy Cattle Using Artificial Neural Networks and Neuro-Fuzzy Systems. In *Computational and Mathematical Methods in Medicine*, vol. 4, p. 127130.
The state of AI in 2021. QuantumBlack AI by Mckinsey. Retrieved in https://www.mckinsey.com/capabilities/quantumblack/our-insights/global-survey-the-state-of-ai-in-2021 (accessed on 25.10.2023).
Transforming Agriculture through Digital Technologies. Retrieved in https://www2.deloitte.com/content/dam/Deloitte/gr/Documents/consumer-businessgr_Transforming_Agriculture_through_Digital_Technologies_noexp.pdf (accessed on 30.11.2022).

Ensuring Basic Technological Processes at a Poultry Farm by Developing an Autonomous Robotic System

Georgy Georgiyevich Klasner[1], Tatiana Alexandrovna Storozhuk[2], Vladislav Frantisekovich Kremyansky[3], Turchanin Igor Olegovich[4], Brommer Alina Denisovna[5]
Kuban State Agrarian University, 13 Kalinina, Krasnodar, Russia
egor.klasner.91@mail.ru

Keywords: Poultry, robotization, smart farm.

Abstract: This paper discusses the issues of poultry technology in the Russian Federation, development prospects, and a new technology called "Smart Farm". Today, to increase the productivity of poultry farms, it is necessary to rethink existing technologies for the production of poultry meat, eggs and introduce new technological solutions for basic technological processes, namely: watering, feeding, disinfection of litter, collection of eggs, monitoring of poultry health by biological external signs. Our idea is that we want to eliminate the human factor from production technology by robotizing the main technological processes. These robots should reduce the likelihood of infections in poultry, increase the productivity of poultry farms, reduce the number of workers involved in the production process, and the number of bulky and energy-intensive stationary installations.

1 INTRODUCTION

Industrial poultry farming is one of the main components of the food safety of our country. This industry is currently undergoing a stage of transition to full automation of all technological processes, and this industry begins its development in 1962. This year, the first mechanized technological solutions for outdoor poultry keeping were manufactured, and mass production was already started in 1965 Modern technology for poultry farming has more than 100 different machines and automated systems.

Mechanization and automation are an integral part of modern poultry farming, its technical basis, and the merger of these two industries gives the concept of robotization of production. On the basis of robotization, not only the consolidation of poultry farms takes place, but also the creation of eco-logical and, no less importantly, sterile technology, which reduces the cost of human labor and increases productivity significantly.

In this regard, the goal is automation and robotization of farms, transition to autonomous operation of the enterprise (without the participation of human labor).

The main problem is to get away from manual labor, which occupies up to 70% of the total volume of robots on poultry farms, by introducing autonomous robots to implement the main technological processes on poultry farms.

2 RESEARCH METHODOLOGY

Description of existing technologies for breeding poultry for outdoor maintenance and comparison with the developed technology "Smart farm". Development and writing of patents.

[1]https://orcid.org/0000-0002-9549-8109
[2]https://orcid.org/0000-0002-9494-9748
[3]https://orcid.org/0000-0001-6273-6660
[4]https://orcid.org/0009-0009-0950-8357
[5]https://orcid.org/0009-0008-2389-5771

3 RESEARCH PART

Outdoor poultry keeping is a fairly widely used method of breeding poultry. With this method, the places of detention are equipped with special feeders, drinkers, roosts and bathrooms with ash.

For the manufacture of roosts, smooth polished wooden blocks are used, the length of the bars should be such that the livestock can fit on it.

Feeders are of great importance in the arrangement of outdoor poultry keeping. Their correct shape allows you to reduce the loss of feed on the placer. Groove feeders are most often used. A bar is attached above the feeder, fixed in such a way that it turns when the bird tries to sit on it. This feature allows you to avoid contamination of the feed with droppings, as well as to prevent the burying of feed by birds.

Basically, either vacuum or round drinkers are used for floor maintenance.

The bedding for poultry should be deep, mainly hay or wood shavings are used to create it. Peat or crushed corn stalks can also be used for these purposes. The bedding is changed annually. The average cost of bedding material for one bird is: for chickens – 10 kg, turkeys – 25-30 kg, geese – 40 kg.

Due to the fact that the litter self-heats up due to chemical reactions occurring in it, the bird is not cold during the cold period of time.

We propose to carry out the robotization of these technical processes by replacing the described technical solutions with autonomous robots, namely a robot drinker, a robot feeder, a robot for collecting eggs, and a robot for stirring the litter.

Next, 4 robotic systems will be described for performing technological operations for growing poultry using the Smart Farm technology.

A robot drinker is necessary to provide birds with water (up to 1000 heads). It consists of a housing in which a chassis with an electric motor and a control unit is enclosed, also located vertically on the tank body with a volume of 200 liters, drinking systems are attached to the tank, which include nipple, removable drinkers in the amount of 12 pieces. The robot's control unit has a trajectory along the working area of the poultry house, it is also equipped with a water level sensor, a filter for purifying water from microorganisms, and a special funnel for refueling water.

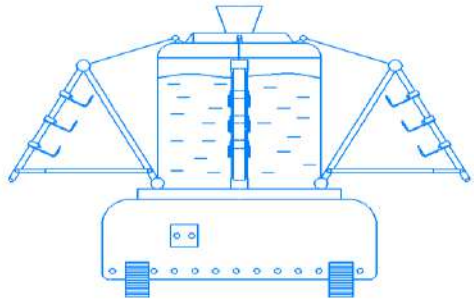


Figure 1: The appearance of the drinker robot (patent No. RU was obtained 2,768,843 C1 IPC A01K 39/024 2021.g).

We want to present the feeding system in the form of a robotic feeder.

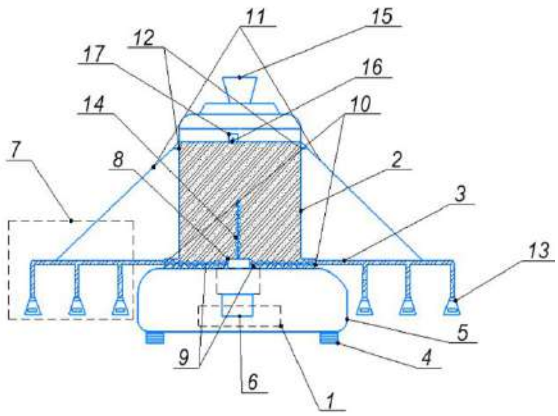


Figure 2: Appearance of the feeder robot: twin electric motor 1, reservoir 2, supply line 3, tracked chassis 4, box-shaped housing 5, control unit 6, sections with feeders 7, gearbox 8, two horizontal augers 9, discharge hatches 10, two winch cables 11, two electric winch units 12, removable cone-shaped feeders 13, vertical auger 14, loading funnel 15, warning light 16, surveillance camera 17.

A robot feeder for feeding agricultural products. birds with outdoor maintenance work as follows: the box-shaped housing 5 begins to move on the tracked chassis 4 along a predetermined route, which is programmed in the control unit 6, the system occupies a predetermined position in the hangar and the control unit sends a signal to two electric winch units 12, which the winch cable 11 begins to lower from the supply line 3 fixed on them, with cone-shaped feeders 13 fixed on them, after that the control unit sends a signal to a dual electric motor 1, which, through a gearbox 8, activates horizontal augers 9, those, in turn, promote the feed into the discharge hatches 10, and from them the feed enters the feed line from where it gets into the feeders, after emptying the tank, the system comes into a transport position and goes to the feed mill to refuel the tank, refueling takes place through the loading funnel 15, the surveillance camera 17 displays the environment around the moving unmanned system, the alarm system lamp 16 reflects its working condition.

There is a problem with the processing of bedding material, as this is one of the sources of poultry diseases. To solve this problem, we present a robot-agitator of bedding material.

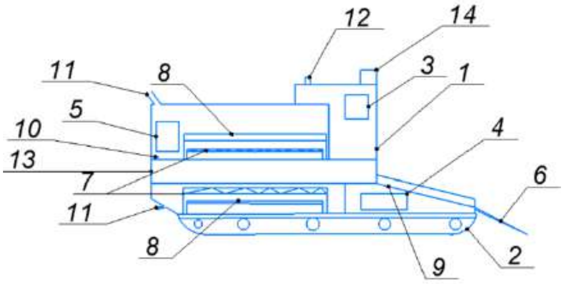


Figure 3: Appearance of the litter trowel robot: housing 1, chassis 2, control unit 3, two electric motors 4, 5, pick-up blades 6, heating elements 7, fans 8, perforated conveyor belt 9, temperature sensor 10, air ducts 11, warning lamp 12, discharge opening 13 video surveillance camera 14.

The robot agitator for processing poultry litter material works as follows: a chassis 2 is attached to the lower part of the housing 1, the control unit 3 sends a signal to two electric motors 4 and 5, a video tracking camera 14 turns on, an unmanned self-propelled system for processing poultry litter material starting movement picks up the litter using a pick-up blade 6, directing it to two heating elements 7 and two fans 8, using a perforated belt conveyor 9, the temperature sensor 10 monitors the temperature in the working area and throughout the unit, giving a signal to the warning lamp 12, air enters the fans 8 through two (upper and lower) air ducts 11, then the bedding material is discharged back through the discharge hole 13, while the heating elements 7 with fans 8 are located above and under the perforated belt conveyor 9, in front of which a pick-up blade 6 is mounted connected to the lower part of the body 1, and the chassis 2 is made tracked.

Our technology also provides for the robotic egg collection of laying hens.

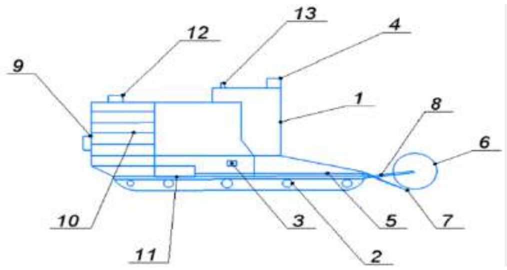


Figure 4: Appearance of the egg collector robot: housing 1, chassis 2, control unit 3, motion controller 4, egg picker made in the form of a belt conveyor 5, feed roller 6, spring–loaded grip fingers 7, two brackets 8, storage hopper 9, cassettes for storing eggs 10 pressure sensor 11, chamber video surveillance 12 and warning light 13.

The egg collector robot works as follows when kept on the floor: the feed roller 6 sends the eggs to the spring–loaded gripping fingers 7, through them they move to the perforated conveyor belt 5 and further into the egg storage cassette 10 located in the storage hopper 9, it contains a pressure sensor 11, necessary to determine the weight of eggs in the cassette storage by this weight, the degree of filling of the hopper is determined. As soon as the cassette is filled with eggs, a signal is sent to the control unit 3 about the need to replace the cassette, it sends a signal to the storage bin 9, to move the cassette to the lower part of the storage bin and an empty cassette is installed in its place, as soon as all cassettes are filled, the control unit 3 starts the crawler chassis 2, it is directed in the unloading shop, the egg cassettes are removed and replaced with empty ones, and so the repeated egg collection cycle begins. Thanks to the video surveillance camera 11, manual control is possible, the warning lamp 13 serves to indicate the status of the robot.

Also, the designed technology includes three automated units shown in Figure 5 for cleaning robots from poultry droppings and other contaminants, a water refueling unit for a drinker robot, and finally a unit for refueling a feeder robot, this unit is connected to the feed shop using a feed line. These blocks make it possible to completely eliminate the factor affecting the spread of infections, namely, to disinfect working installations.

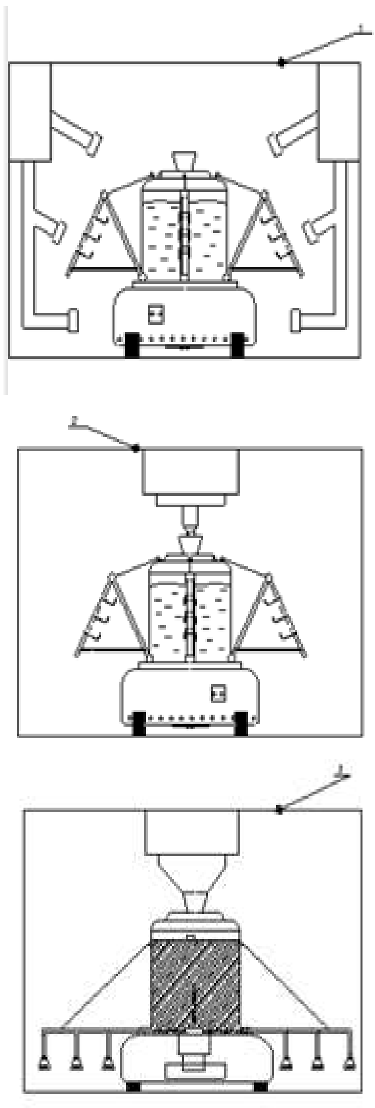


Figure 5: 1 cleaning unit, 2 feed filling unit, 3 water filling unit.

These units together form a machine system called a smart farm. To test and compare with existing technologies, we took a robot sawyer and compared economic indicators in the following section.

4 ECONOMIC EFFICIENCY OF THE RESEARCH RESULTS

To determine the economic efficiency of the developed robotization of a poultry farm, we will calculate the technical and economic data based on the work of the applied and developed means of robotization and compare these technical solutions.

The main productivity of laying hens depends on the conditions of their maintenance, since, for example, with a lack of feed or an incorrectly selected temperature, laying hens stop laying at any time.

Total output:

$$Q_{\text{г}} = n \cdot B \qquad (1)$$

where $Q_{\text{г}}$ – annual volume of poultry products, c/year;
n – number of birds, head;
B – productivity of one bird c/pt.

From these enterprises, the total annual weight of eggs laid by one laying hen is 18 kg per year, B = 0,18 kg/head.

$$Q_{\text{г}}^{\text{с}} = 1000 \cdot 0{,}18 = 180 \text{ c/year;}$$

Due to the introduction of the sawyer's work at the outdoor poultry keeping, the incidence due to infectious diseases will decrease by 7%.

$$Q_{\text{г}}^{\text{п}} = 180+7\% = 193 \text{ c/year;}$$

Labor costs for production are determined by the formula:

$$H_{\text{г}} = l_{\text{р}} \cdot \Phi_{\text{г}}^{\text{р}} \qquad (2)$$

where $H_{\text{г}}$ – labor costs, person.hour./year;
$l_{\text{р}}$ – number of employees, people;
$\Phi_{\text{г}}^{\text{р}}$ – the useful fund of the working time of one employee, h, which is equal to 2190 hours / year.

Let's determine the labor costs:

$$H_{\text{г}}^{\text{с}} = H_{\text{г}}^{\text{п}} = 2 \cdot 2190 =$$

$$= 4380 \text{ person. hour./year;}$$

Labor costs per unit of production:

$$H_y = \frac{H_{\text{г}}}{Q_{\text{г}}} \qquad (3)$$

where H_y – labor costs, pers.h/c.

$$H_y^{\text{с}} = \frac{4380}{180} = 24{,}3 \text{ pers. h/c;}$$

$$H_y^{\text{п}} = \frac{4380}{193} = 22{,}7 \text{ pers. h/c;}$$

The specific labor cost savings will be:

$$H_{эу} = H_y^с - H_y^п \tag{4}$$

where $H_{эу}$ – saving labor costs,

$$H_{эу} = 24{,}3 - 22{,}7 = 1{,}6 \text{ чел. ч/ц}$$

Labor productivity:

$$Р_{тр} = \frac{1}{H_y} \tag{5}$$

where $Р_{тр}$ – labor productivity, kg/person.h.

$$Р_{тр}^с = \frac{1}{24{,}3} = 0{,}041 \text{ kg/person. h.}$$

$$Р_{тр}^п = \frac{1}{22{,}7} = 0{,}044 \text{ kg/person. h.}$$

Рост производительности труда:

$$Р_{тр}^р = \frac{(Р_{тр}^п - Р_{тр}^с)}{Р_{тр}^с} \cdot 100 \tag{6}$$

Then:

$$Р_{тр}^р = \frac{(0{,}044 - 0{,}041)}{0{,}041} \cdot 100 = 7\%$$

where К – investments in means of mechanization, rub.;
a – the rate of depreciation on mechanization funds, %;
r – the rate of deductions for repairs and maintenance of mechanization facilities, %.

$$К_п = 116800 + 7941{,}3 = 124741{,}3 \text{ rub.}$$

Thus, the book value of the developed unmanned self-propelled watering system for outdoor poultry maintenance will amount to 124 741,3 rubles.

Calculation of depreciation costs, as well as calculation of repair and maintenance costs for the existing and proposed technology, respectively:

$$С_а^с = \frac{55800 \cdot 20}{100} = 11160\ rub/year$$

$$С_а^п = \frac{124741{,}3 \cdot 20}{100} = 24947\ rub/year$$

$$С_{р.то}^с = \frac{55800 \cdot 10}{100} = 5580\ rub/year$$

$$С_{р.то}^п = \frac{124741{,}3 \cdot 10}{100} = 12474{,}13\ rub/year$$

The annual electricity consumption is determined by the formula:

$$С_{эл} = А_г \cdot Z_{эл} \tag{7}$$

where $А_г$ – annual electricity consumption kWh/year;
$Z_{эл}$ – the cost of 1 kWh of electricity, rub.;

$$А_г = N \cdot T_{заг} \cdot К_з \cdot \frac{К_о}{К_с} \cdot \eta \tag{8}$$

where N – power consumption of the installed equipment;
$T_{заг}$ – annual load, h;
$К_з$ – numerical multiplier of equipment loading, $К_з$ =0,85;
$К_о$ – the numerical multiplier of the simultaneous operation of the equipment, $К_о$= 0,6-0,7;
$К_с$ – a numerical multiplier that takes into account losses on the network, $К_с$= 0,96;
η – numerical multiplier of the efficiency of the electric motor (0,85-0,9).

Тогда:

$$А_г = 0{,}35 \cdot 766{,}5 \cdot 0{,}85 \cdot \frac{0{,}7}{0{,}96} \cdot 0{,}85 = 141{,}33$$

$$С_{эл} = 141{,}33 \cdot 2{,}7 = 381{,}6\ rub$$

Additional operating costs will amount to 21064 rubles/year.

We know that when using the proposed equipment, the productivity of the poultry farm will increase by 13c eggs per year, which can be sold at a price of 16,670 rubles/c. This will allow you to receive an additional 216,700 rubles annually.

The payback period for additional investments will be:

$$t_о = \frac{124741{,}3}{216700 - 21064} = 0{,}64\ year;$$

Next, we will determine the amount of specific investments.

$$К_у^с = \frac{55800}{180} = 310\, rub/c;$$

$$К_у^п = \frac{124741{,}3}{193} = 646{,}33\, rub/c;$$

Let's calculate the given costs:

$$П_у^с = 3929{,}32 + 0{,}15 \cdot 310 = \\ = 3975{,}82\, rub/c;$$

$$П_у^п = 3773{,}8 + 0{,}15 \cdot 646{,}33 = \\ = 3870{,}75\, rub/c;$$

The energy intensity of the technological process is determined from the expression:

$$А_у = \frac{\sum А_г}{Q_г} \quad (9)$$

$$А_у = \frac{141{,}33}{193} = 0{,}73\, kW/c$$

The metal consumption of the technological process is determined from the ratio:

$$М_у = \frac{\sum М}{Q_г} \quad (10)$$

Then:

$$М_у^с = \frac{110}{180} = 0{,}61\, kg/c$$

$$М_у^п = \frac{70}{193} = 0{,}36\, kg/c$$

The calculated economic indicators indicate the appropriateness of using the developed self-propelled system for watering poultry.

5 CONCLUSIONS

1. As a result of comparing the two technologies being developed and the existing one, a number of advantages of the technology being developed for the robotization of poultry farms were revealed, namely: low equipment costs, investment is much lower than that of existing technologies, and most importantly, it is to obtain an environmentally friendly product of poultry meat and eggs.

2. We also found out after comparisons and analyses that existing technologies for poultry cultivation in outdoor conditions have a number of disadvantages: cumbersome, time-consuming, insufficiently automated, and also sources of infections for poultry due to contamination accumulated on them.

3. After conducting a patent search for structures for robotization of poultry farms, we proposed a constructive and technological diagrams of robots for drinkers, feeders, agitators, litter and egg pickers. We have sent applications for the invention of the Russian Federation.

4. When commissioning the proposed means of robotization, it is possible to reduce the labor costs of 1 kg of products by 6.6%, but operating costs increase by 3%, while the productivity of the poultry farm will increase by 13 kg of products per year, these products by 16,670 rubles /ts, this will increase the annual profit by 216,700 rubles, the payback period of investments will be 8 months. all these data indicate the full feasibility of using these robotic systems in poultry farms.

REFERENCES

Kotelevskaya, E. A., Klasner, G. G., Tolstov, K. S., 2020. Determination of safe conditions for moving ears to the working surface of the plant for sorting ears of seed corn. IOP Conference Series: Earth and Environmental Science : conference proceedings, Krasnoyarsk, Russia, Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations. Vol. 421. – Krasnoyarsk, Russia: Institute of Physics and IOP Publishing Limited, 2020. P. 22014.

Klasner, G. G., Tarasov, V. S., Baranov, V. P., 2020. The study of the moment of resistance of the grinder of legumes. Conference Series: Earth and Environmental Science : conference proceedings, Krasnoyarsk, Russia, Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations. Vol. 421. – Krasnoyarsk, Russia: Institute of Physics and IOP Publishing Limited, 2020. P. 22013.

Kremyansky, V. F., Klasner, G. G., Yaroslavtsev, D. I., 2020. Factor analysis in the lame problem (the problem of composite cylinders).IOP Conference Series: Materials Science and Engineering, Krasnoyarsk, Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations. Vol. 862. – Krasnoyarsk: Institute of Physics and IOP Publishing Limited, 2020. P. 32043.

Examining the Impact of Economic Factors on Air Pollution of the Arctic Regions

Pavel Druzhinin[a]

Luzin Institute for Economic Studies of the Kola Science Center of the Russian Academy of Sciences, 24a Fersman Street, Apatity, Russia

pdruzhinin@mail.ru

Keywords: Arctic regions, air pollution, investments.

Abstract: The article examines the impact of economic development on the environmental performance of the Russian Arctic regions. A model was built and an assessment of the influence of factors determining the dynamics of air pollution was made. It was shown that during the economic downturn, the dynamics of industrial production determined the change in pollutant emissions. With the beginning of economic growth, pollution reduction continued due to the modernization of production, the transition to modern technologies with a significantly lower level of environmental stress. Environmental investments also had a significant impact, the dynamics of which was unstable. In the 2010s, the growth of investment in industry stalled, and pollution began to increase in some regions.

1 INTRODUCTION

There are five Arctic regions in the European part of the Russian Federation. The Murmansk Region and the Nenets Autonomous Okrug (NAO) are fully included in the Arctic Zone of the Russian Federation (AZRF), and in the Arkhangelsk Region, the republics of Komi and Karelia – only the northernmost municipalities.

A significant part of the economy of these regions is mining, in gross regional product (GRP) its share in the NAO reaches 86%, more than in any other subject of the Russian Federation. The extraction of minerals and their primary processing have a significant impact on the environment. For example, in Karelia, more than half of the emissions of pollutants into the atmosphere are accounted for by JSC Karelsky Okatysh, which mines iron ore and produces iron ore pellets. The mining sector suffered less than others during the crisis of the 1990s, and it quickly shifted to exporting its products. Oil, metals and raw wood were in demand on the European market. Already in the late 1990s, the growth of mining began. High revenues from the export of products made it possible to carry out technical re-equipment of enterprises, switch to modern technologies.

In the Arctic regions, paper production and metallurgy related to the processing of local resources are also developed, which also heavily pollute the environment. The recession in the manufacturing industry was much stronger, and growth began later, but the products of the two most important industries were also exported, due to exports, their financial situation improved markedly in the 2000s, and enterprises were able to begin modernizing their production.

The structure of the economy of the capitals of the regions changed in market conditions, industrial enterprises were closed, and new ones appeared outside the regional centers. As a result, the share of services grew and the role of energy increased, the share of which in the volume of their industrial production reached 50%. The use of coal and fuel oil led to large emissions of pollutants. Switching to gas as the main fuel has reduced emissions, but it is associated with the construction of gas pipelines and stretches in the region for decades. Electricity production in the 1990s did not decrease as much as in the manufacturing industry, but in the Republics of Komi and Karelia it remained at the level of 2000.

Various models have been proposed to assess the impact of economic development on the environment. In the 70s, the IPAT model was proposed, which

[a] https://orcid.org/0000-0001-5303-0455

considered three factors – population size, per capita production and technological level. It was also used to study Russian regions (Tretyakova, 2019). The STIRAT model was later built on its basis (Diets, Rosa, 1994; Geely, Mancinelli, Mazzanti, 2014). This model has been improved, and factors affecting the dynamics of pollution have been proposed, complementing the above. Further, the following factors were considered: the dynamics of the urban population, the level of urbanization, the dynamics of industrial production, the share of industry in GRP, the share of agriculture in GRP, the share of mining in GRP, energy consumption, energy consumption per unit of GRP and some others (Wang et al, 2021; Li et al, 2016).

As already noted, the economic downturn of the 1990s led to a noticeable decrease in pollution, and with the beginning of economic growth in the 2000s, pollution began to increase in most regions, but in some regions emissions of pollutants decreased due to changes in the structure of the economy and its modernization (Semyachkov, 2021). To assess the impact of economic development on the environment, special models were built, including econometric, balance, optimization and game models (Glazyrina, 2022; Tretyakova, 2014). Separate models were used for studies of the northern and Arctic regions (Klyuchnikova, 2021; Vasil'tsov, 2021).

The purpose of this article is to analyze the impact of industrial development on the dynamics of emissions of pollutants in the Arctic regions of the European part of the Russian Federation.

2 METHODOLOGY AND DATA

The research examined Rosstat data on the Arctic regions for 1990-2022 (Regiony ..., 2023). Most of the economic and environmental indicators of the regions are available on the Rosstat website https://rosstat.gov.ru, there are indexes of cost indicators, which allows, if necessary, to build data series at comparable prices. The following indicators were used in the course of the research: GRP and its structure, shipped industrial products, investments in the economy, investments in industry, fixed assets, environmental investments by type, environmental protection costs by type, air pollution and others. The Arkhangelsk Region and the NAO began to be listed separately in reference books only from 2006-2012, so calculations were carried out for the combined region.

To analyze the relationship between economic and environmental indicators for each region, graphs were drawn, changes in the dynamics of pollutant emissions were analyzed and hypotheses about possible dependencies were put forward. As a result, pollution functions were built for each region, which helped to understand the causes of environmental changes (Druzhinin, 2012):

$$E(t) = A \times X_1^{\mu}(t) \times X_2^{\nu}(t) \times X_3^{-\eta}(t) \qquad (1)$$

where: $E(t)$ - air pollution; $X_1\ (t)$ – a factor negatively affecting the environment; $X_2\ (t)$ – a factor that can both positively and negatively affect the environment; $X_3\ (t)$ – a factor reflecting environmental protection activities and positively affecting the environment; A, μ, η, ν – constant; t - year. Previous studies have shown that in the Russian Federation, every economic crisis greatly changes the dependence of environmental and economic indicators, which means that the period during which the resulting dependence persists is quite short. As a result, it is difficult to build dependencies with a large number of indicators.

Since almost all types of activities affect the environment, more often the analysis of ecological and economic processes is carried out according to GRP and indicators derived from it. In the Russian Federation, the influence of industry is decisive, approximately 85% of air pollution are accounted for by industry. Therefore, the change in the level of pollution depends primarily on the dynamics of industrial production.

Several factors can have both positive and negative effects. The construction of new industrial enterprises and the expansion of existing ones lead to an increase in pollution, the amount of which depends on the technological level of production. The result may be different when modernizing enterprises. The transition to modern technologies often leads to a reduction in environmental impact. Therefore, investments in the economy and investments in industry, depending on their orientation, can have the opposite effect.

Accordingly, part of the investment does not lead to growth, but to a decrease in pollution, and the final result depends on the ratio of investments of different directions. For models, there is a certain difficulty at the regional level related to the availability of data on the direction of investments, it is available only for all investments in fixed assets. Structural shifts in the economy can also lead to a decrease in pollution with an increase in the share of services.

Environmental protection reduces the amount of pollution, it is reflected by two indicators – environmental investments and current environmental protection costs. In this case, investments in air protection and the costs of air protection are considered.

Data analysis has previously shown the importance of changes in economic policy for the relationship between environmental and economic indicators. As a result of economic crises and changes in economic policy to get out of them, new ecological and economic dependencies have been developing since 1992, 1999 and 2009. For developed countries, changes in environmental policy are also having a noticeable impact, and quite quickly. In the Russian Federation, the situation is different, the execution of decisions is postponed for years, often the initial severity of environmental restrictions disappears due to the decisions of the executive branch.

It should be noted that the pollution functions (1) constructed according to the previous period, which are related to previously made investment decisions, cannot be used to predict after another economic downturn. They are useful only for analyzing the period in which the obtained dependencies were active. The need to overcome the crisis leads to a significant change in economic policy, and the parameters of the pollution function associated with the pre-crisis period (1) must be adjusted.

2 RESULTS

As already mentioned, air pollution is mainly associated with industrial activities, other activities have little effect on this environmental indicator. Emissions are decreasing in all regions, but they have increased in some periods. There was a slight increase in the Murmansk region in 1995-1997. In the Republic of Karelia, their small growth began in 2015, in the Komi Republic they grew strongly in 1994 and in 2011-2013. In the Arkhangelsk region, emissions fell in the 1990s along with the decline of the economy, then the rapid development of the NAO industry began, and emissions continued to grow until 2010. Emissions in the NAO increased from 22 tons in 2000 to 282 tons by 2010, but fell to 156 tons in 2011. As a result, by 2012, emissions had decreased to the level of 2002.

The economic downturn of the 1990s was accompanied by a much smaller reduction in air pollution. As a result, the ratio of air pollution to industrial production (specific emissions) increased in the 1990s and began to decrease since 1997 in all regions (Fig. 1). The least environmentally friendly enterprises turned out to be more competitive in market conditions. Until 1997, specific emissions grew both relative to GRP and relative to industrial production. Then the specific emissions decreased, at first quite quickly, and then more slowly, and only in the Murmansk region continuously. In other regions, there was an increase in specific emissions from time to time, in the Arkhangelsk region – in 2006-2010, in Komi – in 2011-2013, in Karelia – since 2015.

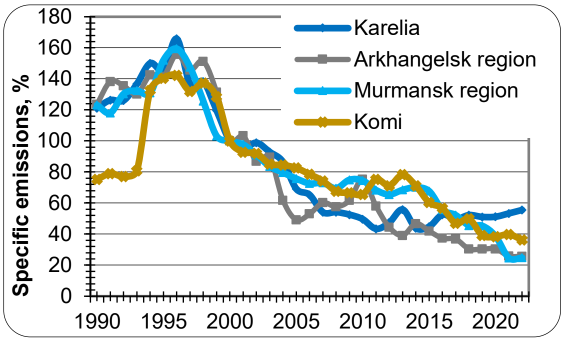


Figure 1: Dynamics of the ratio of pollutant emissions to industrial production, 2000=100%.

In the 1990s, the industry shrank by about half. The industry recovered fairly quickly in the 2000s and slowly in the 2010s. In the Murmansk Region, the Republics of Karelia and Komi, industrial production in 2022 was almost at the level of 1990, and air pollution was 2-5 times less, which most likely indicates the impact of modernization. In the 2010s, the industry of the regions practically did not grow, only in the Murmansk region since 2017 its rapid growth began, as a result of doubling investment in industry. The GRP of the three regions has so far reached only about 2/3 of the 1990 level.

The situation is slightly different in the Arkhangelsk region, whose industry grew rapidly in 2004-2010, when the oil fields of the NAO were being developed. Industrial production in the NAO has increased by more than 40% in some years. Accordingly, both industrial production and GRP in the Arkhangelsk region far exceeded the level of 1990.

Investments in the economy of the regions in the 1990s fell by 8-17 times, and there were no funds for the modernization of enterprises. In the 2000s, investments in the economy of all regions grew rapidly, and enterprises were modernized. In the 2010s, investment growth continued in the Murmansk Region, slowed down in Karelia, stopped in the Arkhangelsk Region, and investment began to decline in the Komi Republic. Investments in industry had a similar dynamic.

Investments in environmental protection vary significantly by region, in some years in the

Murmansk region they were about 200 times more than in Karelia. In the 1990s, the financial resources of enterprises were limited and environmental investments were rapidly declining. During the economic growth, the financial situation of enterprises improved, and for a short time environmental investments grew, then declined and grew again. Relative to 2000, environmental investments increased only in the Murmansk region, while in Karelia they decreased by 8 times. Investments in air protection decreased in all regions, in Karelia by 36 times in 2022 compared to 2000, and in some years there were no investments in air protection at all, which most likely was the reason for the increase in pollutant emissions in Karelia.

The analysis of the interrelationships of the indicators of the four regions in the graphs showed that for the three regions in the 1990s, the dynamics of pollutant emissions and industrial production are very close and equation (1) can have only one factor, which was confirmed by calculations (R^2=0.92-0.98). The decrease in environmental impact was less than the decline in production due to a decrease in environmental investments and negative structural shifts. In the Komi Republic in 1994, an environmental disaster occurred in Usinsk, which affected the dynamics of indicators and calculations for the 1990s were not carried out. Economic policy in the regions began to differ with the beginning of economic growth, respectively, the structure of the economy changed in different ways, environmental investments and modernization began to influence.

According to the collected data, calculations were carried out, which demonstrated the need to allocate three periods separated by the economic crises of 1998, and to a lesser extent 2008-2009. The graphs showed that the change in dependencies in 2008-2009 in the Komi Republic and the Murmansk region was small, for the Arkhangelsk region the most significant. At the same time, the change in environmental legislation has had virtually no effect on the dynamics of environmental and economic indicators of the four regions.

Table 1 and 2 shows the results of calculations, for the Arkhangelsk region it was necessary to allocate two periods and use the spline function. For the other three regions, calculations can be carried out for 1998-2021, which, however, is associated with a deterioration in statistical characteristics. Environmental investments turned out to be insignificant only in the 2010s for the Arkhangelsk region, their sharp decline affected. The Republic of Komi also found the importance of environmental investments to be low. Few industrial enterprises were built in the regions, they were often built near the regional center to replace enterprises with outdated technologies that were closed there, and on a new technological basis. Investments in industry were mainly aimed at modernizing existing enterprises, so investments led to a reduction in pollutant emissions. At the same time, the dynamics of investments in the economy reflected the potential increase in pollution better than GRP and industrial production.

Table 1: Results of calculations of pollution functions (1) for emissions of air pollutants in three Arctic regions for 1998-2021.

	Karelia	Komi	Murmansk Region
A	383.7***	804,3***	720,6***
Investments in the economy	0,069	0,569***	0,114
Investments in industry	-0,317*	-0,937***	-0,409*
Investments in the protection of the atmosphere	-0,042***	-	-
Environmental investments	-	-0,066	-0,120***
R^2	0,78	0,83	0,86
p	0,00000	0,00000	0,00000

*** p<0.01, * p<0.1

Table 2: Results of calculations of pollution functions (1) for emissions of pollutants in the Arkhangelsk region for 1998-2021.

	1998-2010	2011-2021
A	24,78***	0,0004***
Investments in the economy	0,986***	4,642***
Industry	-	0,942*
Investments in industry	-0,527***	-1,247***
Investments in the protection of the atmosphere	-0,142*	-
R^2	0,94	0,94
p	0,00000	0,00000

*** p<0.01, * p<0.1

4 CONCLUSIONS

The calculations carried out have shown the possibility of using pollution functions to identify factors affecting environmental pollution. During the recession until 1998, the dynamics of air pollution was determined by the dynamics of industrial production. Since 1998, other factors have also begun to influence, and the dependence of environmental indicators on economic ones has become very different in the regions. Calculations for 1998-2021 confirmed the importance of modernization, which was the main factor in reducing air pollution. Environmental investments were also affected, which turned out to be insignificant for only one region in the 2010s. In the 2010s, investment growth slowed down and the transition to new technologies stalled, which led to an increase in pollution in some regions.

ACKNOWLEDGEMENTS

The publication was prepared within the framework of the state task of the Luzin Institute for Economic Studies KSC RAS (topic FMEZ-2023-0007).

REFERENCES

Dietz, T., Rosa, E. A., 1994. Rethinking the environmental impact of population, affluence and technology. *Human Ecology Review*. L. 1: 277–300.

Gilli, M., Mancinelli, S., Mazzanti, M., 2014. Innovation complementarity and productivity effects: Reality or delusion? Evidence from the EC. *Ecological Economics*. 103: 56–67.

Glazyrina, I.P., Lavlinskij, S.M., Yakovleva, L.L., 2022. Ekologo-ekonomicheskie modeli v mineralno-syrevom sektore Rossii: formirovanie investicionnoj politiki na osnove gosudarstvenno-chastnogo partnerstva. *Ekonomika i matematicheskie metody*. 58(3): 57-69. (In Russian).

Druzhinin, P.V., Shkiperova, G.T., 2012. Ecological and Economic Models and Predictions in the Regional Management System. *Studies on Russian Economic Development*. 23(1): 66-72.

Klyuchnikova, E. M., Korppoo, A., 2021. Implementation of the “green growth” concept in the Russian Arctic (on the example of the Murmansk region). *The Arctic: ecology and economics.* 11(4): 493-503. (In Russian).

Li, L., Lei, Y., He, C., Wu, S., Chen, J., 2016. Prediction on the Peak of the CO2 Emissions in China Using the STIRPAT Model. *Advances in Meteorology*. Article ID 5213623.

Regiony Rossii. Socialnj-ekonomicheskie pokazateli. 2023: Stat. sb. / Rosstat. 1122 p. (In Russian).

Semyachkov, A. I., Gao, R., Atamanova, E. A. 2021. Management of Regional Natural Resources based on the Variability of Environmental and Economic Indicators. *Economy of Regions.* 17(2): 520-537.

Tretyakova, E.A., 2019. Environmental intensity of economic growth in the Baltic Sea region. *Baltic Region.* 11(1): 14-28.

Tretyakova, E. A., 2014. Assessing Sustainability of Development of Ecological and Economic Systems: A Dynamic Method. *Studies on Russian Economic Development.* 25(4): 423-430.

Vasil’tsov, V. S., Yashalova, N. N., Novikov, A. V., 2021. Climate and environmental risks in the development of Arctic coastal territories. *The Arctic: ecology and economics*. 11(3): 341- 352. (In Russian).

Wang, M., Arshed, N., Munir, M., Rasool, S., Lin, W., 2021. Investigation of the STIRPAT model of environmental quality: a case of nonlinear quantile panel data analysis. *Environment, Development and Sustainability*. 23(2): 1-16.

Enhancing Digital Education Through Modular Testing and Test-Driven Development

Ilya A. Kostylev[1][a], Niyaz A. Sabirov[1][b], Marina G. Lapteva[2][c] and Aurelia V. Tolmacheva[2][d]

[1]Institute of Computer Technologies and Information Security, Kazan National Research Technical University named after A. N. Tupolev – KAI, Kazan, Russia

[2]Institute of Management, Automation and Information Technologies, Kazan National Research Technological University, Kazan, Russia

ilya.kostylev.1997@mail.ru, xakep955@mail.ru, marinnay1@mail.ru, gorgik1996@yandex.ru

Keywords: Modular Testing, Digital Education, Test-Driven Development, Software Quality, Personalized Learning, Educational Technology.

Abstract: This article delves into the pivotal role of modular testing systems and Test-Driven Development (TDD) within the digital education sector, highlighting their transformative potential in enhancing online learning platforms. By integrating principles borrowed from software development, particularly the meticulous approach of modular testing and the iterative cycles of TDD, educational technology can achieve new heights of reliability, usability, and educational efficacy. The methodology of starting with a failing test to define desired functionality before writing the corresponding software and testing individual components in isolation (modular testing) ensures that each educational module is both functional and conducive to an engaging learning experience. This approach not only facilitates the rapid deployment of new features and updates, addressing the dynamic needs of digital education but also enhances the overall learning experience by ensuring technical robustness and minimizing disruptions. The article further explores the challenges of implementing these systems, such as ensuring comprehensive test coverage and maintaining scalable testing frameworks, while also considering the benefits they bring to the digital education landscape, including improved software quality, better user experiences, and the support of personalized learning pathways. Through a detailed examination of these methodologies, the article argues for their critical role in advancing the quality and effectiveness of digital education, making a compelling case for their wider adoption in the development of educational technology platforms.

1 INTRODUCTION

In the realm of modern software development, the imperative to deliver high-quality software underscores every phase of the development lifecycle. The complexity inherent in today's applications and systems carries an increased risk of introducing errors and defects, which can have far-reaching consequences. Against this backdrop, modular testing, or unit testing, emerges as a proactive measure to identify and rectify errors at the level of individual system components early in the development process. This approach not only elevates the overall quality of the software but also streamlines the development workflow, making it more efficient.

Testing in the context of software development transcends being a mere phase; it is a continuous process that is integral to the project lifecycle. It acts as a vital checkpoint to unearth flaws within the proposed solutions. Establishing a comprehensive and diligently maintained test suite yields significant long-term benefits, including enhanced code quality. This, in turn, facilitates a reduction in the time dedicated to debugging and maintenance, speeds up the development process, and decreases the

[a] https://orcid.org/0009-0008-7607-9356
[b] https://orcid.org/0009-0003-0553-8440
[c] https://orcid.org/0009-0007-1727-0460
[d] https://orcid.org/0009-0005-2536-0744

likelihood of incurring expensive fixes after the release.

A closer examination of unit testing reveals its essence in assessing code coverage. This metric reflects the extent of source code executed by tests, with higher coverage typically indicating more thorough testing and, consequently, better code quality. However, the efficacy of tests varies widely; while some are crucial for enhancing the quality of the software product, others may introduce maintenance challenges or fail to detect significant bugs.

Effective unit tests are characterized by their seamless integration into the development cycle, their focus on testing the most critical sections of the code, and their efficiency in maximizing bug detection with minimal maintenance demands. These tests enable the swift identification and correction of errors in isolated code fragments, thus ensuring the system's reliability and maintainability. The attributes of fast, isolated, configuration-free, and consistent testing—summarized by the acronym FICC—highlight the qualities of unit tests that positively impact the development process by maintaining the system's robustness and scalability.

Unit testing is typically divided into three distinct styles: output checking, state verification, and interaction testing. Output checking is the process of verifying the output of a function for a given input and is best suited for pure functions that do not have side effects. State verification goes a step further by inspecting the system or component states after executing operations, particularly applicable in scenarios where operations modify the system's state. Interaction testing, meanwhile, focuses on the interactions between different parts of the system, often utilizing mocks to simulate the behaviors of external dependencies.

Integration testing serves as a critical juncture in the testing process, verifying the seamless operation and interaction of interconnected system components. This stage targets the interfaces and data flow between modules to uncover issues that may not be detected during unit testing. Employing a grey box approach, integration testing provides a balanced perspective between the knowledge of internal module workings and the testing of external behaviours.

The process of integration testing can be approached in two ways: bottom-up integration, which starts with the lowest-level modules and works its way up, and top-down integration, which begins with top-level modules and integrates downward. This ensures that high-level functionalities are tested early in the process.

System testing represents the culmination of the testing process, where the application is evaluated as a complete and integrated entity. This phase includes functional testing along with assessments of performance, security, and other non-functional attributes. Through a black box methodology, system testing aims to mimic real-world usage to validate the application's readiness for deployment, ensuring it meets both its technical specifications and user expectations.

This detailed exploration underscores the critical role of a structured and comprehensive testing strategy in the development of C# software solutions. By adhering to the outlined principles and practices, developers are equipped to deliver software products that are not only of high quality but also reliable and efficient, aligning with both user expectations and industry standards.

2 PRINCIPLES OF MODULAR TESTING CONSTRUCTION

In the realm of software development, modular testing serves as a cornerstone for verifying the functionality and reliability of individual units of code. This approach not only aids in identifying defects at an early stage but also ensures that each component functions correctly in isolation, laying a solid foundation for the overall integrity of the software system. The AAA (Arrange, Act, Assert) pattern, a pivotal framework in modular testing, orchestrates this process through three well-defined stages, guiding developers through the preparation, execution, and verification phases of testing.

The AAA Pattern:

- Arrange: this initial phase sets the stage for the test, involving the instantiation of objects, configuration of prerequisites, and setup of any necessary environment or state before the actual test execution.
- Act: following the setup, the Act phase involves executing the method or function under test. This step is where the actual behavior that needs verification is triggered.
- Assert: the final stage of the AAA pattern is the Assert phase, where the outcomes of the Act phase are evaluated against predefined expectations. Assertions are crucial, as they determine the success or failure of the test

based on whether the actual outcomes align with the expected results.

The .NET ecosystem presents a plethora of tools for facilitating modular testing, among which NUnit, MSTest, and xUnit are prominent. While MSTest marked the inception of modular testing within the .NET framework, its rigidity over time has led to the emergence of more flexible alternatives like NUnit and xUnit. xUnit, in particular, has garnered attention for its compact and elegant design, offering a refined approach to modular testing that appeals to modern development practices.

xUnit distinguishes itself with two noteworthy attributes: Fact and Theory. These attributes represent the essence of modular tests within the framework:

- Fact: a Fact attribute denotes a test that operates without parameters. It represents a singular truth within the domain of the application. Failure of a Fact test signals a deviation from the expected behaviour, necessitating a review and potential correction of either the test or the application code itself.
- Theory: contrary to Fact, a Theory test is parameter-driven, capable of handling multiple data scenarios through the same test method. This flexibility allows Theories to cover a broader spectrum of cases, enhancing the test suite's comprehensiveness.

To maximize the effectiveness and maintainability of modular tests, especially within long-term projects, adhering to a set of established best practices is advisable:

- Expressive Test Naming: opt for descriptive and meaningful test names that reflect the specific functionality being tested, the conditions under which it is tested, and the expected outcome. This practice aids in quickly identifying test purposes and understanding test failures.

- Adherence to the AAA Structure: consistently applying the Arrange-Act-Assert pattern across tests fosters readability and maintainability, making it easier to follow the logical flow of each test.
- Organized Test Projects: maintain a clean separation between production and test code by organizing test classes within a dedicated `Tests` directory. This separation streamlines project navigation and reinforces the distinction between test and production environments.
- Clear Class Naming Conventions: naming test classes to mirror their corresponding production classes, appended with `Tests`, establishes a direct link between the test suite and the unit of code being tested, facilitating easier navigation and understanding.
- One-to-One Class to Test Mapping: strive for a direct correspondence between each production class and its test class. This approach ensures comprehensive coverage and simplifies the process of locating and updating tests corresponding to specific units of code.

While these practices do not provide an absolute guarantee against future maintenance challenges, they significantly contribute to the scalability and manageability of test code. By embedding these principles into the testing workflow, development teams can enhance the quality and reliability of their software products, ensuring that each component performs as intended and contributing to the overall success of the project.

3 TEST-DRIVEN DEVELOPMENT

Test-Driven Development stands at the forefront of agile software development practices, offering a stark departure from traditional programming methodologies. At its core, TDD reimagines the role of testing in software development, transforming it from a posteriori verification to a guiding force for creating new software. This shift places an emphasis on the detailed specification of software behaviors through tests before the software itself is written, thereby intertwining the design and development processes more closely than ever before.

TDD is more than just a methodological shift; it represents a philosophical reorientation towards how software is conceptualized and constructed. By demanding that developers first articulate what a piece of software should do in the form of tests, TDD fosters a development environment where clarity of intention and purpose precedes the act of coding. This approach ensures that every line of code written serves a direct, pre-identified purpose, enhancing the software's overall coherence and integrity.

The operational heart of TDD lies in its iterative cycle, commonly encapsulated by the mantra "Red-Green-Refactor." This cycle describes the rhythm of TDD practice, structured around the creation and satisfaction of tests:

- Red (Write a Failing Test): the cycle initiates with the development of a test for functionality that does not yet exist, ensuring the test will fail ("Red"). This stage is critical as it sets clear objectives for the development work to follow, defining the expected behavior of the software in a concrete, executable form. It challenges developers to think critically about the feature requirements and user needs, translating these into precise, testable expectations.

- Green (Make the Test Pass): once a failing test is in place, the immediate goal shifts to modifying or adding just enough code to pass the test ("Green"). The emphasis at this stage is on practicality and pragmatism; the initial code need not be perfect or even particularly well-designed. Its primary function is to meet the test's criteria, affirming that the desired behavior can be achieved.
- Refactor (Improve the Code): with a passing test, the next step is to refine and improve the existing code without altering its external behavior ("Refactor"). This phase leverages the safety net provided by the test suite to clean up, optimize, and enhance the code's structure and readability. Refactoring is an ongoing process, encouraging developers to continuously seek improvements and efficiencies in the codebase, thereby elevating the software's quality over time.

TDD's iterative, test-first approach yields numerous benefits, significantly influencing both the process and product of software development:

- Enhanced Code Quality: by focusing development efforts around achieving clearly defined, tested behaviours, TDD minimizes the incidence of extraneous or redundant code, leading to cleaner, more reliable software.
- Improved Design Decisions: the requirement to write tests before code encourages developers to think abstractly about the software's design, considering how components interact and how they can be effectively tested. This often results in more modular, flexible architectures.
- Increased Development Confidence: the comprehensive test coverage that naturally results from TDD gives developers confidence to make changes and improvements, knowing that the test suite will catch regressions or unintended side effects.
- Facilitation of Refactoring: the continuous cycle of refactoring encouraged by TDD ensures that the codebase remains clean, well-organized, and adaptable to changing requirements over time.

Test-Driven Development fundamentally alters the software development landscape by placing testing at the heart of the creative process. Through its disciplined, iterative approach, TDD fosters the creation of high-quality, well-designed software that is robust, adaptable, and aligned with user needs and expectations. This methodology not only improves the immediate outcomes of development projects but also sets a foundation for sustainable, long-term software maintenance and evolution.

4 IMPLEMENTING MODULAR TESTING SYSTEMS IN DIGITAL EDUCATION

The integration of modular testing systems into the fabric of digital education platforms signifies a pivotal advancement in online learning's evolution. This approach, which borrows heavily from tried and tested software development methodologies, specifically modular testing, is instrumental in pushing educational technology towards greater heights of quality, usability, and accessibility. Modular testing's essence lies in its capacity to scrutinize individual units or components of a software application in isolation, ensuring their flawless operation before their incorporation into the larger system. In digital education, this meticulous approach translates into testing every quiz, module, lesson, and user interaction interface separately, affirming their functionality. The early identification and rectification of issues facilitated by modular testing drastically reduce the occurrence of bugs and errors, thereby minimizing disruptions in the learning process.

Applying modular testing systems to digital education platforms endows them with robustness and reliability, significantly enhancing the learning experience. For the creators and educators behind these platforms, modular testing instils the confidence to update and expand educational content without the fear of compromising the platform's overall functionality. For learners, it ensures a smoother, more engaging educational journey, unmarred by technical glitches that could impede their academic progress. The benefits of this approach are manifold, including improved reliability through the early detection of errors in individual modules, ensuring platform stability, and enhancing the user experience by minimizing technical frustrations, thereby maintaining student engagement and motivation. Furthermore, modular testing accelerates the development and deployment of new features and content, granting developers the agility needed in the rapidly evolving domain of digital education. This capability to swiftly adapt to new teaching methodologies or changes in the curriculum offers a distinct competitive advantage.

Moreover, the flawless functionality of each platform component, assured by modular testing, lays the groundwork for implementing adaptive learning algorithms and personalized content delivery. This tailored approach to education, proven to enhance learning outcomes, caters to the unique needs and pace of each student, marking a significant step forward in educational personalization.

However, the adoption of modular testing in digital education platforms is not without its challenges. Ensuring comprehensive test coverage to account for the broad spectrum of user interactions and maintaining an efficient, scalable testing framework as the platform expands are daunting tasks. The dynamic nature of educational content, which necessitates regular test updates to reflect changes, calls for a sustained commitment to quality assurance.

The deployment of modular testing systems within digital education platforms marks a significant leap forward, ensuring these platforms achieve higher reliability, user satisfaction, and instructional effectiveness. As digital education continues to expand and evolve, the robust testing frameworks will play a critical role in shaping learning's future, making education more accessible, engaging, and effective for learners worldwide. This strategic integration of modular testing not only elevates the standards of digital education but also heralds a new era of quality and innovation in online learning experiences.

The sequence diagram in Figure illustrates a cohesive process where a student initiates the procedure by selecting a specific module for testing within the digital education environment. Following this selection, the Modular Testing System requests the content for this module from the Learning Management System. Upon receiving the module content from the Learning Management System, the Modular Testing System presents the student with a test interface that is tailored to the selected module. The student then interacts with this interface, submitting their answers back through the Modular Testing System. These responses are processed, and the results of the test are recorded. To conclude the process, these results are communicated back to the Learning Management System, which then updates the student's progress within the course and provides feedback on their performance. This sequence effectively outlines the integrated steps involved in applying a modular testing system within a digital education framework, highlighting the interactive flow between the student, the Modular Testing System, and the Learning Management System.

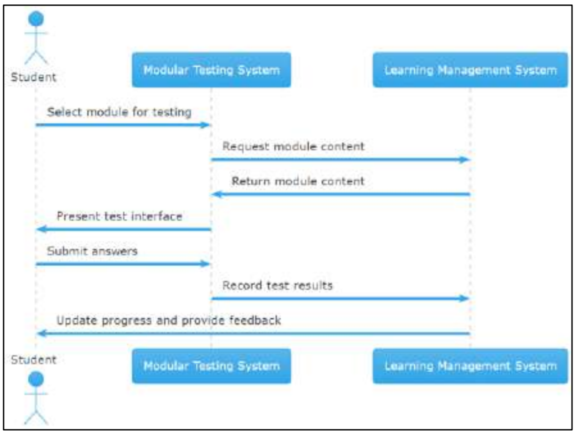


Figure 1: Application of modular testing system in digital education.

5 CONCLUSION

In conclusion, the exploration of modular testing systems within the realm of digital education unveils a significant paradigm shift in the development and delivery of online learning experiences. The meticulous application of the principles of modular testing, as derived from software development best practices, promises not only to enhance the structural integrity and reliability of educational platforms but also to elevate the quality of education imparted through these digital mediums.

The adoption of Test-Driven Development and the implementation of modular testing in digital education platforms underscore a commitment to precision, quality, and adaptability in educational technology. Through the Red-Green-Refactor cycle inherent in TDD, developers are empowered to create robust, error-free learning modules that can adapt to the evolving demands of education in the digital age. This methodical approach ensures that each piece of educational content delivered is not only functional but also conducive to an engaging and effective learning experience.

Furthermore, the integration of modular testing systems into digital education platforms presents a forward-looking approach to addressing the challenges of online learning. By ensuring the reliability and functionality of every educational module through systematic testing, developers can rapidly deploy updates and innovations, thereby keeping pace with the ever-changing landscape of educational needs and technological advancements.

This agility is essential for fostering environments that are responsive to the individual needs of learners, thereby making education more accessible, personalized, and impactful.

The challenges associated with implementing modular testing and TDD in digital education, such as ensuring comprehensive test coverage and maintaining scalable testing frameworks, are substantial yet surmountable. They necessitate a sustained commitment to quality assurance and continuous improvement. However, the benefits of adopting these methodologies – enhanced software quality, improved user experiences, and the facilitation of personalized learning – far outweigh the complexities involved in their implementation.

As we look towards the future of digital education, the strategic application of modular testing systems and the principles of TDD stand out as key contributors to the development of high-quality, engaging, and effective educational platforms. These practices not only exemplify a dedication to excellence in digital learning but also pave the way for innovations that will continue to transform the educational landscape. Through the diligent application of these methodologies, the field of digital education can achieve unprecedented levels of reliability, functionality, and relevance, thereby enriching the learning journey for students across the globe.

REFERENCES

Burris, J. W., 2017. Test-Driven Development for Parallel Applications. In *2017 Second International Conference on Information Systems Engineering (ICISE)*, pp. 27-31.

Yogesh, T., Vimala, P., 2020. Test-Driven Development of Automotive Software Functionality. In *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)*, pp. 1162-1165.

Fontela, C., Garrido, A., 2013. Connection between Safe Refactorings and Acceptance Test Driven Development. *IEEE Latin America Transactions* 11(5): 1238-1244.

Guerra, E., 2014. Designing a Framework with Test-Driven Development: A Journey. *IEEE Software* 31(1): 9-14.

Amrit, C., Meijberg, Y., 2018. Effectiveness of Test-Driven Development and Continuous Integration: A Case Study. *IT Professional* 20(1): 27-35.

Moe, M. M., Oo, K. K., 2020. Evaluation of Quality, Productivity, and Defect by applying Test-Driven Development to perform Unit Tests. In *2020 IEEE 9th Global Conference on Consumer Electronics (GCCE)*, pp. 435-436.

Dookhun, A. S., Nagowah, L., 2019. Assessing The Effectiveness Of Test-Driven Development and Behavior-Driven Development in an Industry Setting. In *2019 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)*, pp. 365-370.

Viktorov, I., Gibadullin, R., 2023. The principles of building a machine-learning-based service for converting sequential code into parallel code. *E3S Web of Conferences* 431: 05012.

Kozlov, E, Gibadullin, R, 2023. Prerequisites for developing the computer vision system for drowning detection. *E3S Web of Conferences* 474: 02031.

Gorodova, J., Pachina, N., Tkachenko, S., Pachin, G., 2021. Digital Literacy in the Aspect of Continuing Teacher's Education. In *2021 1st International Conference on Technology Enhanced Learning in Higher Education (TELE)*, pp. 220-223.

Yoqubjonov, J., Gibadullin, R., Nuriev, M., 2023. Advanced robotic process automation for enterprise efficiency. *E3S Web of Conferences* 431: 07011.

Kondratiev, V., 2020. Fundamental Changes in Mathematics Education in the Context of Digital Transformation. In *2020 Ivannikov Ispras Open Conference (ISPRAS)*, pp. 75-77.

Shakirzyanov, M., Gibadullin, R., Nuriyev, M., 2023. Prerequisites for the development of the system of automatic comparison of video and audio tracks by the speaker’s articulation. *E3S Web of Conferences* 419: 02029.

Chituc, C. -M., 2022. An Analysis of Technical Challenges for Education 4.0 and Digital Education Ecosystems. In *2022 IEEE German Education Conference (GeCon)*, pp. 1-5.

Z-Regression for Analysis and Reliable Prediction of Qualitative Characteristics

Olga Poleshchuk[a]
Bauman Moscow State Technical University, Moscow, Russia

Keywords: Z-number, Z-regression, Type-2 fuzzy set.

Abstract: A regression model under Z-information has developed in the paper. The initial information for constructing the model is linguistic Z-numbers, defined on the unit segment. For a Z-number, an interval type-2 fuzzy number is defined, using aggregating characteristics of reliability (second component of Z-number). To do this, the aggregating segment of reliability and its middle are use. In the paper was made a choice in favor of transforming Z-numbers into type-2 fuzzy numbers, since Z-numbers are closer in structure to them than to type-1 fuzzy numbers, which, however, are most often used to transform Z-numbers and construct different models. Input and output interval type-2 fuzzy numbers are determined for the initial Z-numbers. The optimization function is defined as the sum of squares for the differences between parameters of output type-2 fuzzy numbers and the model type-2 fuzzy numbers. To determine the unknown regression coefficients, the minimum of the optimization function was found using known methods. Reliability recognition of model output information has developed.

1 INTRODUCTION

Quantitative and qualitative characteristics are used to assess the green infrastructure of cities. For example, the height of a tree or the leaf area of a tree are quantitative characteristics, while the state of plants or satisfaction with a green area are qualitative characteristics. It is quite difficult to analyze qualitative characteristics and predict their values, since arithmetic operations for their values are not defined.

If the values of qualitative characteristics are estimated with a certain level of reliability, then the tasks of their analysis and prediction become even more complicated. For example, when assessing the state of green spaces, even an experienced expert cannot be absolutely sure of the reliability of his data, and therefore provides not only his assessment - "No signs of weakness", but also the reliability of this assessment - "Very likely". To analyze and predict data with fuzzy estimates of the values of qualitative characteristics, as well as with fuzzy reliability of these estimates, a special mathematical apparatus based on regression analysis and Z-numbers is required.

Regression analysis plays a key role in the analysis of relationships between input and output qualitative information, as well as in prediction problems. This analysis is especially important when processing Z-information (information with Z-numbers or information in which fuzzy data is presented with a certain level of reliability) (Zadeh, 2011).

To be able to analyze Z-information, arithmetic operations have been developed (Zadeh, 2012; Kang, Wei, Li, Deng, 2012;Kang, Wei, Li, Deng, 2012; Aliev, Alizadeh, Huseynov, 2015; Aliev, Huseynov, Zeinalova, 2016; Aliev, Huseynov, Aliyeva, 2015) and Z-numbers have been used to formalize expert reasoning (Yager, 2012). Distances between Z-numbers and ways to rank them have been determined (Wang, Mao, 2019; Poleshchuk, 2019; Aliyev, Talal Mraizid, Huseynov, 2015; Aliyev, 2015). Methods for solving applied decision-making problems under Z-information have been developed (Kang, Wei, Li, Deng, 2012; Wang, Mao, 2019; Poleshchuk, 2019; Aliyev, Talal Mraizid, Huseynov, 2015; Poleshchuk, 2023).

Regression models were urgently needed to predict and study dependencies in the context of Z-information. The first models appeared in works

[a] https://orcid.org/0000-0002-2418-2289

(Sadikoglu, Huseynov, Memmedova, 2016; Zeinalova, Huseynov, Sharghi, 2017), which were built on the basis of operations with Z-numbers and probability distributions of random variables. The optimization problem for finding the unknown coefficients (ordinary numbers) of the regression model was posed using the Jaccard measure.

The problem was that in defining the Z-number, Professor Lotfi Zadeh did not limit the Z-number to considering only the probability distributions of random variables in determining the reliability of its first component. Therefore, this limitation was supposed to be removed so that it would be possible to use a regression model for any Z-information without limitation.

This limitation was removed in (Poleshchuk, 2021), where a linear regression model with fuzzy coefficients was developed. The author has moved away from direct operation with Z-numbers (which is always quite difficult) and has defined aggregating segments for the input and output information represented by Z-numbers. With the help of these aggregating segments, operations on Z-numbers and distances between them were determined, an optimization problem was posed and solved, and output Z-numbers were recognized.

The next regression model under Z-information was nonlinear regression with crisp coefficients, developed in (Poleshchuk, 2022). For its development, the basics of the paper (Poleshchuk, 2021) were used.

Both models of papers (Poleshchuk, 2021; Poleshchuk, 2022) were based on a single approach to the step-by-step transformation of both components of Z-numbers into aggregation segments with subsequent operation on them, and on a single approach to the formulation of optimization problems. Therefore, the question arose of developing a model based on a different approach to the presentation of initial data and the formulation of an optimization problem for the purpose of comparative analysis and the selection of the best model for solving practical problems.

In (Poleshchuk, 2023), a linear regression model under Z-information with coefficients in the form of fuzzy triangular numbers was constructed. In the paper, it was defined the loss function for the difference between the initial output Z-number and the model output Z-number. The optimization problem was solved from the minimum condition of the sum of loss functions for the differences between the initial output Z-numbers and the model output Z-numbers. The solution of the optimization problem was reduced to the solution of the well-known linear programming problem.

If you look deeper, then one way or another, when constructing regression models, there is a transformation from Z-numbers to type-1 fuzzy numbers (ordinary fuzzy numbers). However, Z-numbers in their essence and structure are closer to type-2 fuzzy numbers, as evidenced by studies, for example, in the paper (Aliev, Guirimov, 2018).

Based on this, when constructing a regression model and using type-2 fuzzy numbers that are closer to Z-numbers compared to type-1 fuzzy numbers, we should expect to retain more information about the initial information and improve the quality of the model. Therefore, this paper aims to develop a regression model under Z-information using the relationships between Z-numbers and type-2 fuzzy numbers, described and proven in the paper (Aliev, Kreinovich, 2017).

Section 2 of the paper gives the basic concepts and definitions. Section 3 proposes a regression model under Z-information. Section 4 gives conclusions.

2 BASIC CONCEPTS AND DEFINITIONS

Consider a trapezoidal type-1 fuzzy number $\tilde{A} = (a_1, a_2, a_L, a_R)$:

$$\tilde{A} = \begin{cases} \frac{x-a_1+a_L}{a_L}, a_1 - a_L \le x \le a_1, a_L \ge 0, \\ 1, a_1 \le x \le a_2 \\ \frac{a_2+a_R-x}{a_R}, a_2 \le x \le a_2 + a_R, a_R \ge 0. \end{cases}$$

Then α -cut of $\tilde{A}$ is A_α such that:

$$A_\alpha = \{x \in R: \mu_A(x) \ge \alpha\} = [a - (1-\alpha)a_L, a + (1-\alpha)a_R], \alpha \in [0,1].$$

In (Domrachev, Poleshuk, 2003), based on A_α an aggregating segment $[\beta_1, \beta_2]$ for fuzzy number $\tilde{A} = (a_1, a_2, a_L, a_R)$ is determined:

$$\beta_1 = \int_0^1 \frac{2a_1 - (1-\alpha)a_L}{2} 2\alpha \, d\alpha = a_1 - \frac{1}{6}a_L, \tag{1}$$

$$\beta_2 = \int_0^1 \frac{2a_2 - (1-\alpha)a_R}{2} 2\alpha\, d\alpha = a_1 - \frac{1}{6}a_R.$$

In (Poleshchuk, 2023), a weighted point β for a fuzzy number $\tilde{A} = (a_1, a_2, a_L, a_R)$ according to (1) is determined as follows:

$$\beta = \frac{\beta_1+\beta_2}{2} = \frac{a_1+a_2}{2} + \frac{a_R-a_L}{12}. \quad (2)$$

A linguistic variable X with terms $T(X) = \{X_l,\ l = \overline{1,m}\}$ is called a collection $\{X, T(X), U, V, S\}$. Term names $X_l, l = \overline{1,m}$ are determined by the rule V and the corresponding fuzzy sets of U for fuzzy variables $\tilde{X}_l, l = \overline{1,m}$ are determined by the rule S (Zadeh, 1975).

The construction of linguistic variables with the properties described in (Ryjov, 1994) is described in detail in (Poleshchuk, 2018).

An interval type-2 fuzzy number (IT2 FS) $\tilde{A}$ is defined by lower fuzzy number (LFN) $\underline{\tilde{A}} = (a_1^L, a_2^L, a_L^L, a_R^L)$ and upper fuzzy number (UFN) $\overline{\tilde{A}} = (a_1^U, a_2^U, a_L^U, a_R^U)$ (Liu, Mendel, 2009).

In the paper (Poleshchuk, Komarov, 2012) for LFN $\underline{\tilde{A}} = (a_1^L, a_2^L, a_L^L, a_R^L)$ and UFN $\overline{\tilde{A}} = (a_1^U, a_2^U, a_L^U, a_R^U)$ IT2 FS $\tilde{A}$ are defined respectively aggregating segments $[\beta_1^L, \beta_2^L]$, $[\beta_1^U, \beta_2^U]$ in accordance with (1). For two IT2 FSs $\tilde{A}, \tilde{B}$ with aggregating segments $[\beta_1^L, \beta_2^L]$, $[\beta_1^U, \beta_2^U]$, $[\delta_1^L, \delta_2^L]$, $[\delta_1^U, \delta_2^U]$ the distance $d(\tilde{A}, \tilde{B})$ is defined in the same paper:

$$d(\tilde{A}, \tilde{B}) = \sqrt{(\beta_1^L - \delta_1^L)^2 + (\beta_2^L - \delta_2^L)^2 + (\beta_1^U - \delta_1^U)^2 + (\beta_2^U - \delta_2^U)^2}. \quad (3)$$

Z-number is defined in (Zadeh, 2011) as a pair $Z = (\tilde{C}, \tilde{R})$, where $\tilde{C}$, $\tilde{R}$ are fuzzy numbers and $\tilde{R}$ is reliability of $\tilde{C}$.

A Z-number whose components are the values of linguistic variables is called a linguistic Z-number (Ding, Zhu, Lu, Wang, Feng, 2020).

In (Poleshchuk, 2023), a weighted fuzzy number $\mathcal{\tilde{A}}$ for the Z-number $Z = (\tilde{A}, \tilde{R})$, $\tilde{A} = (a_1, a_2, a_L, a_R)$, $\tilde{R} = (r_1, r_2, r_L, r_R)$ is determined as follows: $\mathcal{\tilde{A}} = (\gamma a_1, \gamma a_2, \gamma a_L, \gamma a_R)$, where $\gamma = \frac{r_1+r_2}{2} + \frac{r_R-r_L}{12}, \gamma > 0$ is a weighted point for the fuzzy number $\tilde{R} = (r_1, r_2, r_L, r_R)$.

3 PROBLEM FORMULATION AND SOLUTION

Let's denote the initial input data with $Z_{ij} = (\tilde{X}_{ij}, \tilde{R}_{ij}), i = \overline{1,m}, j = \overline{1,n}$ and the initial output data with $Z_j = (\tilde{Y}_j, \tilde{R}_j), j = \overline{1,n}$, $\tilde{X}_{ij} = (x_{ij}^1, x_{ij}^2, x_{ij}^L, x_{ij}^R), i = \overline{1,m}, j = \overline{1,n}$, $\tilde{Y}_j = (y_j^1, y_j^2, y_j^L, y_j^R), j = \overline{1,n}$, $\tilde{R}_{ij} = (r_{ij}^1, r_{ij}^2, r_{ij}^L, r_{ij}^R)$, $\tilde{R}_j = (r_j^1, r_j^2, r_j^L, r_j^R), i = \overline{1,m}, j = \overline{1,n}$.

The initial Z-numbers are linguistic Z-numbers with universal sets U=[0,1]. This means that the first components of Z-numbers are formalizations of linguistic scales used to assess the input qualitative characteristics $X_i, i = \overline{1,m}$ и and the output qualitative characteristic Y.

Each of fuzzy number $\tilde{R}_{ij}, \tilde{R}_j, i = \overline{1,m}, j = \overline{1,n}$ equals to one of value $\tilde{R}_\nu, \nu = \overline{1,V}$ a linguistic variable «Reliability».

Let construct a regression model in the form:

$$Z = a_1 Z_1 + a_2 Z_2 + \cdots a_m Z_m, \quad (4)$$

Where $a_i, i = \overline{1,m}$- crisp numbers.

Using the relationship between Z-numbers and type-2 fuzzy numbers (T2 FNs), described and proven in the paper (Aliev, Kreinovich, 2017), we transform Z-number $Z = (\tilde{A}, \tilde{R})$, $\tilde{A} = (a_1, a_2, a_L, a_R)$, $\tilde{R} = (r_1, r_2, r_L, r_R)$ into IT2 FN $\tilde{\mathbb{A}}$, defined by LFN $\underline{\tilde{\mathbb{A}}} = \left(a_1, \frac{\beta_1+\beta_2}{2} a_2, a_L, \frac{\beta_1+\beta_2}{2} a_R\right)$ and UFN $\overline{\tilde{\mathbb{A}}} = (\beta_1 a_1, a_2, \beta_1 a_L, a_R)$ where $[\beta_1, \beta_2]$ an aggregating segment for fuzzy number $\tilde{R} = (r_1, r_2, r_L, r_R)$ (reliability for $\tilde{A} = (a_1, a_2, a_L, a_R)$).

In the paper (Poleshchuk, 2023), Z-number $Z = (\tilde{A}, \tilde{R})$, $\tilde{A} = (a_1, a_2, a_L, a_R)$, $\tilde{R} = (r_1, r_2, r_L, r_R)$ transformed into ordinary fuzzy number $\mathcal{\tilde{A}} = \left(\frac{\beta_1+\beta_2}{2} a_1, \frac{\beta_1+\beta_2}{2} a_2, \frac{\beta_1+\beta_2}{2} a_L, \frac{\beta_1+\beta_2}{2} a_R\right)$.

As $\beta_1 < \frac{\beta_1+\beta_2}{2} < 1, \frac{\beta_1+\beta_2}{2} < 1, 0 \le \beta_1 \le 1, 0 \le \beta_2 \le 1, \beta_2 > \beta_1$, then the values of the membership function of the number $\mathcal{\tilde{A}} = \left(\frac{\beta_1+\beta_2}{2} a_1, \frac{\beta_1+\beta_2}{2} a_2, \frac{\beta_1+\beta_2}{2} a_L, \frac{\beta_1+\beta_2}{2} a_R\right)$ belong to the values of the membership function of the number $\tilde{\mathbb{A}}$, defined by LFN $\underline{\tilde{\mathbb{A}}} = \left(a_1, \frac{\beta_1+\beta_2}{2} a_2, a_L, \frac{\beta_1+\beta_2}{2} a_R\right)$ and UFN $\overline{\tilde{\mathbb{A}}} = (\beta_1 a_1, a_2, \beta_1 a_L, a_R)$.

Thus, the representation of the Z-number $Z = (\tilde{A}, \tilde{R})$, $\tilde{A} = (a_1, a_2, a_L, a_R)$, $\tilde{R} = (r_1, r_2, r_L, r_R)$ in the paper (Poleshchuk, 2023) as an ordinary fuzzy number $\tilde{\mathcal{A}} = \left(\frac{\beta_1+\beta_2}{2}a_1, \frac{\beta_1+\beta_2}{2}a_2, \frac{\beta_1+\beta_2}{2}a_L, \frac{\beta_1+\beta_2}{2}a_R\right)$ can be considered as a special case of representing the Z-number в виде IT2 FN $\tilde{\mathbb{A}}$, defined by LFN $\underline{\tilde{\mathbb{A}}} = \left(a_1, \frac{\beta_1+\beta_2}{2}a_2, a_L, \frac{\beta_1+\beta_2}{2}a_R\right)$ and UFN $\overline{\tilde{\mathbb{A}}} = (\beta_1 a_1, a_2, \beta_1 a_L, a_R)$.

Define IT2 FNs $\tilde{\mathbb{X}}_{ij}, i = \overline{1,m}, j = \overline{1,n}$ with LFN $\underline{\tilde{\mathbb{X}}_{ij}}$ and UFN $\overline{\tilde{\mathbb{X}}_{ij}}$ for input Z-numbers $Z_{ij} = (\tilde{X}_{ij}, \tilde{R}_{ij}), i = \overline{1,m}, j = \overline{1,n}$, $\tilde{X}_{ij} = (x_{ij}^1, x_{ij}^2, x_{ij}^L, x_{ij}^R), = \overline{1,m}, j = \overline{1,n}, \tilde{R}_{ij} = (r_{ij}^1, r_{ij}^2, r_{ij}^L, r_{ij}^R), i = \overline{1,m}, j = \overline{1,n}$:

$$\underline{\tilde{\mathbb{X}}_{ij}} = \left(x_{ij}^1, \frac{\beta_{ij}^1+\beta_{ij}^2}{2}x_{ij}^2, x_{ij}^L, \frac{\beta_{ij}^1+\beta_{ij}^2}{2}x_{ij}^R\right), \overline{\tilde{\mathbb{X}}_{ij}} = (\beta_{ij}^1 x_{ij}^1, x_{ij}^2, \beta_{ij}^1 x_{ij}^L, x_{ij}^R), \quad (5)$$

where $[\beta_{ij}^1, \beta_{ij}^2]$ are aggregating segments for fuzzy numbers $\tilde{R}_{ij} = (r_{ij}^1, r_{ij}^2, r_{ij}^L, r_{ij}^R), i = \overline{1,m}, j = \overline{1,n}$.

Define IT2 FNs $\tilde{\mathbb{Y}}_j, j = \overline{1,n}$ with LFN $\underline{\tilde{\mathbb{Y}}_j}$ and UFN $\overline{\tilde{\mathbb{Y}}_j}$ for output Z-numbers $Z_j = (\tilde{Y}_j, \tilde{R}_j), j = \overline{1,n}, \tilde{Y}_j = (y_j^1, y_j^2, y_j^L, y_j^R), \tilde{R}_j = (r_j^1, r_j^2, r_j^L, r_j^R)$:

$$\underline{\tilde{\mathbb{Y}}_j} = \left(y_j^1, \frac{\beta_j^1+\beta_j^2}{2}y_j^2, y_j^L, \frac{\beta_j^1+\beta_j^2}{2}y_j^R\right), \overline{\tilde{\mathbb{Y}}_j} = (\beta_j^1 y_j^1, y_j^2, \beta_j^1 y_j^L, y_j^R), \quad (6)$$

where $[\beta_j^1, \beta_j^2]$ are aggregating segments for fuzzy numbers $\tilde{R}_j = (r_j^1, r_j^2, r_j^L, r_j^R), j = \overline{1,n}$.

Define IT2 FNs $\tilde{\mathbb{Y}}_{M_j}, j = \overline{1,n}$ f with LFN $\underline{\tilde{\mathbb{Y}}_{M_j}}$ and UFN $\overline{\tilde{\mathbb{Y}}_{M_j}}$ *f*or the model output Z-numbers $Z_j = \sum_{i=1}^m a_i Z_{ij}, j = \overline{1,n},$ using (5):

$$\underline{\tilde{\mathbb{Y}}_{M_j}} = \left(\sum_{i=1}^m a_i\, x_{ij}^1, \sum_{i=1}^m a_i \frac{\beta_{ij}^1+\beta_{ij}^2}{2} x_{ij}^2, \sum_{i=1}^m a_i\, x_{ij}^L, \sum_{i=1}^m a_i \frac{\beta_{ij}^1+\beta_{ij}^2}{2} x_{ij}^R\right), a_i > 0, i = \overline{1,m}, j = \overline{1,n}$$

$$\overline{\tilde{\mathbb{Y}}_{M_j}} = \left(\sum_{i=1}^m a_i\, \beta_{ij}^1 x_{ij}^1, \sum_{i=1}^m a_i x_{ij}^2, \sum_{i=1}^m a_i\, \beta_{ij}^1 x_{ij}^L, \sum_{i=1}^m a_i x_{ij}^R\right), a_i < 0, i = \overline{1,m}, j = \overline{1,n}.$$

In general,

$$\underline{\tilde{\mathbb{Y}}_{M_j}} = \left(\sum_{i=1}^m a_i\, x_{ij}^{pi}, \sum_{i=1}^m a_i \frac{\beta_{ij}^1+\beta_{ij}^2}{2} x_{ij}^{qi}, \sum_{i=1}^m a_i\, x_{ij}^{M_{pi}}, \sum_{i=1}^m a_i \frac{\beta_{ij}^1+\beta_{ij}^2}{2} x_{ij}^{M_{qi}}\right), j = \overline{1,n},$$

$$\overline{\tilde{\mathbb{Y}}_{M_j}} = \left(\sum_{i=1}^m a_i\, \beta_{ij}^1 x_{ij}^{pi}, \sum_{i=1}^m a_i x_{ij}^{qi}, \sum_{i=1}^m a_i\, \beta_{ij}^1 x_{ij}^{M_{pi}}, \sum_{i=1}^m a_i x_{ij}^{M_{qi}}\right), j = \overline{1,n},$$

where

$$p_i = \begin{cases} 1, a_i > 0 \\ 2, a_i < 0 \end{cases}, \; q_i = \begin{cases} 1, a < 0 \\ 2, a_i > 0 \end{cases}, \; M_{p_i} = \begin{cases} L, p_i = 1 \\ R, p_i = 2 \end{cases}, \; M_{q_i} = \begin{cases} L, q_i = 1 \\ R, q_i = 2 \end{cases}, i = \overline{1,m}.$$

The optimization problem for finding the unknown coefficients $a_i < 0, i = \overline{1,m}$ is following:

$$F(a_1, a_2, \dots, a_m) = \sum_{j=1}^n \left[\left(y_j^1 - \sum_{i=1}^m a_i\, x_{ij}^{pi}\right)^2 + \left(\frac{\beta_j^1 + \beta_j^2}{2} y_j^2 - \sum_{i=1}^m a_i \frac{\beta_{ij}^1 + \beta_{ij}^2}{2} x_{ij}^{qi}\right)^2 + \left(y_j^L - \sum_{i=1}^m a_i\, x_{ij}^{M_{pi}}\right)^2 + \left(\frac{\beta_j^1 + \beta_j^2}{2} y_j^2 - \sum_{i=1}^m a_i \frac{\beta_{ij}^1 + \beta_{ij}^2}{2} x_{ij}^{qi}\right)^2 + \left(\beta_j^1 y_j^1 - \sum_{i=1}^m a_i\, \beta_{ij}^1 x_{ij}^{pi}\right)^2 + \left(y_j^2 - \sum_{i=1}^m a_i x_{ij}^{qi}\right)^2 + \left(\beta_j^1 y_j^L - \sum_{i=1}^m a_i\, \beta_{ij}^1 x_{ij}^{M_{pi}}\right)^2 + \left(y_j^R - \sum_{i=1}^m a_i x_{ij}^{M_{qi}}\right)^2 \right] \to min.$$

Function $F(a_1, a_2, \dots, a_m)$is piecewise differentiable function since $\sum_{i=1}^m a_i\, x_{ij}^{pi}$,

$$\sum_{i=1}^{m} a_i \frac{\beta_{ij}^1+\beta_{ij}^2}{2} x_{ij}^{qi}, \sum_{i=1}^{m} a_i x_{ij}^{M_{pi}}, \sum_{i=1}^{m} a_i \frac{\beta_{ij}^1+\beta_{ij}^2}{2} x_{ij}^{qi}, \sum_{i=1}^{m} a_i \beta_{ij}^1 x_{ij}^{pi}, \sum_{i=1}^{m} a_i x_{ij}^{qi},$$

$\sum_{i=1}^{m} a_i \beta_{ij}^1 x_{ij}^{M_{pi}}, \sum_{i=1}^{m} a_i x_{ij}^{M_{qi}}$ are piecewise linear functions. Unknown coefficients $a_1, a_2, \dots, a_m$ are found according to the method (Coleman, Li, 1996).

The first component of the model output Z -number is found using a regression model into which the first component of the input Z -number is substituted. To determine the reliability of the resulting fuzzy number (to determine the second component of the model output Z -number), it is necessary to compare IT2 FN $\underline{\tilde{\mathbb{Y}}_M} = (u_1^L, u_2^L, u_L^L, u_R^L)$, $\overline{\tilde{\mathbb{Y}}_M} = (u_1^U, u_2^U, u_L^U, u_R^U)$, into which the model Z -number is transformed, and IT2 FNs $\underline{\tilde{\mathbb{Y}}_\nu} = (u_{1\nu}^L, u_{2\nu}^L, u_{L\nu}^L, u_{R\nu}^L)$, $\overline{\tilde{\mathbb{Y}}_\nu} = (u_{1\nu}^U, u_{2\nu}^U, u_{L\nu}^U, u_{R\nu}^U)$, $\nu = \overline{1,V}$, into which Z -numbers are transformed, the first component of which is the first component of the model Z -number, and the second components are the formalization $\tilde{R}_\nu, \nu = \overline{1,V}$ of the values of a linguistic variable with name –«Reliability». If

$$\begin{aligned}
&\left(u_1^L - u_{1p}^L\right)^2 + \left(u_2^L - u_{2p}^L\right)^2 + \left(u_L^L - u_{Lp}^L\right)^2 \\
&\quad + \left(u_R^L - u_{Rp}^L\right)^2 + \left(u_1^U - u_{1p}^U\right)^2 \\
&\quad + \left(u_2^U - u_{2p}^U\right)^2 + \left(u_L^U - u_{Lp}^U\right)^2 \\
&\quad + \left(u_R^U - u_{Rp}^U\right)^2 \\
&\quad = \min_{\nu=\overline{1,V}} (u_1^L - u_{1\nu}^L)^2 + (u_2^L - u_{2\nu}^L)^2 \\
&\quad + (u_L^L - u_{L\nu}^L)^2 + (u_R^L - u_{R\nu}^L)^2 \\
&\quad + (u_1^U - u_{1\nu}^U)^2 + (u_2^U - u_{2\nu}^U)^2 \\
&\quad + (u_L^U - u_{L\nu}^U)^2 + (u_R^U - u_{R\nu}^U)^2,
\end{aligned}$$

then the reliability of the second component of the model output Z -number is fuzzy number $\tilde{R}_p$ and accordingly p-th term of linguistic variable «Reliability».

4 CONCLUSIONS

To conduct environmental monitoring of cities, assess the qualitative characteristics of the state of green spaces and ecosystem services of urban green areas, experts are involved, for whom it is natural to use words and phrases of professional language that introduce fuzziness into the information coming from them. Since the most experienced expert cannot be absolutely sure of his estimates, it is necessary to take into account the reliability of these estimates when analyzing and predicting them. As a result, we receive information with fuzzy estimates and fuzzy reliability of these estimates, which must be analyzed and predicted in order to develop timely control actions.

For this purpose, the paper has developed a regression model, the input and output information of which are Z-numbers. The proven property of proximity of the structures Z -numbers and type-2 fuzzy numbers was used in the construction. Input and output interval type-2 fuzzy numbers are determined for the initial Z-numbers. The optimization function is defined as the sum of squares for the differences between parameters of output type-2 fuzzy numbers and the model type-2 fuzzy numbers.

To predict the output information, a model has been developed for recognizing its reliability and presenting it as the value of the scale used to evaluate it.

The Z-regression developed in the paper opens up new opportunities for the analysis and predicting of qualitative information, taking into account its reliability in monitoring the environmental state of cities for the development of timely control actions.

REFERENCES

Zadeh, L. A., 2011. A Note on Z-numbers. Inform. Sci. 14(181), 2923-2932.

Zadeh, L. A., 2012. Methods and Systems for Applications with Z-Numbers United States Patent, Patent No.: US 8,311,973 B1.

Kang, B., Wei, D., Li, Y., Deng, Y., 2012. Decision making using Z-numbers under uncertain environment. J. Inform. Comput. Sci. 7(8), 2807-2814.

Kang, B.,Wei, D.,Li,Y., Deng, Y., 2012. A method of converting Z-number to classical fuzzy number. J. Inform. Comput. Sci. 9(3), 703-709.

Aliev, R.A., Alizadeh, A.V., Huseynov, O.H., 2015. The arithmetic of discrete Z-numbers. Inform. Sci. 1(290), 134-155.

Aliev, R.A., Huseynov, O.H., Zeinalova, L.M., 2016. The arithmetic of continuous Z-numbers. Inform. Sci. 373, 441-460.

Aliev, R.K., Huseynov, O.H., Aliyeva, K.R., 2015. Aggregation of an expert group opinion under Z-information. In: Proceedings of the Eighth International Conference on Soft Computing, Computing with Words and Perceptions in System Analysis, Decision and Control, (ICSCW-2015), pp. 115-124, Kaufering: b-Quadrat Verlag, Germany.

Yager, R. R., 2012. On Z-valuations using Zadeh`s Z-numbers. Int. J. Intell. Syst. 3(27), 259-278.

Wang, F., Mao, J.: Approach to multicriteria group decision making with Z-numbers based on Topsis and Power Aggregation Operators. Mat. Probl. Eng. 1-18 (2019). doi.org/10.1155/2019/3014387

Poleshchuk, O. M., 2019. Novel approach to multicriteria decision making under Z-information. In: Proceedings of the International Russian Automation Conference, (RusAutoCon-2019), p. 8867607, Sochi, Russia.

Aliyev, R.R., Talal Mraizid, D. A., Huseynov, O.H., 2015. Expected utility based decision making under Z- information and its application. Comput. Intell. Neurosci. 3, 364512.

Aliyev, R.R., 2015. Similarity based multi-attribute decision making under Z-information. In: Proceedings of the Eighth International Conference on Soft Computing, Computing with Words and Perceptions in System Analysis, Decision and Control, (ICSCW-2015), pp. 33-39, Kaufering: b-Quadrat Verlag, Germany.

Aliev, R.A., Zeinalova, L. M., 2013. Decision-making under Z-information. Human-centric decision-making models for social sciences, 233-252.

Poleshchuk, O., 2023. Multi-criteria analysis of the objects state under Z- information. Stud. Fuzziness Soft Comput. 422, 271-278.

Sadikoglu, F, Huseynov, O, Memmedova, K., 2016. Z-Regression analysis in psychological and educational researches. Procedia Comput. Sci. 102, 385 – 389.

Zeinalova, L.M, Huseynov, O.H, Sharghi, P., 2017.A Z-Number Valued Regression Model and its Application. Intell. Autom. Soft Co**.** 24, 187-192.

Poleshchuk, O.M., 2021. Multiple Z-Regression with Fuzzy Coefficients. Adv. Intell. Syst. Comput, 1306, 63-70.

Poleshchuk, O. M., 2022. A Predictive Nonlinear Regression Model under Initial Z-Information. LNEE, 857, 383-392.

Poleshchuk, O., 2023. Quintile multiple regression with fuzzy coefficients and initial Z-information. E3S Web of Conferences, 431,05015.

Aliev, R, Guirimov, B., 2018. Z-Number Clustering Based on General Type-2 Fuzzy Sets. In: Proceedings of the 13th International Conference on Theory and Application of Fuzzy Systems and Soft Computing, (ICAFS-2018), p. 04164, Kaufering: b-Quadrat Verlag, Germany.

Aliev, R, Kreinovich, V., 2017. Z-Numbers and Type-2 Fuzzy Sets: A Representation Result. Intelligent Automation and Soft Computing, 24(1), 205-210.

Domrachev, V.G., Poleshuk, O.M., 2003. A regression model for fuzzy initial data. Automat. Rem. Contr+. 64 (11), 1715 – 1724.

Zadeh, L.A., 1975. The Concept of a linguistic variable and its application to approximate reasoning. Inform. Sci. 8, 199-249.

Ryjov, A.P., 1994. The Concept of a Full Orthogonal Semantic Scope and the Measuring of Semantic Uncertainty. In: Proceedings of the Fifth International Conference Information Processing and Management of Uncertainty in Knowledge-Based Systems, (IPMU-1994), pp. 33–34, IEEE, Iran.

Poleshchuk, O.M., 2018. Creation of linguistic scales for expert evaluation of parameters of complex objects based on semantic scopes. In: Proceedings of the International Russian Automation Conference, (RusAuto-Con – 2018), p. 8501686, IEEE, Sochi, Russia.

Liu, F., Mendel, J.M., 2009. Encoding words into interval Type-2 fuzzy sets using an interval approach. IEEE Tranns. Fuzzy Systems, 16(6), 1503-1521.

Poleshchuk, O., Komarov, E., 2012. A fuzzy linear regression model for interval type-2 fuzzy sets. In: Proceedings of Annual Conference of the North American Fuzzy Information Processing Society (NAFIPS'2012), p. 6290970, IEEE, Berkeley, California, USA.

Ding, X-F., Zhu, L-X., Lu, M-S., Wang, Q., Feng, Y-Q., 2020. A Novel Linguistic Z -Number QUALIFLEX Method and Its Application to Large Group Emergency Decision Making. Scientific Programming, 10, 1-12.

Coleman, T. F., Li, Y., 1996. A reflective newton method for minimizing a quadratic function subject to bounds on some of the variables. SIAM J. Optim. 6, 1040-1058.

The Purpose of Assessing a Person's Entrepreneurial Capacity is to Classify their Quality Characteristics

Mansur Matkarimov[1][1], Qaxramon Madraximov[1][2], Gulnara Alieva[2][3], Sherjon Sherjonov[1][4], Sevinchbek Egamov[1][5]

[1] *"Mamun university", 220900, Qibla Tozabog, Khiva, Uzbekistan*

[2] *Urgench state university, 220100, Khamid Olimjon 14, Urgench, Uzbekistan.*

matkarimov_mansur1@mamunedu.uz, matkarimov_qahramon1@mamunedu.uz, aliyevagulnora65@gmail.com, sherjonov_sherjon@mamunedu.uz, egamovsevinchbek2106@gmail.com

Keywords: entrepreneurial capacity, quality characteristics, assessing.

Abstract: Assessing an individual's entrepreneurial capacity is fundamental to understanding the traits and attributes that contribute to their potential for entrepreneurial success. This study explores the purpose of assessing a person's entrepreneurial capacity, with a focus on classifying their quality characteristics. Drawing upon a comprehensive review of literature from entrepreneurship studies and related fields, as well as insights from expert consultation, a conceptual framework is developed to guide the classification process. The framework delineates key dimensions, traits, and attributes that underpin entrepreneurial capacity assessment, encompassing aspects such as creativity, risk-taking, resilience, and leadership. Through literature review and validation, the classification of quality characteristics is refined to ensure coherence and applicability. The findings of this study contribute to a deeper understanding of entrepreneurial capacity assessment and provide insights for research, practice, and policy in the field of entrepreneurship. By elucidating the quality characteristics associated with assessing entrepreneurial capacity, this study aims to inform the development of tools, interventions, and strategies aimed at identifying and nurturing entrepreneurial talent.

1 INTRODUCTION

Entrepreneurship, as a driving force of economic development and innovation, has garnered significant attention from scholars, policymakers, and practitioners alike. Central to the study and practice of entrepreneurship is the assessment of individuals' entrepreneurial capacity, which serves as a cornerstone for identifying, nurturing, and harnessing entrepreneurial talent. At the heart of this assessment lies the endeavor to classify the quality characteristics that underpin an individual's potential for entrepreneurial success (Flevy, 2018).

The purpose of assessing a person's entrepreneurial capacity is multifaceted, encompassing both academic inquiry and practical application. At its core, this endeavor seeks to unravel the intricacies of entrepreneurship by dissecting the key traits and attributes that distinguish successful entrepreneurs from their counterparts. By delving into the quality characteristics exhibited by individuals with entrepreneurial prowess, researchers and practitioners can glean valuable insights into the underlying mechanisms driving entrepreneurial behavior and outcomes (Bacigalupo et al, 2016).

One fundamental aspect of assessing entrepreneurial capacity is the classification of quality characteristics. These characteristics represent the core attributes, skills, and behaviors that define an individual's entrepreneurial potential. From creativity and innovation to resilience and adaptability, the spectrum of quality characteristics spans a diverse range of traits that collectively shape

[1] https://orcid.org/0009-0006-9184-0911
[2] https://orcid.org/0009-0009-5198-2503
[3] https://orcid.org/0009-0000-9478-7665
[4] https://orcid.org/0009-0002-3892-4316
[5] https://orcid.org/0009-0005-7862-8679

an individual's entrepreneurial profile. Understanding and categorizing these characteristics not only facilitate the identification and evaluation of entrepreneurial talent but also inform the development of strategies and interventions aimed at fostering entrepreneurial growth and success (Saidmamatov et.al, 2021).

In this paper, we aim to explore the significance of assessing a person's entrepreneurial capacity through the lens of quality characteristics. Drawing upon theoretical insights and empirical evidence from the field of entrepreneurship studies, we will delve into the various dimensions of entrepreneurial capacity assessment, elucidate the key quality characteristics associated with entrepreneurial success, and discuss implications for research, practice, and policy. By shedding light on the intricacies of assessing entrepreneurial capacity, we endeavor to contribute to a deeper understanding of entrepreneurship as a dynamic and multifaceted phenomenon with profound implications for economic development and societal progress (Kuziboev et.al 2024).

2 METHODOLOGY

In this paper we used methods such as literature review, by using conceptual framework development insights from the literature review have been drawn and conceptual framework that outlines the key dimensions, traits, and attributes associated with entrepreneurial capacity assessment has been developed. Expert consultation method also used to conduct semi-structured interviews or focus group discussions with experts in the field of entrepreneurship, including academic researchers, educators, and practitioners. The last method used in paper is documentation and reporting which helps the classification of quality characteristics in a structured format, including descriptive summaries, definitions, and illustrative examples.

3 RESULTS AND DISCUSSION

If a person's professional success in the 19th century was defined by their proficiency in reading and writing skills, by the 20th century, success in the workforce became closely linked to English language proficiency and computer literacy. "Today, in the 21st century, the ability to think and act like an entrepreneur is particularly important, as transitioning from employee to entrepreneur is increasingly becoming the norm," states Nicholas Business, leader of the Vienna Institute for Entrepreneurship and Innovation. Therefore, to succeed in entrepreneurship, it is essential to possess the entrepreneurial capacity to "add value to entrepreneurship," as Business believes that many entrepreneurs fall short in acquiring a sufficient level of knowledge and skills. The presence and level of entrepreneurial capacity are closely related to a range of personal traits, professional competencies, and entrepreneurial skills of an individual. Therefore, in this paragraph of the dissertation, we examine various approaches (Table 1) regarding the classification of quality characteristics of entrepreneurial capacity. By doing so, we aim to base our analysis on scientific grounds.

Table 1: Different approaches exist for categorizing the quality characteristics of entrepreneurial capacity.

Authors	Classification marks	Quality features
Peter Druker	On creating a client for the business	Marketing skills Managerial qualities Innovative activity
Hall, B.P	Hull-Tonna model of determination of entrepreneurial skills	Instrumental abilities Interpersonal skills Imagination skills Systematic skills
Fotekova T.A	Qualities describing the psychological characteristics of entrepreneurship	Qualities that describe the characteristics of the nervous system and thinking Qualities describing motivational characteristics The phenomenon of leadership
Bacigalupo, M., Kampylis, P	Entrepreneurial competence	Ideas and possibilities Resources Actions
Dani G.K	Qualities describing human monoeconomic abilities	Initiative Management Innovation Risk taking Marketing

In the current era, the traditional virtues of entrepreneurship such as resilience, organization, leadership, and innovation are still maintaining their relevance. However, given the conditions of globalization and digital transformation, there is a demand to identify and incorporate new virtues into their composition. In the 20th century, the most influential management theorist, Peter Drucker, collaborated with J. Maciarello in creating the original "Management" textbook, where he expressed the following idea regarding entrepreneurship: "Because the purpose of business is to create a customer, every business enterprise has only two basic functions – marketing and innovation" (Kuziboev et.al 2023). Drawing from this notion, the significant virtue of modern entrepreneurship is considered to include "marketing prowess" instead of placing emphasis solely on innovation. According to the renowned marketing theorist Philip Kotler, marketing is defined as "the activity of a human enterprise directed at satisfying needs and wants through exchange processes." Marketing serves as an essential tool in contemporary business philosophy and as a means of entrepreneurship. In the present era, marketing plays a crucial role in shaping new markets, creating new customers, reducing costs, increasing profits, enhancing competitiveness, and improving the efficiency and effectiveness of entrepreneurial activities. The higher a entrepreneur's marketing skills, the more successful their entrepreneurial endeavors are likely to be.

Identifying entrepreneurial competencies is based on the Hall-Tonna model, which categorizes four types of competencies:

1. Instrumental skills. The unique combination of intellectual and physical abilities enables individuals to competently execute tasks. This competency is focused on task performance, providing entrepreneurs with indispensable qualities not easily replaceable and recognized as recurring merits.

2. Interpersonal skills. Playing a key role in establishing relationships and interactions among individuals through verbal and non-verbal communication, especially concerning attitudes and behaviors towards others.

3. Imaginative skills. Facilitating the expression of new ideas through the unique combination of imagination and sensations. These competencies are operationalized through language and create synergy, enhancing personal growth by serving as the foundation for contributing to others' development.

4. Systemic skills. Facilitating the expression of the various components of a system as a whole through the interaction of imagination, perception, and skill. Such competencies contribute to systemic awareness, fostering the enhancement of the ability to integrate, laterally connect components, and identify interdependencies. Instrumental, interpersonal, imaginative, and systemic entrepreneurial competencies, as defined by the Hall-Tonna model, are crucial in perceiving entrepreneurship as a process. Their importance lies in their relevance to research, implementation, and management stages, as they represent competencies specific to investigation, implementation, and management phases. However, in researching entrepreneurship activity quality management objectively, it is necessary to consider managerial competencies specific to entrepreneurs, such as marketing skills and adaptability to novelty.

Classification of entrepreneurial competency in terms of its psychological aspect assigns personal attributes indicative of readiness for entrepreneurial activity and psychological preparedness to the following groups:

1. Group of attributes describing nervous system and thinking characteristics. These include adaptability, resilience, strategic thinking, stress management, ability to act in uncertain situations, and readiness for risk-taking.

2. Group of characteristics of the motivational sphere. This group includes attributes such as entrepreneurial intention (desire to engage in entrepreneurial activity), motivation for achieving success, and fame-seeking.

3. Group related to the phenomenon of leadership. Attributes such as leadership and organizational skills, responsibility, decision-making ability, networking skills, and readiness for conducting negotiations and discussions are included in this group.

Research conducted within the framework of the Entrepreneurship Competence Framework by the European Commission suggests three areas of competency and recommends 15 specific competencies within them as a means to enhance the entrepreneurial abilities of European citizens and organizations (Ghicajanu, 2015). Within this context, competency is understood as "knowledge, skills, and attitudes." The fields and competencies of entrepreneurship competence are as follows:

1. Competency area - "Ideas and Opportunities." It consists of the following competencies:

-Identifying Opportunities (utilizing your imagination and abilities to identify opportunities for value creation).

-Creativity (developing innovative and purposeful goals).

-Future Orientation (taking action based on your vision of the future).

-Valuing Ideas (maximizing the use of goals and opportunities).

-Persistence and Ethical Thinking (evaluating the consequences and impacts of goals, opportunities, and actions).

2. Competency area - "Resources." This competency area comprises the following competencies:

-Self-Awareness and Self-Efficacy (believing in yourself and continuing personal development).

-Motivation and Perseverance (maintaining focus and resilience).

-Resource Mobilization (gathering necessary resources and managing them effectively).

-Financial and Economic Literacy (developing financial and economic know-how).

-Mobilizing Other Resources (motivating, inspiring, and attracting others).

3. Competency area - "Actions." This competency area is shaped around four competencies:

-Taking Initiative (taking initiative).

-Planning and Management (defining objectives, organizing, and monitoring).

-Adaptability, Diversity, and Problem-solving (making decisions with adaptability, diversity, and confidence).

-Working with Others (building teams, collaborating, and networking).

3-Learning through Experience (learning through action).

One of the advantages of being within the scope of a wide-ranging competency is that it provides the opportunity to promote initiatives that are conducive to entrepreneurship competency as a whole, which, based on the order, enables the promotion of initiatives that involve customization and assistance in understanding entrepreneurship (Benedicta et.al 2016). Based on foreign and national experiences in evaluating entrepreneurial competencies with the aim of categorizing the described entrepreneurial qualities, we propose the classification of three types: hard skills, soft skills and digital skills entrepreneurial competencies (see figure 1).

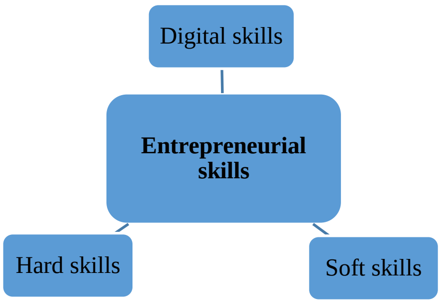


Figure 1: Three levels of entrepreneurial skills.

Based on the advanced foreign experience, the "HSDS model" of classifying the entrepreneur's qualities was developed as a mechanism for assessing entrepreneurial ability. HSDS acronym visual. HSDS - Hard, Soft, Digital, Skills - hard, soft and digital skills are recommended by the author as a model for classifying the qualities of an entrepreneur. In this case, the development of entrepreneurship is related to the level of development of entrepreneurial skills. The Cambridge Dictionary defines 'skill' as 'the ability to do an activity or thing well, especially because you have practiced it'. In the literature, the skills that characterize the specialist are divided into two categories

Scientists from the Polytechnic University of Valencia in Spain recommend that the following qualities of an entrepreneur should be included in the "soft" skills for entrepreneurship within the framework of the Trans-European project: initiative; leadership; conduct negotiations; network connection; accessibility to communication; creativity; planning and organization; teamwork and cooperation; self-confidence; self control; personnel management; loyalty to the organization; sympathy; flexibility and change management; striving for success; strategic orientation; analytical thinking; conceptual thinking; quality and efficiency; teaching and using knowledge.

The soft skills listed above are considered the most important in the field of entrepreneurship, and some of them are mixed, for example, personnel management refers to both soft and hard skills. Also, a number of soft skills such as "seeing and taking advantage of opportunities", "persevere", "information seeking", "focusing on high-level work productivity", "problem-solving" influence strategy" are not fully taken into account.

4 CONCLUSION

In conclusion, assessing a person's entrepreneurial capacity serves as a crucial tool to categorize and understand their quality characteristics. Through such assessments, individuals can gain insights into their strengths, weaknesses, and potential areas for development in the realm of entrepreneurship. By identifying key traits and aptitudes, such as innovation, risk-taking propensity, resilience, and leadership skills, this process enables tailored support and guidance for aspiring entrepreneurs. Moreover, it facilitates the selection and nurturing of individuals with the most promising entrepreneurial potential, thereby contributing to the fostering of vibrant and successful entrepreneurial ecosystems. Ultimately, by recognizing and harnessing the diverse qualities that individuals bring to the entrepreneurial landscape, assessments of entrepreneurial capacity play a pivotal role in driving innovation, economic growth, and societal progress.

We can give the following recommendations related to assessing a person's entrepreneurial capacity and classifying their quality characteristics:

-utilize a comprehensive assessment framework;
-employ multiple assessment methods;
-tailor assessments to context;
-provide constructive feedback;
-promote lifelong learning;
-facilitate collaboration and support networks;
-monitor and Evaluate Progress.

By implementing these recommendations, organizations, educators, and support providers can enhance their capacity to assess and nurture entrepreneurial talent effectively, ultimately fostering a thriving ecosystem of innovation and entrepreneurship.

REFERENCES

Lasrado, F., 2018. Achieving Organizational Excellence: A Quality Management Program for Culturally Diverse Organizations. Springer. Dubai. UAE. 195 p.

Bacigalupo, M., Kampylis, P., Punie, Y., Van den Brande, G. , 2016. EntreComp: The Entrepreneurship Competence Framework. Luxembourg: Publication Office of the European Union; EUR 27939 EN; 39 p.

Saidmamatov, O., Matyakubov, U., Khodjaniyazov, E., Day, J., Ibadullaev, E., Chuponov, S., Bekjanov, D., Matniyozov, M., Matyusupov, B., 2021. Analiza TOWS możliwości zrównoważonego rozwoju ekoturystyki i pomocy państwa w czasie pandemii – region Jeziora Aralskiego w Uzbekistanie. *Turyzm*, *31*(1), 47–57.

Kuziboev, B., Rajabov, A., Ibadullaev, E., Matkarimov, F., Ataev, J., 2024. The role of renewable energy, tax revenue and women governance in environmental degradation for developing Asian countries. Energy Nexus 13, 100262.

Kuziboev, B., Ibadullaev, E., Saidmamatov, O., Rajabov, A., Marty, P., Ruzmetov, S., Sherov, A., 2023. The Role of Renewable Energy and Human Capital in Reducing Environmental Degradation in Europe and Central Asia: Panel Quantile Regression and GMM Approach. Energies 16, 7627.

Dwi Riyanti, B.P., Sandroto, Ch.W., M. Tri Warmiyati, D.W., 2016. Soft Skill Competencies, Hard Skill Competencies, and Intention to Become Entrepreneur of Vocational Graduates. *International Research journal of Buseness Stusies.* Vol 9, no 2. pp. 119 – 132.

Ghicajanu, M., Irimie, S., Marica, L., Munteanu, R., 2015. Criteria for excellence in business. Procedia Economics and Finance, 23, 445–452.

Differences among Entrepreneurship, Intrapreneurship, Manager. https://www.iedunote.com/difference-entrepreneur-intrapreneur-manager.

Digital skills: chto eto i pochemu eto vazhnye navyki budushchego. https://inskills.space/digital-skills-chto-eto-i-pochemu-eto-vazhnye-navykibudushhego/

EFQM, 2013. EFQM Excellence Model. Website EFQM, available at: https://www.efqm.org/.

Full definition at the Digital Entrepreneurship Monitor website: https://ec.europa.eu/growth/tools-databases/dem/monitor/project-description

The Impact of Artificial Intelligence in Human Resource Development

Redar Hameed Ali[a], Alena Fedorova[b] and Olga Koropets[c]
[1]*Department of Personnel Management and Psychology, Ural Federal University, Mira Street, Yekaterinburg, Russia*
Redarhamid879@gmail.com, a.e.fedorova@urfu.ru, o.a.koropets@urfu.ru

Keywords: Artificial Intelligence (AI), Human Resource Management (HRM), Planning, Decision-making, Strategy, Employee Engagement

Abstract: The integration of Artificial Intelligence (AI) in Human Resource Management (HRM) has garnered significant attention due to its potential to revolutionize decision-making, streamline operations, enhance employee engagement, and improve overall organizational efficiency. This study aims to explore the benefits of incorporating AI technologies into HRM processes and to provide insights into the impact of intelligent automation on workplace outcomes. A systematic review methodology was employed, drawing data from prominent databases such as Web of Science, Elsevier, and Google Scholar. Initially identifying 150 records, a rigorous screening process resulted in the exclusion of 94 records based on predefined eligibility criteria. Subsequently, 24 reports were assessed for eligibility, revealing key themes related to the integration of AI in HRM. The findings highlight the importance of leveraging AI to enhance performance management, planning, decision-making agility, and employee development. The study underscores the need for a cohesive framework that positions HRM as a key player in bridging the gap between AI implementation and workplace outcomes. Further research is recommended to address gaps in understanding the interconnected nature of AI implementation and its implications for organizational success.

1 INTRODUCTION

When it comes to using AI in the workplace, HRM plays a crucial role for every company (Strohmeier and Piazza, 2015). A new body of research on the topic of artificial intelligence (AI) and its real and possible impacts on the workplace has emerged in recent years (Strohmeier and Piazza, 2015). As stated by Minbaeva (2021) that Additional advantages can be generated for a business by integrating HRM procedures with artificial intelligence. Artificial intelligence (AI) refers to sophisticated computer programs and systems that are able to learn, reason, and plan in a manner similar to the human brain (Pereira *et al.*, 2023). Researchers have also shown that HRM can utilize AI in a number of ways that are good for both workers and businesses (Sekhri and Cheema, 2019). When used to the task of regulating and managing performance, artificial intelligence can alleviate worries about the validity, reliability, and bias of such processes (Schneider and Schoorman, 1988). Regardless of these advancements, a cohesive framework that positions HRM as a key player in the connection between AI implementation and results in the workplace is still missing. There is a lack of a holistic view of the interconnected nature of HRM's many subfields in the existing literature. These include human resource planning, safety and well-being, performance management and appraisal, compensation and rewards management, training and development, recruitment and selection (Pereira *et al.*, 2023). There is a continuum between weak AI applications that act intelligently and strong AI machines that are intellectually on par with humans. Both types of AI are finding more and more uses in today's world (Yang, 2022). However, research and development is ongoing in the latter kind, which makes use of automated processes that can do all jobs independently (Yang, 2022).

[a] https://orcid.org/0009-0008-0973-1535
[b] https://orcid.org/0000-0002-4600-6489
[c] https://orcid.org/0000-0002-7449-3325

As argued by DiClaudio (2019) that organizations must use sophisticated technology in order to maintain competitive advantages, and prior research has shown that HRM can help train employees to use these tools effectively. The capacity to learn and adapt automatically to provide more refined reactions to circumstances is at the heart of artificial intelligence (AI), which can make judgments in real time using pre-installed computer technologies and development. HRM, which incorporates both humans and AI, can provide a better working environment for a company's workers (Pereira et al., 2023). Contextualizing AI usage inside respective HR silos is useful for understanding workplace outcomes and dangers connected with AI adoption, as AI is likely to be deployed differently across varied HRM departments. Taking into account the HR tasks that make use of AI, we provide a critical synthesis of AI and employee outcomes (Sekhri and Cheema, 2019).

The objective is following that:

1. Aims to discuss how integrating AI technologies with HR processes can revolutionize decision-making, streamline operations, enhance employee engagement, and improve overall organizational efficiency.
2. Seeks to highlight the potential benefits of AI in HRM, such as talent acquisition, performance management, training programs, and creating a more inclusive and diverse workplace.

2 METHODS

The findings of a scoping study helped us decide to conduct a systematic review on this research issue by assessing the extent and relevance of the literature and defining the subject area (Rajwani and Liedong, 2015). Our goal in conducting this systematic literature evaluation was to identify recurring themes in the field of intelligent automation in HRM and to suggest potential new research directions (Tranfield, Denyer and Smart, 2003). Because it improves the review's overall quality via the use of a clear and readily reproducible procedure, a systematic approach was considered acceptable (Crossan and Apaydin, 2010).

Data collection the first step we started to collect data in 28.02.2024 in the process is the identification of records. In this case, records were identified through various databases such as Web of Science, Elsevier, and Google Scholar. The total number of records identified is not specified in the text. After the identification, the records were screened. The total number of articles screened was 150. This screening process led to the exclusion of 94 records for various reasons 35 articles were about ineligible subjects, meaning they did not meet the criteria set for the review. 30 articles were duplicates, i.e., they were repeated in the dataset. 29 articles were solely focused on HRM which presumably was not the focus of this review. The remaining 56 records (150 initial records – 94 excluded records) were then assessed for eligibility. However, 70 reports were not retrieved for some reason, leaving only 24 reports to be assessed. Out of these 24 reports, further exclusions were made: 11 reports were excluded because they were systematic reviews themselves. Including other reviews in a new review could lead to duplication of data. 7 reports were excluded because they were based on secondary data. The review could have been focusing on primary research articles. 6 reports were excluded because they only contained an abstract, with no full text available for a detailed review. After the entire process of identification, screening, and assessing eligibility, 24 reports were finally included in the review (Table). These are the studies that passed all the criteria and were deemed suitable for the review.

List of journals and number of articles found related to the study.

Journals (in descending order of articles number)	Articles number
The International Journal of Human Resource Management	8
Computers in Human Behavior	6
Human Resource Management Review	4
Computer Modelling & New Technologies	2
Journal of International Management	2
Journal of Information Technology	1
Heliyon	1

The provided table enumerates several academic journals, each accompanied by the number of articles procured from them. These journals are methodically arranged in descending order based on the quantity of articles found. This order implies that the journal contributing the highest number of articles is listed at the forefront. The International Journal of Human Resource Management takes the lead, contributing eight articles. It is an annual publication that covers a range of topics relevant to Human Resource Management. These topics include the management of service leavers and veterans, as well as the use of language in international HRM. Following closely is Computers in Human Behavior with six articles. This journal, holding the second position, has also made a significant contribution. Ranked third with four articles is the Human Resource Management Review. This quarterly academic journal is known for publishing scholarly conceptual and theoretical articles. These articles are related to human resource management and allied fields, such as industrial/organizational psychology, human capital, labor relations, and organizational behavior. In fourth place, with two articles, is Computer Modelling & New Technologies. However, the specific topics of these articles have not been provided in the table. The fifth position is held by the Journal of International Management. Like its predecessor, it also contributed two articles. Journal of Information Technology is sixth on the list, having contributed one article. Finally, the Journal of Heliyon also appears on the list in seventh place, with one article.

3 RESULTS

3.1 AI in HRM

According to the literature on AI, the technology can be categorized into many categories of intelligence, each with its own set of uses in corporate organizations (Chowdhury *et al.*, 2023). Sheehan, N. Garavan and Carbery (2013) said that Human resource analytics in AI is a "must have" skill for HR professionals since it helps them make better use of their employees' time and provides a mechanism to increase the strategic impact of HR initiatives. This is why AI-driven HR analytics is quickly becoming a hot topic in HRM research (Baakeel, 2020). AI has the ability to make HR decisions (involving workers, for example) less subjective and more objective by mining employee data for relevant information (Chornous and Gura, 2020). As claimed by Margherita and Bua (2021) that the creation of expert systems for assessing work performance was the first focus of AI's involvement. Due to its ability to assess several streams of large data and aid in decision-making, AI shows great promise in bolstering organizational research. AI has the potential to improve job descriptions, which in turn attracts the most qualified people, conduct sentiment analysis to track new planning, organizing, and more (Kaushik and Kakkar, 2019). The goal of implementing AI-based intelligent systems into data-driven decision-making is to improve decision-making agility and business process optimization via the use of large data (Wilson and Daugherty, 2018). Based on their analysis of the latest research on AI's effect on businesses, concludes that AI is having a significant influence on decision-making and the workforce. The strategic direction of the planning sector is being influenced by the use of AI, which is having an effect on cost management and the number of applicants for customers (Upadhyay and Khandelwal, 2018). With the use of AI, HRM procedures can be made more scalable by increasing the number of applicants for design making. This has several benefits, including a decrease in organizational time and costs and an increase in the diversity of new organizing (Wilson and Daugherty, 2018). While this is going on, a new line of inquiry is investigating how the use of AI affects HRM methods and processes. The bulk of these studies are based on theories that are developed at the level of organizations and industries. In particular, one of the most important focuses of these efforts is the investigation of how the implementation of AI affects the dynamics of the labor market and employment (Acemoglu and Lelarge, 2020). When small and medium-sized enterprises align and validate their digital and operational strategies, it improves their HRM, creates more effective teams, and ultimately builds their legacy (Bender and Fish, 2000). For instance, HR strategies that aid firms in tackling competitive technology issues impacting their goods or services and the development of scalable, agile workforces are two areas where HR scholars have emphasized the function's critical importance (Biron *et al.*, 2021). A growing number of companies have begun to use AI-powered tools to improve their HR operations in the last few years. Businesses can simplify their HR operations and make better decisions with the aid of AI, thus this trend is expected to continue (Chatterjee *et al.*, 2023). To ensure that the benefits of AI development are maximized while its hazards are avoided, its development requires careful analysis and control (Vrontis *et al.*, 2022). Businesses can lessen the likelihood of bias in their AI solutions by regularly auditing their systems and making sure they are based on several impartial data sets (Bhardwaj, Singh and Kumar, 2020). The best way for administrations to deal with this problem is to invest in retraining and skill enhancement programs so that employees can take on more human-centric roles. Organizations can benefit from AI in many ways, including better human resources procedures, improved efficiency, and better decision-making (Butler and Callahan, 2014).

3.2 Human Resource development

Domain specialists in AI are working tirelessly to train machine-learning algorithms to imitate human capabilities. However, AI still has a long way to go before it can replicate higher-level talents like reasoning, leading, sense-making, connection building, problem-solving, and communication (Huang and Rust, 2018). When applied to HRM, AI refers to a suite of software algorithms that automates tasks typically performed by humans. In HRM, most software algorithms are static; that is, their computer-programmed steps don't change no matter what data is entered into them. However, in AI, and development algorithms like machine learning change depending on the data they process (Meijerink *et al.*, 2021). Thus, AI-powered HRM is of HRM. In HRM, a self-learning algorithm can alter the factors used to forecast an applicant's future performance, the relative importance of those variables, or the sequence in which the predetermined steps are executed. In a similar vein, self-learning algorithms improve the distribution of assignments to employees on learning and developing services by analyzing data availability (Newlands, 2021). found that fast-growing companies had a tough time with a lot of issues, including getting workers involved in decision-making and creating an open work environment, recruiting top talent, retaining employees with important knowledge or confidential information, having who can articulate the company's vision, and training executives to be effective leaders and managers (Saunders and Chan, 2002). With the development of IA technologies, companies can improve their methods for training and development as well as performance management. In the past, managers often had to invest a lot of effort on staff development (Belanche, Casaló and Flavián, 2019). As cited by Li (2023) Performance management is another area that is seeing the application of AI. This system can sift through data from a variety of sources, including, job satisfaction, developing employee, and training opinions. And also (Tarhini *et al.*, 2017) said that Personal innovation can help human resource managers recruit and maintain teams who are creative, inventive, and full of new ideas to improve healthcare processes. Human resource managers can discover employees with an entrepreneurial spirit by encouraging personal creativity. Afterwards, these employees can participate in programs designed to foster growth in their capacity for innovative and inventive problem-solving. One way to measure an employee's ability to come up with new ideas and approaches is to look at their level of personal innovativeness (Širůček and Galečka, 2017). By automating HR operations, enhancing strategy and talent acquisition, increasing engagement and the employee experience, streamlining decision-making, and easing the development and upskilling of employees, AI is transforming HR procedures (Nam *et al.*, 2021). Based on Dalal and Akdere (2018), companies value their bright employees highly because they help with strategy and help the company stay ahead of the competition. Companies gain when employees acquire new skills.

As directed by Bondarouk and Brewster (2016) that in HRM, AI is often utilized for activities such as planning, providing ongoing strategy and development, assessing performance, creating job descriptions, and improving the overall work experience for current employees. Similarly, new technology like electronic HR information systems provide a number of chances to enhance and lower the expense of HRM tasks like, say, evaluating job candidates and evaluating employees' performance (Abraham *et al.*, 2019). When it comes to adopting new technologies, human resources managers can be changing agents. Their openness to AI adoption, therefore, has the dual effect of reducing opposition to change and giving doubtful workers a voice (Caldwell, 2001). Kehoe and Wright (2013) said that Investing in personnel and implementing HR policies that harness their talents and expertise to produce strategic value are highlighted in research on strategy. Coleman-Jensen, Gregory and Singh (2014) mention that strategy and planning has been used to gauge employee well-being by evaluating its effects on organizational performance or by mediating the relationship between work satisfaction and anxiety.

This encourages upper-level management to reevaluate the effectiveness of HR in the company and come up with fresh strategies, such as cutting-edge training and development programs, to improve HR operations (Nagendra and Deshpande, 2014). Training, Virtual training assistants powered by AI can also tailor their lessons to each employees' unique requirements and learning style. Implementing these strategies can enhance the efficacy of training programs and foster more employee engagement (Pan *et al.*, 2022). The use of AI can aid in the detection of possible performance problems and the delivery of coaching and training to enhance employee performance (Li, Bonn and Ye, 2019). As provided by Lin and Albert (2014) that AI computer agents have been seen as valuable resources for improving employees' abilities to engage in strategic and negotiating settings, which in turn saves a lot of time and produces better results. The integration of AI in HRM has proven to be a transformative tool, enhancing areas like strategic planning, performance assessment, job description creation, and overall employee experience.

Furthermore, technological innovations like electronic HR information systems have simplified HR tasks such as candidate evaluation and performance review, resulting in both improved efficiencies and cost reductions. HR managers play a pivotal role as change agents, facilitating the adoption of AI and minimizing resistance to change while giving a voice to skeptical employees.

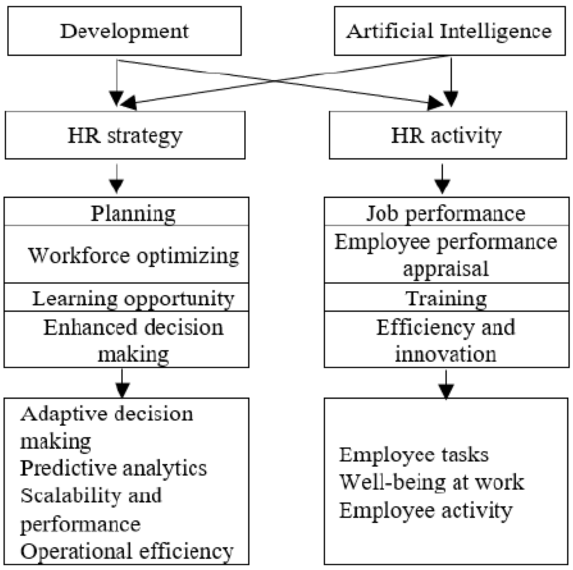


Figure 1: Theoretical framework of the study.

Research underscores the importance of investing in personnel and implementing strategic HR policies to leverage their skills and expertise. AI can also enhance training programs, tailoring them to individual learning styles, and boost employee engagement. AI tools can help identify performance issues, provide coaching, and improve employees' strategic and negotiation skills, leading to time savings and better results.

4 DISCUSSIONS

The integration of AI in HRM has the potential to revolutionize the way businesses operate and manage their workforce. By incorporating AI technologies into HR processes, organizations can enhance decision-making, streamline operations, and improve employee engagement. AI can assist HR professionals in making more informed and objective decisions by analyzing large volumes of employee data to identify patterns and trends. This can lead to more effective talent acquisition, performance management, and training programs. Additionally, AI-powered tools can help HR departments automate repetitive tasks, freeing up time for strategic initiatives and employee development. Furthermore, AI can contribute to creating a more inclusive and diverse workplace by facilitating unbiased recruitment processes and promoting equal opportunities for all employees. By leveraging AI for job matching and candidate screening, organizations can ensure a fair and transparent hiring process. Overall, the adoption of AI in HRM holds great promise for enhancing organizational efficiency, optimizing decision-making processes, and fostering a positive work environment for employees. As businesses continue to embrace AI technologies, the role of HR professionals in driving organizational success is evolving to encompass a more data-driven and strategic approach.

5 CONCLUSIONS

The integration of AI with HRM procedures presents significant opportunities for businesses to enhance performance management, decision-making, and employee development. The evolving landscape of AI in HRM research highlights the potential benefits of leveraging AI technologies to streamline operations, improve decision-making agility, and optimize business processes. However, there remains a need for a cohesive framework that positions HRM as a key player in bridging the gap between AI implementation and workplace outcomes. By embracing AI-driven HR analytics and intelligent systems, organizations can create a more objective and efficient work environment that fosters innovation, talent retention, and strategic growth. A systematic review was conducted by collecting data from various databases such as Web of Science, Elsevier, and Google Scholar. Initially, 150 records were identified, of which 94 were excluded due to ineligible subjects, duplicates, and focus solely on HRM. After screening, 24 reports were assessed for eligibility, with exclusions made for systematic reviews, secondary data-based reports, and abstract-only articles. In the end, the systematic review identified key themes in the field of intelligent automation in HRM, suggesting potential new research directions. The analysis highlighted the importance of integrating AI with HRM procedures to enhance decision-making, streamline operations, and improve employee outcomes. Further research is needed to address gaps in understanding the interconnected nature of AI implementation and its impact on the workplace.

REFERENCES

Abraham, M., Niessen, C., Schnabel, C., Lorek, K., Grimm, V., Möslein, K., Wrede, M., 2019. Electronic monitoring at work: The role of attitudes, functions, and perceived control for the acceptance of tracking technologies. *Human Resource Management Journal*, 29(4), pp. 657–675.

Acemoglu, D., Lelarge, C., 2020. Pascual Restrepo. Forthcoming. Competing with Robots: Firm-Level Evidence from France. *AEA Papers and Proceedings*, 110, pp. 383–388.

Baakeel, O.A., 2020. The association between the effectiveness of human resource management functions and the use of artificial intelligence. *International Journal of Advanced Trends in Computer Science and Engineering*, 9(1), pp. 606–612.

Belanche, D., Casaló, L. V., Flavián, C., 2019. Artificial Intelligence in FinTech: understanding robo-advisors adoption among customers. *Industrial Management & Data Systems*, 119(7), pp. 1411–1430.

Bender, S., Fish, A., 2000. The transfer of knowledge and the retention of expertise: the continuing need for global assignments. *Journal of Knowledge management*, 4(2), pp. 125–137.

Bhardwaj, G., Singh, S.V., Kumar, V., 2020. An empirical study of artificial intelligence and its impact on human resource functions. In *2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM)*. IEEE, pp. 47–51.

Biron, M., et al., 2021. Structuring for innovative responses to human resource challenges: A skunk works approach. *Human Resource Management Review*, 31(2), p. 100768.

Bondarouk, T., Brewster, C., 2016. Conceptualising the future of HRM and technology research. *The International Journal of Human Resource Management*, 27(21), 2652–2671.

Butler, M. G., Callahan, C. M., 2014. Human resource outsourcing: Market and operating performance effects of administrative HR functions. *Journal of Business Research*, 67(2), pp. 218–224.

Caldwell, R., 2001. Champions, adapters, consultants and synergists: the new change agents in HRM. *Human Resource Management Journal*, 11(3), pp. 39–52.

Chatterjee, S., et al., 2023. Assessing organizational users' intentions and behavior to AI integrated CRM systems: A meta-UTAUT approach. *Information Systems Frontiers*, 25(4), pp. 1299–1313.

Chornous, G. O., Gura, V. L., 2020. Integration of information systems for predictive workforce analytics: Models, synergy, security of entrepreneurship. *European Journal of Sustainable Development*, 9(1), p. 83.

Chowdhury, S., et al., 2023. Unlocking the value of artificial intelligence in human resource management through AI capability framework. *Human Resource Management Review*, 33(1), p. 100899.

Coleman-Jensen, A., Gregory, C., Singh, A., 2014. Household food security in the United States in 2013. *USDA-ERS Economic Research Report*, (173).

Crossan, M. M., Apaydin, M., 2010. A multi-dimensional framework of organizational innovation: A systematic review of the literature. *Journal of Management Studies*, 47(6), pp. 1154–1191.

Dalal, R., Akdere, M., 2018. Talent development: Status quo and future directions. *Industrial and Commercial Training*, 50(6), pp. 342–355.

DiClaudio, M., 2019. People analytics and the rise of HR: how data, analytics and emerging technology can transform human resources (HR) into a profit center. *Strategic HR Review*, 18(2), pp. 42–46.

Huang, M.-H., Rust, R. T., 2018. Artificial intelligence in service. *Journal of Service Research*, 21(2), pp. 155–172.

Kaushik, R., Kakkar, M., 2019. A Study of Energy Conservation Using Green Cloud Computing. *Indian Journal of Computer Science*, 4(1).

Kehoe, R. R., Wright, P. M., 2013. The impact of high-performance human resource practices on employees' attitudes and behaviors. *Journal of Management*, 39(2), pp. 366–391.

Li, J. J., Bonn, M. A., Ye, B. H., 2019. Hotel employee's artificial intelligence and robotics awareness and its impact on turnover intention: The moderating roles of perceived organizational support and competitive psychological climate. *Tourism Management*, 73, pp. 172–181.

Li, K., 2023. 'Determinants of college students' actual use of AI-based systems: An extension of the technology acceptance model. *Sustainability*, 15(6), p. 5221.

Lin, F. R., Albert, M., 2014. Hearing loss and dementia–who is listening? *Aging & Mental Health*, pp. 671–673.

Margherita, E. G., Bua, I., 2021. The role of human resource practices for the development of Operator 4.0 in Industry 4.0 organisations: a literature review and a research agenda. *Businesses*, 1(1), pp. 18–33.

Meijerink, J., et al., 2021. Algorithmic human resource management: Synthesizing developments and cross-disciplinary insights on digital HRM. *The International Journal of Human Resource Management*, pp. 2545–2562.

Minbaeva, D., 2021. Disrupted HR? *Human Resource Management Review*, 31(4), p. 100820.

Nagendra, A., Deshpande, M., 2014. Human Resource Information Systems (HRIS) in HR planning and development in mid to large sized organizations. *Procedia-Social and Behavioral Sciences*, 133, pp. 61–67.

Nam, K., et al., 2021. The adoption of artificial intelligence and robotics in the hotel industry: prospects and challenges. *Electronic Markets*, 31, pp. 553–574.

Newlands, G., 2021. Algorithmic surveillance in the gig economy: The organization of work through Lefebvrian

conceived space. *Organization Studies*, 42(5), pp. 719–737.
Pan, Y., et al., 2022. The adoption of artificial intelligence in employee recruitment: The influence of contextual factors. *The International Journal of Human Resource Management*, 33(6), pp. 1125–1147.
Pereira, V., et al., 2023. A systematic literature review on the impact of artificial intelligence on workplace outcomes: A multi-process perspective. *Human Resource Management Review*, 33(1), p. 100857.
Rajwani, T., Liedong, T. A., 2015. Political activity and firm performance within nonmarket research: A review and international comparative assessment. *Journal of World Business*, 50(2), pp. 273–283.
Saunders, C., Chan, Y. E., 2002. Rapid-Growth Firms: The challenge of managing information technology; Uncertainty aside, the CEOs of rapid-growth firms have a particular set of challenges and a particular opportunity to manage the growth of their firms. *Ivey Business Journal*, 66(3), pp. 62–68.
Schneider, B., Schoorman, F. D., 1988. Facilitating work effectiveness. Lexington Books Lexington, MA.
Sekhri, A., Cheema, D. J., 2019. The new era of HRM: AI reinventing HRM functions. *International Journal of Scientific Research and Review*, 7(3), pp. 3073–3077.
Sheehan, M., N. Garavan, T., Carbery, R., 2013. Innovation and human resource development (HRD). *European Journal of Training and Development*, 38(1/2), pp. 2–14.
Širůček, M., Galečka, O., 2017. Alternative evaluation of S&P 500 index in relation to quantitative easing. In *Forum Scientiae Oeconomia*, pp. 5–18.
Strohmeier, S., Piazza, F., 2015. Artificial intelligence techniques in human resource management – a conceptual exploration. *Intelligent Techniques in Engineering Management: Theory and Applications*, pp. 149–172.
Tarhini, A., et al., 2017. Factors influencing students' adoption of e-learning: a structural equation modeling approach. *Journal of International Education in Business*, 10(2), pp. 164–182.
Tranfield, D., Denyer, D., Smart, P., 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, 14(3), pp. 207–222.
Upadhyay, A. K., Khandelwal, K., 2018. Applying artificial intelligence: implications for recruitment. *Strategic HR Review*, 17(5), pp. 255–258.
Vrontis, D., et al., 2022. Artificial intelligence, robotics, advanced technologies and human resource management: a systematic review. *The International Journal of Human Resource Management*, 33(6), pp. 1237–1266.
Wilson, H. J., Daugherty, P. R., 2018. Collaborative intelligence: Humans and AI are joining forces. *Harvard Business Review*, 96(4), pp. 114–123.
Yang, C.-H., 2022. How artificial intelligence technology affects productivity and employment: firm-level evidence from Taiwan. *Research Policy*, 51(6), p. 104536.

Digital Transformation of Uzbekistan in Higher Pedagogical Education

Sarvar Djumaboev[1] [a], Dustkul Botirov[1] [b], Khurram Tangirov[1] [c], Buvsara Djurayeva[1] [d] and Ulugbek Khonimkulov[1] [e]

[1]*Jizzakh State Pedagogical University, Sh.Rashidov street, Jizzakh city, Uzbekistan*
sarvarjm@mail.ru, {botirovdb, xurramtangirov, buvsarajuraeva, xonimqulovulugbek1985}@gmail.com

Keywords: Artificial intelligence, digital technologies in education, digital, information technology, student improvement of the education system.

Abstract: The article is devoted to the issue of digitalization and digital technologies in education. Modern society is characterized by a large flow of information and the introduction of innovations in various fields of activity, which requires a certain amount of knowledge and skills from a person, at the head of which is creativity and creative thinking. This article substantiates the need to use digital technologies and ensure digital socialization of students, considers the concept of digitalization and presents digital technologies in education.

1 INTRODUCTION

At the present stage of development of society, innovations are actively being introduced into various areas of human activity, which requires from people, firstly, constant development and improvement of existing knowledge and skills, and secondly, creativity competencies, creative thinking and willingness to cooperate, since routine work is all The computer is transferred more often. In this connection, information and communication technologies acquire particular importance. Providing complete, accessible and reliable information is the key to success in any field of activity. In this regard, it is important to note that the "Digital Uzbekistan-2030" program has been approved for 2023 – 2030, aimed at informatization and digitalization of society. The document also states that the country's population actively using digital resources should be at least 50% by 2025. This requirement clearly requires a significant restructuring in the education system, associated both with the use of information and communication technologies and with the digital socialization of students developing and improving ICT competencies.

New tools expand and complement human capabilities; the use of more complex tools (Internet + search engines + social networks) requires the development of increasingly complex cognitive processes. Also important is the increase in the number of schoolchildren using digital resources, which indicates their increased interest in using the capabilities of modern digital technologies. This creates an additional impetus for the digitalization of education. Thus, there is a need to form an information culture in modern people and ensure digital socialization as prerequisites for comfortable life activities already from school age o age. These areas should become priorities in the higher education system. The education system should be aimed at ensuring a confident transition to a digital society, which is characterized by economic growth and productive labor relations. As noted earlier, computers based on artificial intelligence are already actively used in the labor market, which successfully cope with routine work. The task of a modern person

[a] https://orcid.org/0000-0001-7557-2511
[b] https://orcid.org/0000-0002-7553-5574
[c] https://orcid.org/0000-0003-3852-5198
[d] https://orcid.org/0000-0003-4526-4387
[e] https://orcid.org/0000-0001-5771-7529

is to demonstrate creativity and creative thinking in order to create and introduce innovations. The use of digital technologies along with traditional ones will significantly increase the flexibility and technological effectiveness of education, as well as the motivational component of students for the educational process. The need to increase the motivational component is reflected in documents such as “Personnel and Education”, the “Digital Economy of Uzbekistan” program, which are aimed at increasing the motivation of modern regular students to master digital competencies. Based on the above, we come to the conclusion that the concept of digitalization appears in connection with the intensive development and use of information and communication technologies.

2 MATERIALS AND METHODS

However, the first mention of digitalization is associated with the name of the German economist Klaus Schwab. He named 1960-1980. years of the digital revolution, believing that its catalyst was the development of semiconductor computers, then in the 60–70s - the emergence of personal computers, starting from the 90s - the emergence of the Internet. Klaus Schwab suggested that the fourth industrial revolution is approaching, which will also be associated with digitalization, the improvement of the Internet, gadgets that contain many functions and the development of artificial o intelligence. Wiktionary gives the following interpretation of the concept of “digitalization”: “a digital method of communication, recording, transferring data using digital devices”. Marey understands digitalization as: “a change in the paradigm of communication and interaction with each other and society”. Clarifying the concept of digitalization, E.L. Vartanova, M.I. Makseenko, S.S. Smirnov note: “this is not only the transfer of information into digital form, but a comprehensive solution of an infrastructural, managerial, behavioral, cultural nature”.

Analyzing the content of the concept of “digitalization”, we can conclude that the development of the Internet, artificial intelligence and gadgets are the basic technologies of digitalization on which productive activities are built. In the field of education, the concepts of “digitalization of education” and “digital technologies” are introduced. Digitalization of education leads to changes in the labor market, in educational standards, identification of needs for the formation of new competencies of the population and is aimed at reorganizing the educational process, rethinking role of a teacher. On the one hand, digitalization undermines the methodological basis of school inherited from the past, on the other hand, it creates the availability of information in its various forms, not only text, but also audio and visual y. Availability of information will require constant search and selection of relevant and interesting content, high speeds of its processing. Consequently, the digitalization of education leads to its fundamental, qualitative restructuring. The teacher must learn to use new technological tools and practically unlimited information resources. Virtual reality technologies create the possibility of using digital simulators that are not tied to one workplace, which expands the range of technologies being studied. Mobile learning technologies allow you to study at any time and anywhere. One of the main elements of digitalization of education is digital literacy. Digital literacy is the main priority of education, this is the ability to design and use content using digital technologies, using computer programming, graphic visualization techniques tions, computer graphics, multimedia development of online courses, etc., search and exchange of information, communication with other students. Under digital literacy, we consider its various types: media literacy, attitude to innovation, communication, computer, information literacy. To solve the problems of digitalization, our education will have to go through digital transformation.

The digital transformation of education, according to scientists, is the answer to global information challenges occurring in the world. In his research, A.Yu. Uvarov notes that the digital transformation of education should be accompanied by a “synergistic” update of content, which will lead to a radical improvement in the quality of education. We agree with the opinion of A.Yu. Uvarov that the digital transformation of education will lead society to a digital economy if the education system meets the requirements and capabilities of the digital society. The modern stage of digitalization in education consists of immersing all its subjects in the digital educational environment. Currently, educational technologies such as online courses, which are provided by universities for all students, have become widespread. Educational technologies such as mass educational courses, used remotely, will help students study in any form convenient for them and will allow them to receive qualified training in specific areas this direction of preparation. In modern Uzbekistan, online courses are posted on educational platforms like “melion of programmers, these platforms contain massive online courses from leading Uzbek universities, they provide the opportunity to register apply for these courses and study, then receive a certificate and present it to your university for re-credit in the relevant discipline. Online learning in a digital educational environment provides for the already known synchronous and asynchronous learning. A synchronous online lesson involves electronic interaction between a student and a teacher at a specific time. Asynchronous courses are distinguished by the fact that the teacher posts theoretical materials and various course assignments on the Internet, and students work with the information at any time convenient for them. We are impressed by "blended learning," which involves "combining real-life learning" face-to-face with a teacher in the classroom and interactive opportunities. A popular technology nowadays is "mobile learning" technology, which allows you to use educational information from personal digital devices (smartphones, tablets, etc.).

The use of webquest technology allows teachers to solve the following problems: increasing motivation, improving educational achievements; use graphic visualization methods in teaching; create an information culture; solve creative problems; optimize educational activities. The strategy for digitalization of education includes such promising innovative technologies as artificial intelligence, blockchain and virtual reality. Artificial intelligence is a technology that is used in solving "intelligent" problems, and all its developments are aimed at creating programs for image recognition, systems for automatic vehicle control and machine translation, etc. In education, a teaching program is used that enhances the interactivity and intellectual component characteristic of the teacher. Intelligent educational programs and expert systems are very promising and are spreading rapidly. Blockchain, a technology that provides data storage with a distributed resource, is designed to work with the digital currency Bitcoin. It guarantees the security of storing data in digital format, and also monitors their changes. In the education system, the blockchain is used to store information about exams, issued diplomas and certificates, etc., and this information can be obtained immediately, making sure of its authenticity and without resorting to archival data. data on paper. Virtual reality technologies. Existing There are the following types of virtual reality systems: – ordinary (classical) virtual reality (Virtual Reality – VR), where students interact or are immersed in the virtual world using a computer program; – augmented or computer-mediated reality (Amended Reality – AR), where computer-generated information is overlaid on top of images of the real world; – mixed reality (Mixed Reality – MR), where the real world is connected with the virtual one, and they are united with each other. MR technology can be used to solve various problems and is universal. Teachers have the opportunity to create virtual laboratories to study global environmental problems, etc. Virtual reality makes it possible to conduct video conferences, which have the greatest effect compared to web conferences, which resemble telephone conversations.

These technologies are used for virtual travel, getting to know other cultures and learning a foreign language. When studying natural science disciplines, students, using virtual reality glasses, can find themselves in virtual laboratories and conduct various experiments, interact with various objects and observe natural scientific processes occurring in nature. With the help of virtual reality, you can design three-dimensional objects. Virtual reality modeling provides students with the formation of skills that in reality are not possible to develop due to various circumstances - this is the danger of making a mistake and other limitations problems (high cost of equipment, danger to other people, etc.). For example, training of airline pilots is carried out using the MR application. Thus, the digitalization of education and the use of digital technologies changes the content of training, as well as the presentation of information, these are not only presentations or videos, these are already direct connections to information networks, databases data, forums. When practical classes are conducted, it is possible to use social networks. Electronic publications are becoming relevant in education; many publishing houses specializing in the publication of educational literature are switching to electronic versions of textbooks. Digital technologies are rapidly developing and updating (high-speed Internet, smartphones, tablets, etc.). Web 2.0 tools, blogs, wikis, social networks; cloud services Google, Office 365, etc. All this provides unlimited opportunities for access to digital tools.

In this context, digital transformation has the potential for further modernization of society and integration of the national economy into global processes. As part of the ongoing reforms, as well as the Development Strategy of New Uzbekistan for 2022-2026, special attention is paid to the digitalization of key areas of activity and the construction of a genuine information society in the country. Today, digital transformation is happening in almost every field of activity. For example, in education we observe: schools and universities are increasingly using interactive whiteboards, electronic diaries and magazines, creating audio and video lessons, teachers providing consultations through social networks and more (Zhukovskaya, 2021).

At the same time, under the influence of the global pandemic, the country's government reviewed and modernized the national digitalization strategy. In this direction, the Strategy "Digital Uzbekistan 2030" dated October 5, 2020 was approved by the Presidential Decree. According to the document, all state duties and fines are carried out using online electronic payment systems. In addition, over 400 information systems, electronic services and other software products are being implemented in various areas of socio-economic development of regions.

The "Digital Uzbekistan-2030" strategy provides for the approval of two programs: digitalization of regions and industries, as well as "road maps" for their implementation. Undoubtedly, this will ensure the most complete coverage and effective implementation of the document, which includes such priority areas as the development of digital infrastructure, e-government, the national market for digital technologies, education and advanced training in the field. It is also known that in accordance with the "Digital Uzbekistan-2030" Strategy, a methodology for rating the digital development of territories has been developed to monitor the state of digital transformation in the regions, which allows for a preliminary diagnosis of digitalization on the ground. The criteria include the use of the Internet in social institutions (preschools, schools, clinics), the introduction of educational and other systems and software products, the coverage of certified teachers in computer science, as well as school students within the framework of the "One Million Programmers" project, the number of training IT centers.

Through the Decree of the President of the Republic of Uzbekistan No. PF-6079, we can see that our state is paying great attention to the introduction of information technologies in education and increasing the effectiveness of education. In the educational process, using digital technologies, conducting the lesson process through electronic textbooks, electronic study guides, introducing digital technologies into the educational process, in particular, creating electronic educational resources for subjects, students' learning serves to increase the level. For this, it is important to have knowledge, skills and competencies in the fields of algorithms and programming languages, mobile technologies, which are considered important in creating electronic educational resources and mobile applications (Botirov, Tangirov, Mamatkulova, Aliboyev, Khaitova, Alkorova, 2020).

3 RESULT AND DISCUSSION

The strategy contributes to the implementation of other national strategic documents and programs and, first of all, will be important for solving national problems, achieving the Sustainable Development Goals, as well as for the Development Strategy of New Uzbekistan for 2022-2026.

Initiatives of the Government of Uzbekistan in the field of digital education:

Moodle program. The Moodle program was launched in May 2020 to make e-learning more accessible to students and teachers, and to promote and strengthen digital education in Uzbekistan. It aims to integrate all activities related to online/digital education and is expected to benefit approximately 250 thousand students.

National Digital Educational Architecture HEMIS: As part of the World Bank project 2016-2023, the Government of Uzbekistan has created the National Digital Educational Architecture (HEMIS) to strengthen digital infrastructure and support activities related to educational planning. It aims to propose a clear architecture of the educational ecosystem for the development of digital infrastructure in the country and guarantee the autonomy of stakeholders, especially higher educational institutions (Djumaboev, 2022).

Ziyonet Portal: The government launched the Ziyonet portal in 2015 to create a repository of educational videos, audios, flipbooks, etc. The resources on the portal are available in 3 languages such as Uzbek, Russian and English and can be accessed through smartphones, laptops , desktop computers and tablets.

Benefits of digital education

Some of the benefits of digital education in Uzbekistan have been discussed below:

• There are no restrictions regarding the place of study or study. With digital learning, a student can participate in online classes or study anywhere and anytime.

• Through this initiative, students not only gain bookish information but also practical and technical knowledge.

• With digital education, learning can be more fun and interactive between students and teachers.

• Digital education acts as a supplement and does not completely replace physical education.

• With study materials available online, students can take their time to understand any topic.

Disadvantages of Digital Education

• There is no human touch.

• There is always a danger that unmotivated students will be left behind.

• Interaction with a teacher/instructor/expert is not always possible.

• Developing countries lack proper infrastructural support such as networks, cheaper bandwidth, availability of working infrastructure, power, etc.

Priority areas for the future

To make ICT and digitalization of education successful with more fruitful results in terms of knowledge sharing and learning, the following areas should become priority areas in the near future. Modern educational technologies are less effective when learning goals are unclear and the focus of technology use is blurred. Schools should convene a technology planning team consisting of administrators, teachers, technology coordinators, students, parents, and community representatives (whole-community participation) to determine educational goals for students and the types of technology that will support efforts to achieve the goals.

The team must also develop a vision for how technology can improve teaching and learning. Students cannot be expected to benefit from technology if their teachers are not familiar with it and are not comfortable with it. Many teachers lag behind their students when it comes to up-to-date technology skills and competencies, making it difficult to keep children interested, motivated and engaged in regular lessons. They must have experience working with technology. Therefore, it is important to provide professional development to teachers to help them not only learn how to use new technologies, but also how to provide meaningful instruction and activities using technology in the classroom.

The daily schedule should include longer study periods and more opportunities for group learning. Students may need more than a 30- or 40-minute period per day to locate, learn, and synthesize material. Therefore, there should be more time in the daily schedule for teachers to collaborate and work with their students. Given the potentially powerful effects of the media and the growing body of empirical evidence about the negative effects of technology on students, parents should take care to limit their exposure to harmful technologies. They must monitor what content their wards read and watch in the name of online education.

The government is also focusing on research and innovation to identify sectors that can further support and strengthen digital education initiatives in Uzbekistan. In 2022, the government announced that space technologies (such as satellite communications) are being used for digital education in Uzbekistan.

In addition, it is necessary to develop high-quality electronic content in the state language. Adding advanced training courses, virtual laboratories, virtual vocational training. Develop guidelines for online/digital education to bridge the digital divide.

4 CONCLUSIONS

Developing digital classrooms by integrating educational systems and technologies. Development of an assessment system in the era of digital education. Provide a consistent user experience through multi-modal access to education through mobile apps, web portals, TV channels, radio and podcasts. To provide “anytime, anywhere” access and increase penetration, the focus will be on increasing the use of mobile phones.

There is no disagreement that digitalization of education is the need of the hour to match the educational environment and system prevailing all over the world. At the same time, it is necessary to analyze how this system should be adopted to nullify the adverse effects of over-reliance on electronic media on the youth and protect them from behavioral and psychological imbalances. Care must also be taken to ensure that students do not have access to information that is not intended for them and may lead them in the wrong direction, causing them to engage in antisocial behavior and aggressive thinking. It is time for policymakers to develop such a system that is a mixture of traditional and modern modes of teaching, that protects the teacher and teacher relationships, and promotes a digital education system.

REFERENCES

Decree of the President of the Republic of Uzbekistan UP-60 dated January 28, 2022 “On the development strategy of the new Uzbekistan for 2022 - 2026” [Electronic resource]. Access mode: https://lex.uz/ru/docs/5841077.

Decree of the President of the Republic of Uzbekistan, UP-5635 dated January 17, 2019 “Strategy of action for five priority areas of development of the Republic of

Uzbekistan in 2017-2021” [Electronic resource]. Access mode: https://lex.uz/ru/ docs/4168757
Decree of the President of the Republic of Uzbekistan PF-5847 dated October 8, 2019 “On approval of the Concept for the development of the higher education system of the Republic of Uzbekistan until 2030.”
Message from the President of the Republic of Uzbekistan Shavkat Mirziyoyev to the Oliy Majlis dated January 25, 2023.
Zhukovskaya, I.E., 2021. Main trends in improving the activities of a higher educational institution in the context of digital transformation. *Open Education*. T. 25. No. 3.
Decree of the President of the Republic of Uzbekistan UP-6079 dated 10/05/2020 “On approval of the strategy “Digital Uzbekistan-2030” and measures for its effective implementation” [Electronic resource]. Access mode: https://lex.uz/ru /docs/5031048/
Botirov, D.B., Tangirov, K.E., Mamatkulova, U.E., Aliboyev, S.K., Khaitova, N.F., Alkorova, U.M., 2020. The importance of teaching algorithms and programming languages in the creation of electronic education resources. *Journal of Critical Reviews*, 7(11), 365-368.
Djumaboev, S.M., 2022. Pedagogical basis for the use of digital technologies in the education system. *“Problems and solutions to directing youth to education in the system of continuous education”* Materials of the Republican Scientific and Theoretical Conference. Jizzakh 476 p.
HEMIS [Electronic resource]. Access mode: https://hemis.uz.
Ziyonet [Electronic resource]. Access mode: http://ziyonet.uz.
Top five digital learning tools for students and teachers [Electronic resource]. Access mode: https://www.educationworld.in/top-five-digital-learning-tools-for-students-and-teachers.
Positive and Negative Impact of ICT [Electronic resource]. Access mode: https://positivenegativeimpact.com/ict/.
Djumaboev, S.M., Khuzhaev, T.A., 2022. Artificial intelligence in modern higher education. *Pedagogical sciences and teaching methods*: a collection of scientific works of the International scientific conference (17 October, 2022) -Copenhagen: 2022. PART16 – 252 p. http://interonconf.net/index.php/psa/issue/view/73.

Interpretation of Lexical Terms in the Field of Digital Technologies

Stafeeva Natalia Anatolievna[a], Medvedeva Inessa Alexandrovna[b]
and Zaichko Margarita Vasilievna[c]
Industrial University of Tyumen, Tyumen, Russia
natali.stafeeva.78@mail.ru, inessa2370@list.ru, rzaichko@mail.ru

Keywords: conceptual systems, digitization of education, anglicism, neural networks, neurons, deep learning, translation, terminology.

Annotation: This article explores a new educational approach centered around the digital transformation of the educational sector. It delve into the translation of terms related to neural networks, highlighting how these translations are influenced by differences in conceptual systems across languages. The authors argue for the importance of consolidating and refining terminology in the neural network domain to ensure accurate and comprehensible transmission of meaning. They assert that precise translations facilitate effective communication within the scientific community. The evolving landscape of digital technologies underscores the imperative of precise translation in facilitating effective communication and knowledge dissemination. As digital skills assume greater significance in contemporary society, harnessing the potential of automation and digital tools promises to revolutionize education and foster interdisciplinary collaboration.

1 INTRODUCTION

The second decade of the 21st century has been characterized by the search for new ways of improving the quality of education, and one such approach is the introduction of digital technologies. Digital transformation is increasingly affecting the education system and determining the direction of our future. In order to be up to date, you need to acquire new and relevant skills.

Translation of terms plays an important role in the exchange of knowledge between different cultural and linguistic backgrounds, especially in specialized areas where unique terms are used. In the area of neural networks, which is a key area of research in the field of artificial intelligence, accurate and adequate translation of terms from English to Russian is needed.

Currently, interest in the study of a topic such as neural networks in the field of computer science is very high, and as a result many specialized terms are used in writing scientific literature to describe entities or processes.

The problem of translating terminology from English into Russian in the field of neural networks arises due to differences in specific terms and concepts between these two languages. Some terms may not have an exact equivalent in Russian, which creates difficulties in trying to convey their meaning and context. In such cases, translators and specialists in the subject area face the challenge of choosing the most accurate and understandable translation, which corresponds to the peculiarities of the Russian language and preserves the meaning and accuracy of the original term. This requires a deep understanding of the technical aspects of neural networks and the ability to find relevant terms and concepts in Russian to ensure a correct and understandable translation.

2 METHODS

The purpose of our article is to analyze the characteristics of translation of terms associated with neural networks. Thus, we have identified the following objectives:

[a] https://orcid.org/0009-0004-4754-3472
[b] https://orcid.org/0000-0001-6746-0990
[c] https://orcid.org/0000-0002-6572-4005

• Explore publications that reveal the translation of terms of neural networks in a specific context. These studies also take into account semantics, which can be lost in simple translation.
• Consider translation practices in this regard;
• Summarize your own experience

We used the following methods: theoretical (content-analysis of pedagogical articles on translation, generalization) and empirical (including pedagogical observation, descriptive method, conversations)

3 RESULTS AND DISCUSSIONS

One of the main reasons for the difficulties with translating the terminology of neural networks is due to the fact that in Russian there are no exact analogues for some of the terms and concepts used in English. This is because some terms of neural networks have a strong connection to specific contexts and semantics that can be lost in simple translation.

For example, the term "neural network" is a key concept and its translation should convey the essence of the concept. However, in the Russian language there is no exact analogue for this term, which leads to the need to use it in its original form or to use an approximate translation, which may not cover all aspects and semantics of the original term.

If you understand the phrase "neuronal network", it consists of two words: "neuron" and "network". The word "neuron" takes its roots from the Greek language, meaning "veins, tendons, nerves". In the Russian language, the word "neuron" was originally present, which was finally replaced in 1960 by the word neuron, which takes its roots from German. The word "Neuron" was proposed by the German anatomist and histologist Waldier G. V. in 1981 to denote a nerve cell. Subsequently, this word is transformed in both Russian and English and will have the usual name for us "neurons".

Also, some terms may have ambiguous or multiple translations into Russian, which increases the difficulty of choosing the most suitable translation in the context of neural networks. For example, the term “activation function” can be translated as "activation function" or "activating function", and each of these options may have nuances in the meaning to be taken into account when translating.

To successfully translate the terminology of neural networks from English to Russian, translators and specialists must have an understanding of both English and Russian, as well as technical knowledge in the field of neuronal networks. This allows you to choose the most accurate and understandable translations, taking into account the peculiarities and context of both languages, in order to preserve the meaning and accuracy of the original terminology. Neural networks are a complex and rapidly developing field that uses special terms and terminology, which cannot always be translated unambiguously into Russian because similar concepts can have different terms in different scientific disciplines and create additional difficulties in translating terminology.

Therefore, it is worth understanding the topic of neural networks to have an idea of those words that have been translated into Russian from other languages. The first model of an artificial neuron was proposed by W. McCallock and W. Pitts in 1943 in their article "Logical calculation of ideas relating to nervous activity". In their work, the authors described a neural network as interconnected neurons, where one neuron is capable of solving certain tasks, and two or more neurons give the ability to solve a larger number of problems as well as increase their complexity. The authors suggested not only the model of the artificial neuron itself but also a way to establish a connection between these neurons, which forms a neural network with a layer structure.

In 1957, a model called "perceptron" (Perceptron is a mathematical or computer model of the brain's perception of information) was proposed by scientist Frank Rosenblatt based on the idea of McCallock and Pitt. Perceptron was the first neural network to be realized.

Subsequently, the topic of deep learning or deeplearning began to develop, following research which increased interest in neural networks, because deep learning allowed the training of models on more data with a certain method that defined patterns more accurately and thus gave better results. Back propagation algorithm was used in 1990 for deep learning, but it turned out that neural networks were learning quite slowly. At the time, neural networks were very much lagging behind in learning speed compared to other machine learning algorithms, such as the support vector method (Support Vector Machines is a set of controlled learning techniques used to classify, regress and detect emissions).

With the development of computing technology, neural networks began to solve various tasks from many areas of human life, which led researcher interest not only in technical fields, but also in medicine, finance, transport, retail, marketing, natural language processing and others. This interdisciplinary interaction and interest in neural networks opens up new opportunities for collaboration and exchange of knowledge between different fields.

Various authors were involved in studying the topic of anglicisms in the neural network area, but it is notable that Diakov A.I. and Chireykina O.Y., who considered Anglicism in Russian terminological systems and compiled the "Dictionary of Englishisms of the Russian language" (Abramova, 2022). From the authors' point of view, Anglicism should be understood as an English word, phrase or sentence that has been translated into the Russian language through transformation in a certain way or has left its original appearance. The transformation itself can occur in different ways, which are divided into models with their own processes:

1) transcribed anglicisms, that is, they are anglicisms that transmit the sound of the word (e.g.:Clustering and clusterization is a class of tasks for grouping a number of objects into subsets, by a certain feature and a group of characteristics).

2) Transliterated anglicisms-anglicism, in which there is a transformation by reflecting a graphic form without taking into account the phonetic content (e.g.: Algorithm and Algorytm - Process of performing a set of prescriptions to perform tasks. It is commonly used in computers (Tadeusevich, Shalenets, 2022)).

3) transformed anglicisms are the reworking of Anglicism into Russian, i.e. imitation of the Russian word. (for example: Dropout and Dropaut – regulation technique used in neural networks to prevent re-learning (Tykina, Puzhenko, 2018)).

4) Calculated anglicisms are translations that preserve the original semantics and often the structure of borrowing (e.g.: Neural network and Neural Network are computer systems modeled on the model of the human brain (Tadeusevich, Shalenets, 2022)).

5) Transplanted anglicisms are anglicisms that do not have the form of Russian letters, but are used in their original form (for example, Backpropagation is a method of learning neural networks and refers to the methods of learning with the teacher (Tadeusevich, Shalenets, 2022)).

6) Combined anglicisms are such angelicisms that collect certain qualities from all the above models (for example: Generative adversarial networks and Generative competitive network – a method by which two neural networks, one of which generates content, the other tries to distinguish genuine content from generated).

7) compensated anglicisms are words that have received a certain form in the Russian language, without having formal or distinctive features in the source language (for example: Data mining and Intellectual Data Analysis are the process of studying and discovering patterns in data to obtain new information).

However, it should not be forgotten that not all words are created in English, and also undergo a certain transformation and acquire their form, but most often it is from English words that there is a transformation into other languages. This is due to the fact that English is the most popular language on the planet, which is why a lot of research and scientific papers are written in English to cover the majority of researchers. As a result, many scientists design their works in English and produce the transformation of certain words, which are later established words or phrases that are used by many other people in their works with reference to the original source.

Also, the theme of the peculiarities of translation of English-language terms was considered by Abramova E.V., highlighting a number of ways that are used when translating concepts from a foreign language (Kovalyeva, Alekseev, 2021):

1)An acronym is a word consisting of the first letters of the words of a sentence. The words for the abbreviation are selected in such a way that it is possible to make another understandable word, and it conveys the essence of the substance or process. In this way it is also possible to replace certain words with synonyms to get an acronym (FACT–fully automatic completing technique – fully automatic compilation method)

2)Artificial Intelligence is the science and technology of developing computers that perform functions that were until recently considered the prerogative of human intelligence (Tadeusevich, Shalenets, 2022) (Tadeusevich, Shalenets, 2022))

3)Literal translation is the translation of a foreign word or its exact reproduction by means of another language. The exact translation retains the same sequence as the original (Computer vision - Computer vision - Interdisciplinary scientific subject area of AI and computer science, devoted to the study and development of computers capable of visual recognition of information at the input (Tykina, Puzhenko, 2018)).

4) Transliteration is the reproduction of the alphabetical composition of a foreign word in the language into which the translation is carried out (Heuristics-Euristics is a process of finding a solution by the method of samples and bits in the process of which the "experience" - rules is formed (Tadeusevich, Shalenets, 2022))

As a result, it turns out that the English language collects a certain list of words used by specialists in their field of study. Because the sphere of neural networks is connected to other fields, such as computer technology, data analysis, mathematics, computer science, and so on, words can transform depending on where they are applied.

The fashion and authority of the source language are important reasons for borrowing. From the point of view of Russian scientist Krysin L.P., "perception of a foreign language word is more prestigious", which is one of the factors in borrowing a word from a language (Ilina, Ionikova, 2023).

4 CONCLUSIONS

Thus, today the area of neural networks enjoys huge popularity among researchers of different countries.

1. Therefore, it is necessary to translate the terminology carefully in order to accurately convey the meaning, process or method.
2. The use of different methods of translation helps scientists come to a common understanding of the meaning of words and phrases without the need to refer to precise definitions.
3. Digital skills are becoming increasingly important in today's world as automation changes work processes and requires new knowledge. It is therefore important to constantly update skills and to look for new ways of applying them.
4. The use of automation and digital tools can significantly improve the performance of teachers and students. Online classes, joint projects with other universities and interactive stories - all this is made accessible through digital technologies.

REFERENCES

Abramova, E. V., 2022. Personalities of the translation of English-language terms related to information technology on the material of the terminology used in research articles “SKOLKOVO COMMUNITY” and “RUSBASE”. *Scientific journal “Science, technology and education”.*

Glossary of the most frequently used terms in machine learning - URL: https://nnz-ipc.ru/glossarij/osnovnye_ponyatiya_mashinnogo_obucheniya/ (Date: 01.12.2023).

Diakov, A.I., Chireikin, O.Y., 2020. Englishisms in Russian terminological systems. ANOVO CRF Sibupk, Novosibirsk, Russia.

Ilina, T. S., Ionikova, E. P., 2023. Anglicisms as a Specific in the Scientific and Technical Terminology of the Russian Language.

Kovalyeva, E.R., Alekseev, V.P., 2021. Causes of the rapid development of neural networks. *Scientific journal E-Scio.*

Features of the influence of Anglicisms on the Russian language of the XX-XXI centuries - https://cyberleninka.ru/article/n/osobennosti-vliyaniya-anglitsizmov-na-russkiy-yazyk-xx-xxi-vekov .

Tadeusevich, R., Shalenets, M., 2022. Neural networks. Interpretative dictionary: dictionary. Translation from Polish I. D. Rudinsky. 2022- 3-4c.

Tykina, L. A., Puzhenko, I. N., 2018. Information technologies in the professional activity of the translator. Professionally oriented translation: reality and prospects: compilation of scientific papers. Issue 13. Moscow: Russian University of Friendship of Peoples.

Conducting Interactive Activities to Enhance the Information Security Culture of the Organisation's Staff

Yuriy V. Golchevskiy[a] and Natalia R. Oleneva[b]
Institute of Exact Sciences and Information Technologies, Pitirim Sorokin Syktyvkar State University, Oktyabrsky ave., Syktyvkar, Russian Federation
yurygol@gmail.com, kib@syktsu.ru

Keywords: Information Security Management, Information Security Culture, Information Security Training, Compliance with Information Security Rules and Protocols.

Abstract: Social engineering is one of the most common threats to the information security of commercial firms, government and other organisations. Various technical and administrative protection mechanisms can be applied to reduce the risks associated with social engineering. This paper proposes an approach to designing measures to improve information security culture based on employee training and behavioural monitoring. Employees in the financial and IT sectors were tested using the proposed framework. Training and subsequent series of coordinated test attacks were used to simulate the actual activities of the attackers and monitor the employees' reactions to them. From the test results, it was concluded that the employees tested had a high level of awareness of the attackers' methods and were critical of the information they received. Vulnerable employees were identified who needed additional training and improved information security related skills. In this way, potential threats to user data were identified to be serious, and staff were shown to be more convinced that they must apply the rules and adhere to the organisation's information security policy in their day-to-day practices. Subsequent sharing of experiences and collective reflection, combined with the use of incentives, did have a noticeable impact on information security compliance intentions.

1 INTRODUCTION

In the context of the growing influence of the digital economy adherence to information security rules, policies and standards is critical to protecting valuable corporate information for companies and organisations. The consequences of violating these rules are enormous financial and reputational losses. There is a wide variety of technical, software and hardware security solutions available. However, all of them can be almost useless in preventing information security incidents if the organization's personnel do not follow the protocols for their use. The majority of successful attacks on corporate IT infrastructure exploit the human factor, as evidenced by reports from reputable cybersecurity companies InfoWatch (InfoWatch, 2019), Trend Micro (Trend Micro, 2020) and others. Many malicious programs work in such a way that to launch them, the user has to perform certain actions: open a document sent by email, click a malicious link, etc., which often means departing from well-known cybersecurity rules.

Positive Technologies reports cite statistics showing that cyber-attacks often target government organizations, as well as banks and online services. According to data published by the Bank of Russia Center for Monitoring and Responding to Computer Attacks in the Financial Industry, common crimes in the financial industry include employee email hacking, social engineering techniques, unauthorized access to company data, compromised credentials, exploitation of software vulnerabilities and web vulnerabilities.

The success of this type of attack is often due to reasons such as:

- Lack of or insufficient understanding of information security principles and protocols;
- Carelessness or absent-mindedness in handling corporate information;
- A variety of reasons for employee vigilance, such as opening emails from dubious sources;

[a] https://orcid.org/0000-0003-2047-9138
[b] https://orcid.org/0009-0003-8969-7368

- Perpetrators using new social engineering techniques and improved methods for delivering malware downloaders;
- Insufficient vigilance or equipment of information security officers.

As a result, perpetrators are able to carry out their actions for long periods without being detected. It is evident that there are many causes that are driven by the behaviour of an organisation's employees, which raises the question for its management “What causes this behaviour and what can be done to reduce the risks caused by non-compliant employee behaviour?”

This article explores how, in practice, an organisation can increase employee accountability and awareness of the need for information security compliance by designing an approach to organising training and monitoring of employee compliance with information security rules. The proposed approach have been tested in the activities of organisations operating in the IT services and credit-financial sectors of activity.

2 RELATED WORKS

In the late 1990s, a concept called “information security culture” emerged, closely intertwined with organisational culture. It implied a measure to encourage employees to behave appropriately in the face of emerging information threats and to follow information security norms.

For example, Connolly, Lang, and Tygar (Connolly, Lang, and Tygar, 2014) proposed the conceptualisation of information security culture. Alnatheer (Alnatheer, 2015) presented a study of critical success factors for information security culture, in which he showed that the most important factors are support from senior management for information security, creation of effective information security policy, awareness raising and training, information security compliance, and ethical conduct policy and organizational culture. Soomro, Shah and Ahmed (Soomro, Shah, and Ahmed, 2016) reached the same view based on a systematic review of the literature related to the role of management in information security, further emphasising that organisations need a more holistic approach to information security and suggesting ways in which managers can play an effective role in ensuring it.

Research results cited in (Batmetan, Kembuan, 2024; Tejay, Mohammed, 2023; Choi, Park, and Kang, 2024) suggest that information security knowledge sharing, collaboration, collective reflection, practical experience, response efficiency, self-efficacy, informal work practices and subjective norms have a significant impact on information security compliance behavioural intentions. Sekulla et al. (Sekulla et al., 2020) proposes a tool for knowledge sharing between organisations and the accumulation of experience.

The significant impact of organisational culture based on collaboration, innovation, consistency and efficiency on information security culture is presented in (Alhogail, 2015). It is shown that its change has a significant impact on the ability to address key information security challenges. It is noted that organizational culture has a significant impact on confidentiality and integrity, but not on the availability of information.

Thus, the general message of many works is that more attention should be paid to the behavioural viewpoints of users in relation to information security.

Of course, researchers could not avoid the issue of measuring an organization’s information security culture. In (Rohan et al., 2023; Tang, Li, and Zhang, 2016) the authors discuss management ideas related to how to measure the information security culture of an organization and subsequently determine which viewpoints are important to the organization, as well as evaluation approaches for further implementation and improvement of such culture.

Many works identify and focus on factors that provoke unfavourable employee behaviour in organisations, e.g. Connolly et al. (Connolly, Lang, and Tygar, 2014). At the same time, researchers focus on the existence of a conflict of values between information security and other organizational values, which is often the cause of security non-compliance among employees (Karlsson, Denk, and Åström, 2018).

A significant proportion of researches is motivation researches. Deterrence theory, which is widely used in behavioural information security research, suggests that controls can serve as deterrence mechanisms, increasing the importance of the threat of punishment for non-compliance with information security rules. The paradigm proposed in (Siponen, Adam Mahmood, and Pahnila, 2014) combines elements of defence motivation theory, motivated action theory and cognitive evaluation theory. The authors show that the perception of the severity of potential threats to information security, the belief that employees should apply the established rules and adhere to the information security policy, and the social norms of compliance with this policy have a significant positive impact on the actual compliance of employees with the established rules and policies of information security. In (Connolly, Lang, and Tygar, 2015) the influence of a combination of security countermeasures and cultural factors on employee security behaviour is investigated, and in (Liu, Zhang, and Zhang, 2020) it is argued that informal social control and self-control are more likely to be effective in enforcing security compliance than formal control, and in addition, the influence of formal and informal control on security compliance is also partly due to traditional cultural characteristics. Organisations often use methods to reward and/or punish employees in order to reduce risky behaviour. The authors of the study presented in (Blythe, Gray, and Collins, 2020) investigated how organizations use these methods and what factors influence the use of rewards or punishments (sanctions). It was noted that sanctions are used in 90% of organisations.

The study of the problems associated with the audit of employee behaviour is the topic of (Vroom, von Solms, 2004). It demonstrates that the human behaviour audit procedure is quite complex and therefore, alternative methods should be used where observation of the employee is not necessary. Instead, a more informal approach is proposed to improve the information culture.

D'Arcy, Hovav and Galletta (D'Arcy, Hovav and Galletta 2009) shows that three aspects deter information system misuse: user awareness of security policies, training programs and computer monitoring, and that the perceived severity of sanctions is more effective than the certainty of sanctions.

In the context of the rapidly increasing importance of digital technologies considerable attention is also paid to discussions on the importance, applicability and effectiveness of security training methods. As an example, the following works can be cited (Alyami et al., 2024; McIlwraith, 2021; Kweon et al., 2021). The studies sheds light on the role of security training and education. T. Gundu emphasizes the importance of continuous learning as the cornerstone of cybersecurity culture, presenting cybersecurity culture model that encapsulates the principles of "Learn, Unlearn, and Relearn" as a strategic stance (Gundu T., 2024).

Additionally, it should be noted that many organisations allow employees to use their own personal equipment (e.g. mobile devices) to access corporate networks and data (a phenomenon referred to as "Bring Your Own Device" – BYOD). However, while the technical aspects of BYOD security have been addressed (e.g., papers (Ratchford, Wang, 2019; Zungur et al., 2019)), the information security culture aspects of the BYOD approach remain rather understudied.

In summary, the notion of information security culture is currently a dynamic and evolving one that is being transformed by new realities and research.

3 METHODS

This study is based on empirical research method. The empirical method was applied in the process of approbation of some of the described solutions in the activities of specific organizations, observation and comparison of data obtained in the course of practical approbation of the authors' activities, as well as interviewing representatives of professional communities for a deeper understanding of the described problem.

The approach presented in this article has been tested at an enterprise providing technical support for the operation of information systems. A service to protect users from phishing attacks (hereinafter referred to as the Service) by reproducing the actions of potential attackers was developed and implemented. More than 1.5 thousand users participated in the study.

The functional feature of the developed Service was the possibility to conduct a simulated attack on users that consisted of sending prepared emails with elements of social engineering that resembled typical emails from attackers but had no destructive functions. The simulations were divided into two types: those with links to a fake website that required input, and those with malicious attachments.

The user actions (simulation results) after receiving the email were divided into three options: neutral, failure and success.

If there was no response from the user, then this result was marked as neutral and was considered close to unwanted, because the goal of the Service was not only to reduce the number of failed online attacks, but also to increase vigilance, e.g. the number of emails sent by users to be checked. Therefore, with this result, the user is reminded to send suspicious emails for verification and the rules for secure handling of emails.

A failure was defined as launching a malicious attachment from an email or entering the requested data on a fake website. In this case, the user was notified of the failure by an email containing a description of the user's error and secure email practices.

A success meant that the user did not launch the malicious attachment or enter the requested data and sent the email itself for verification.

The second type of simulation was far more likely to fail because the user had to do less (click a link, enter data on the site). Running an attachment was more suspicious.

4 RESULTS AND DISCUSSION

Creating a culture of information security in organisations influences employees' security perceptions and behaviour in ways that can protect against many of the information security threats posed by insiders.

But how do you create such a culture in an organisation? The sources studied suggest several approaches to enhancing information security culture, among which are:

- Learning;
- Play methods;
- Motivational methods (both rewarding and punitive methods).

In our opinion, training staff based on lectures alone is not always effective enough, as it can be difficult to absorb the material and subsequently link it to a particular threat with this approach. There are now other ways of training. One example is Riskio, a cybersecurity awareness board game for people without a technical background. Riskio provides an active learning environment where players accumulate knowledge about cybersecurity, attacks and defence, playing both the role of attacker and defender of an organisation's critical assets (Hart et al., 2020).

Despite the challenges of conducting employee behavioural audits noted earlier, we consider them a crucial part of the ongoing effort to improve an organisation's information security.

The use of interactive techniques, such as mock attacks on users, can be an effective method. With this approach, the user can "feel" the effects of the attack (hardware failure, data theft and blockage, etc.) Hacker attack simulation allows you to identify your most vulnerable employees and give them extra training. That is, the knowledge and skills acquired during training must be accompanied and reinforced by practical verification of employees' compliance with information security rules in the organization.

Consider the stages of implementing such an interactive methodology, described using the SADT diagram shown in Figure 1.

Four stages can be distinguished:

1. Definition of the main objectives;
2. Testing: initial and re-testing, which takes place after the training phase;
3. Training - a stage in which staff (users) at risk are trained and tested;
4. Testing of system effectiveness – evaluation of how useful and effective the methodology used was.

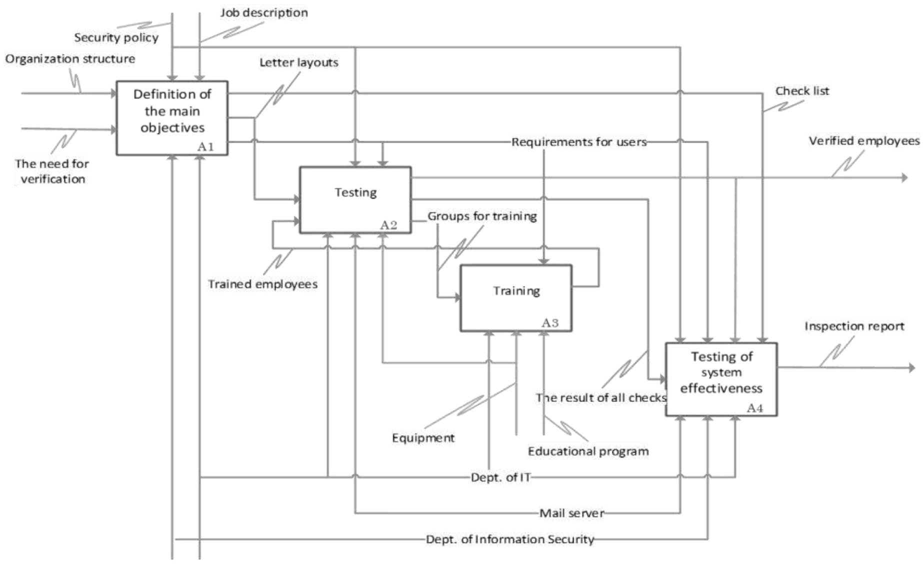


Figure 1: SADT diagram presenting the stages of the approach to implementing an information security compliance check for company employees.

Let us consider each stage in more detail.

A1 – The goal setting stage, where the scope and extent of the audit, the requirements to be checked, and the timeframe for the audit are defined. Based on this information, a checklist for verification is drawn up.

A2 – Verification of employees. A simulated attack is performed (e.g., sending out a trap email according to the focus groups defined in the first step), followed by the collection and analysis of statistics on insecure behavior (e.g., clicking links, opening attachments, etc.).

Once the data is systematised, employees who have made mistakes are divided into training groups and additional training is provided to them (Block A3). This scheme can be applied more than once for repeated checks. The results of the checks will form the basis for the last stage.

A4 – Check the effectiveness of the system. A checklist check is carried out in this final stage:

- The status of each item for all selected divisions in the organisational structure of the company or organisation (divisions, departments etc.) is determined;
- The results of the check are recorded.

After this, it is possible to proceed to:

- Formulation of proposals for the elimination of deficiencies;
- Formulate a plan to eliminate them;
- Conduct an analysis of the necessary costs and capabilities of the organisation to eliminate and prevent re-occurrence of incidents.

Decomposition of stage A4 shown in Figure 2.

A report can be generated at the end of the verification, including the results obtained in step A2 "Verification", a checklist evaluation and a plan of recommended actions.

In the event that a company decides to carry out such an audit in-house, it will be necessary to:

- Draw up a list of mailboxes and users to whom the test letter will be sent.
- Create a web resource that is set up to monitor requests and keep a personalised record of visitors. In addition to this, the user is informed of a test infection of their computer by malicious code that they need to report to their manager.
- Prepare a test file that will take the user to the web resource described above.
- Register e-mail addresses on various mailing resources to organise a mailing list.
- Determine the type of messages to be sent. The messages should be relevant to the activity profile of the employees being tested.

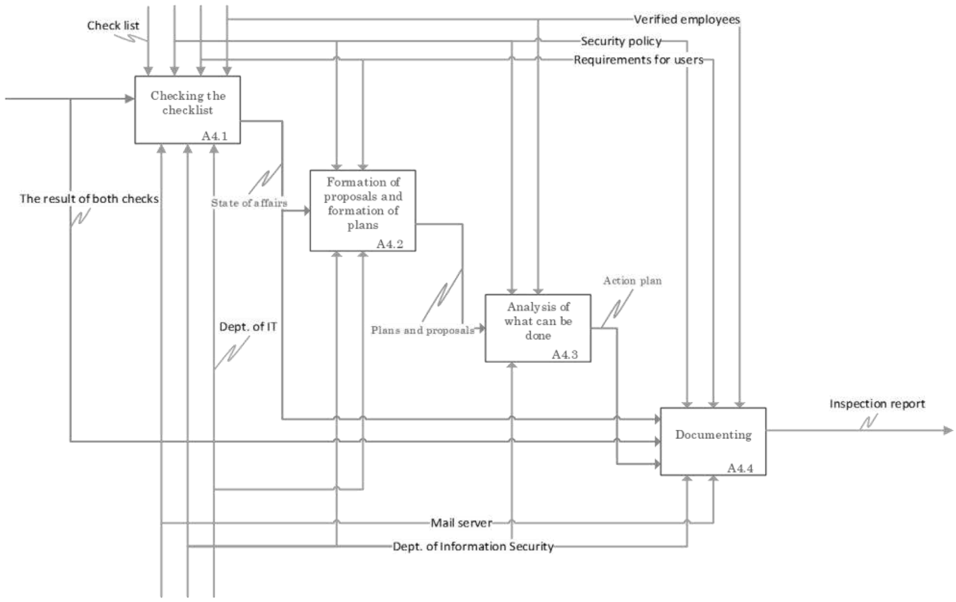


Figure 2: SADT diagram presenting the decomposition of stage A4 "Testing of system effectiveness".

During the piloting of the Service, feedback was maintained with the users: phone calls, emails, text reports etc. to evaluate the functioning of the Service, the possibility of further analysis of the situation and staff attitudes towards issues related to the formation of secure behaviour. In the first two months of the trial, there were a large number of complaints from users that they received simulations too often (every six months to a month) and that this distracted them from their duties.

This problem was solved by creating a Service function that would take into account users' proven skills and knowledge and regulate the frequency of receiving simulations depending on them.

To this end, the concept of "competence" was introduced. A competence is an electronic mark indicating the possession of certain skills and knowledge in the field of information security.

However, we would like to point out that in general the use of the Service did not provoke any strong negative reactions from employees.

The main purpose of testing the tool was to increase the security culture of the users and hence reduce the number of failed simulations.

The Service was piloted over a five-month period. Over five months the number of failed simulation emails with a link to a fake website decreased by around 19%, the average number of simulation emails with a malicious attachment decreased by 11%, and the number of simulation emails sent for review increased by more than 30%, as shown in Figure 3 and Figure 4.

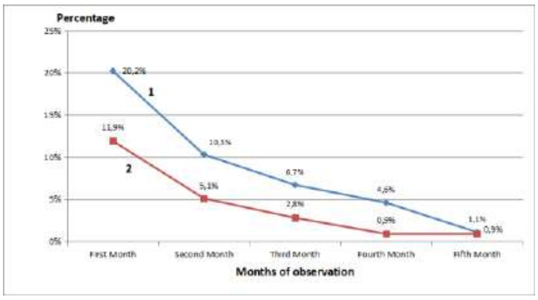


Figure 3: Graph of changes in the number of failed simulations (1 – Simulations with links, 2 – Simulations with attachments).

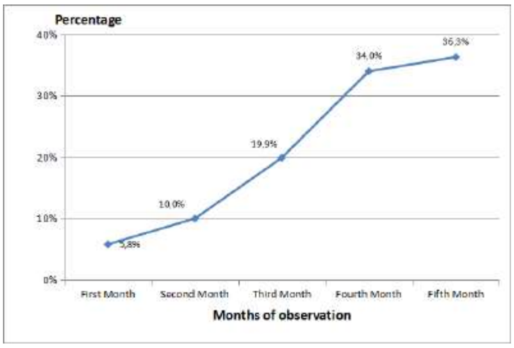


Figure 4: Graph of changes in the number of letters sent by employees for additional checking.

When a similar methodology was tested in an organisation operating in the financial services industry, similar results were obtained, with a difference in quantitative indicators, largely due to the smaller number of employees involved in the piloting.

Studies were conducted with both employees using corporate equipment and those using their own equipment (BYOD). It was noted that the second group had a more serious attitude towards compliance.

5 CONCLUSIONS

Social engineering is one of the most common threats to the information security of commercial firms, government and other organisations. Various technical and administrative protection mechanisms can be applied to mitigate the risks associated with its use.

The proposed scheme was used to test and train employees of financial and IT organisations. Training and a subsequent series of coordinated test attacks were used to simulate actual attacker activity and track employee reactions to them. Harmless files were used to send out email messages and only the launch was recorded during the test.

From the test results it was concluded that the tested employees had a high level of awareness of the attackers' methods, were critical about the information they received and could detect a phishing email for example, that is they paid attention to the sender details, the subject of the email, logos and names (the emails used company logos and name-calling), links in the email text, signatures and contact information as well as grammar and spelling mistakes in the text. Vulnerable employees were identified who needed additional training and improved information security-related skills.

Thus demonstrating the seriousness of potential threats to user data, there was a growing conviction among employees that they should apply the established rules and adhere to the information security policy in their day-to-day practice. The ensuing exchange of experience and collective reflection, together with the application of incentives, did have a noticeable impact on information security compliance intentions, shaping some collective norms on the issue.

Overall, such testing in practice proved to be useful for the organisation and was highly appreciated by the organisations' management.

The importance and usefulness of having management controls and activities in place to help build and maintain an information culture was noted by staff themselves. It was felt, however, that it was more useful to encourage secure behaviour than to punish and sanction risky behaviour.

In our view, formal management control (i.e. deterrence, reward and monitoring) remains an important part of building and developing an information security culture. Getting it right is one of the most complex, but essential, solutions for ensuring an organisation's information security.

REFERENCES

Alhogail, A., 2015. Cultivating and Assessing an Organizational Information Security Culture; an Empirical Study. International Journal of Security And Its Applications, 9(7), 163–178.

Alyami, A., Sammon, D., Neville, K. and Mahony, C., 2024. Critical success factors for Security Education, Training and Awareness (SETA) programme effectiveness: an empirical comparison of practitioner perspectives. Information and Computer Security, Vol. 32 No. 1, pp. 53-73.

Alnatheer, M. A., 2015. Information security culture critical success factors. Proceedings – 12th International Conference on Information Technology: New Generations, ITNG 2015, 731–735.

Batmetan, J. R., Kembuan, D. R. E., 2024. Effects of Knowledge Sharing Methods on Cyber Security Practice in Small Medium Enterprises'. Proceedings of the 5th Vocational Education International Conference (VEIC-5 2023), Advances in Social Science, Education and Humanities Research 813, Atlantis Press, pp. 28 – 37.

Blythe, J. M., Gray, A., Collins, E., 2020. Human cyber risk management by security awareness professionals: Carrots or sticks to drive behaviour change? Lecture Notes in Computer Science, Vol. 12210, 76–91.

Choi, H., Park, S., and Kang, J., 2024. Enhancing Participatory Security Culture in Public Institutions: An Analysis of Organizational Employees' Security Threat Recognition Processes. IEEE Access.

Connolly, L., Lang, M., Tygar, D., 2014. Managing employee security behaviour in organisations: The role of cultural factors and individual values. IFIP Advances in Information and Communication Technology, 428, 417–430.

Connolly, L., Lang, M., Tygar, J. D., 2015. Investigation of employee security behaviour: A grounded theory approach. IFIP Advances in Information and Communication Technology, 455, 283–296.

D'Arcy, J., Hovav, A., Galletta, D., 2009. User awareness of security countermeasures and its impact on information systems misuse: A deterrence approach. Information Systems Research, 20(1), 79–98.

Gundu T., 2024. Learn, Unlearn and Relearn: Adaptive Cybersecurity Culture Model. Proceedings of The 19th International Conference on Cyber Warfare and Security, 95-102.

Gurvirender P. S. Tejay, Zareef A. Mohammed, 2023. Cultivating security culture for information security success: A mixed-methods study based on anthropological perspective. Information & Management, Vol. 60, Issue 3, 103751.

Hart, S., Margheri, A., Paci, F., Sassone, V., 2020. Riskio: A Serious Game for Cyber Security Awareness and Education. Computers and Security, 95.

InfoWatch, 2019. Data Leakage News. Available at: https://infowatch.com/analytics/leaks_monitoring Accessed 4 Apr 2024

Karlsson, M., Denk, T. and Åström, J., 2018. Perceptions of organizational culture and value conflicts in information security management. Information and Computer Security, 26(2), 213–229.

Kweon, E., Lee, H., Chai, S. et al., 2021. The Utility of Information Security Training and Education on Cybersecurity Incidents: An empirical evidence. Information Systems Frontiers, Vol. 23, 361–373.

Liu, J., Zhang, J., Zhang, J., 2020. Validating a control-based model of information security policy compliance – A meta-analysis. 40th International Conference on Information Systems, ICIS 2019. Munich, Germany

McIlwraith, A., 2021. Information Security and Employee Behaviour. How to Reduce Risk Through Employee Education, Training and Awareness. Routledge. London, 2nd Edition.

Rohan, R., Pal, D., Hautamäki, J., Funilkul, S., Chutimaskul, W., and Thapliyal, H., 2023. A systematic literature review of cybersecurity scales assessing information security awareness. Heliyon, 9(3). Available at: https://www.cell.com/heliyon/pdf/S2405-8440(23)01441-X.pdf Accessed 4 Apr 2024

Ratchford, M. M., Wang, Y., 2019. BYOD-Insure: a Security Assessment Model For Enterprise BYOD. 5th International Conference on Mobile and Secure Services, MobiSecServ 2019, 1–10. Miami, United States. Sekulla, A., Giatagantzidis, J., Dax, J., Pipek, V., 2020. A lightweight tool for measuring the impact of IT security controls in critical infrastructures. ECSCW 2019 – Proceedings of the 17th European Conference on Computer Supported Cooperative Work. Salzburg, Austria.

Siponen, M., Adam Mahmood, M., Pahnila, S., 2014. Employees' adherence to information security policies: An exploratory field study. Information and Management, 51(2), 217–224.

Soomro, Z.A., Shah, M. H., Ahmed, J., 2016. Information security management needs more holistic approach: A literature review. International Journal of Information Management, 36(2), 215–225.

Tang, M., Li, M., and Zhang, T., 2016. The impacts of organizational culture on information security culture: a case study. Information Technology & Management, 17, 179–186.

Trend Micro, 2020. Disrupting the Workplace: Trend Micro 2020 Midyear Cybersecurity Report. Availible at: https://documents.trendmicro.com/assets/rpt/rpt-securing-the-pandemic-disrupted-workplace.pdf Accessed 4 Apr 2024

Vroom, C., von Solms, R., 2004. Towards information security behavioural compliance. Computers & Security, 23(3), 191–198.

Zungur, O., Suarez-Tangil, G., Stringhini, G., Egele, M., 2019. BorderPatrol: Securing BYOD using Fine-Grained Contextual Information. Proceedings – 49th Annual IEEE/IFIP International Conference on Dependable Systems and Networks, 460–472.

Saving Humanity from Global Warming. New Ecologically Balanced Catalytic Method for Processing of Renewable Plant Raw Materials: Quantitative ^{1}H and ^{13}C NMR Spectroscopy.

Igor A. Kozlov[1] [1], Valery A. Pashinin[2] [2], Philip I. Sukhov[2] [3]
[1]*Frumkin Institute of Physical Chemistry and Electrochemistry Russian Academy of Sciences, Leninsky Prospekt, 31, bldg. 4, Moscow, Russian*
[2]*Federal State Institution of Higher Education «Russian University of Transport», 9, Obraztsova st., bldg. 9, Moscow, Russian*
cnn.67@mail.ru

Keywords: global warming, lignin, catalyst delignification, NMR spectroscopy, mechanism delignification cellulose.

Abstract: The most high-tonnage product of processing vegetable raw materials is cellulose. Currently, sulfate cooking is the most common method of pulp production. However, this method is extremely toxic and has a huge negative impact on the environment. An alternative to this is a catalytic process. Catalysts reduce harmful emissions into the atmosphere by up to 80%. During cellulose cooking, the most important chemical reaction is the destruction (hydrolysis) of lignin macromolecules. A comparative study of the macromolecular structure of pine dioxane lignin and lignins obtained by various methods of alkaline pine wood delignification such as soda process, soda with elemental sulphur and soda with 1,4–dihydro–9,10–dihydroxyanthracene (DDA) disodium salt as a delignification catalyst and with a novel delignification catalyst (DC) was carried out using quantitative ^{1}H and ^{13}C NMR spectroscopy.

1 INTRODUCTION

Investigations in the field of alkaline delignification have led to considerable success. However, there is still much to be understood. Complete understanding of the chemical structure of lignin macromolecule component gives a good idea of the processes occurring due to wood delignification by either of the above methods. In the present work a comprehensive qualitative and quantitative information concerning the chemical structure of lignin products obtained by different methods of alkaline pine wood delignification is presented. A comparison with the literature data has been carried out. Quantitative ^{1}H and ^{13}C NMR spectroscopy was employed as the method of investigation.

2 MATERIALS AND METHODS

Pine dioxanlignin **(PDL)** was obtained by the Pepper method in a nitrogen flow (Sarkanen, Ludvig, 1971). Elemental composition: C 62,74%, H 5,45%, ash 2.53%. The yield of lignin is 25% of its content in wood. Comparative pulpings of pine chip under the conditions of soda process during 150 **(1)** and 240 min **(2),** soda process + elemental sulfur during 180 min **(3),** that with DDA during 150 min **(4)** and with DC during 150 min **(5)** were performed without soda circulation in 200-ml autoclaves placed in an oil bath with electric heating. Temperature conditions of the process are as follows: temperature rise from 80 to 100 °C for a period of 100 min. The liquid: wood ratio was 4.5. For soda pulping the use was made of white soda liquor, the consumption of active alkali being 20% in NaOH units of the wood mass. The discharge

[1] https://orcid.org/0009-0003-9940-0193
[2] https://orcid.org/0000-0002-7709-8654
[3] https://orcid.org/0000-0002-8455-5710

of active additives was 0.6, 0.1 and 0.6 % of the wood mass for elemental sulfur, DDA and DC, respectively. After pulping the lignocellulose materials were analyzed for yield and delignification degree using the Kappa method. The relative error in delignification degree determination was 2.0 Kappa units (Table 1). The DC catalyst was prepared by (Kozlov, Rubalchenko, Gogotov, 2000).

^{1}H and ^{13}C NMR spectra of lignin samples were run on a Varian VXR-500S spectrometer, resonance frequency 500 MHz (^{1}H) and 125.5 (^{13}C). The procedure for estimating the contents of hydrogen atoms, phenol group and H atoms in aldehyde groups from ^{1}H NMR spectra was described in (Sarkanen, Ludvig, 1971). The ^{13} C NMR spectra of lignin speciments with proton decoupling according to the method IGD were recorded. Subspectra primary and tertiary, secondary and quaternary carbon atoms obtained according to the method of spin echo with multiplet de-phasing (CSE and GASPE) were recorded offer 5000 accumulations (relaxation delay 2.5 s; 90º pulse); DMSO-D_6 was used as solvent and $Cr(acac)_3$ (0.02 mol/l) was used as a relaxant. Quantitative calculations on the ^{1}H and ^{13}C NMR spectra were carried out 1by a technique described in (Sarkanen, Ludvig, 1971).

Table 1: The elemental composition of lignin preparations 1-5 and pulp characteristics.

№ (τ,min)	Elemental composition of lignins, %				Lignin content in cellulose		
	C	H	S	ash	Kappa number	Klason lignin, %	Yield, %
1 (150)	52,85	6,82	0	3,99	70-72	8,8	48-49
2 (240)	63,66	5,48	0	2,14	48-49	6,1	45-46
3 (180)	62,04	7,04	2,89	1,05	32-34	4,1	43-44
4 (150)	64,26	7,30	0	3,24	32-33	4,0	43-44
5 (150)	60,38	5,92	2,24	3,43	31-32	3,9	42-43

3 RESULTS AND DISCUSSION

Table 2 shows final results of calculating the number of structural fragments and bonds basing on ^{1}H and ^{13}C NMR spectra and elemental analysis data.

3.1 Chemical structure of PDL

As shown by analysis of the ^{1}H and ^{13}C NMR spectra of the pine dioxanlignin preparation the macromolecule consists of guayacyl rings (G, G'), the structures close in the aromatic ring A substitution to tannis (A') and pyrocatechol (3,4–dioxyphenyl units). The presence of aromatic rings substituted by type A' is indicated by resonance signals of aromatic ring quaternary carbon atoms C–3 in subspectrum ($C+CH_2$) with chemical shifts in the 114-116 ppm spectral range, C–5 atoms with chemical shifts with approximately 100 ppm and OCH_3 group atoms with ~61 ppm chemical shifts in subspectrum ($CH + CH_3$).

The intense ^{13}C resonance signals off 151-154 ppm show the presence of a large number of G units bound directly by 4–O–5 bonds. The number of G units with α–C=O and C(O)H groups, C–4, also present in the 151-154 range, does not exceed 3-4 per AR. The presence of 3,4-dioxyphenyl structures in the PDL molecules is supported by ^{13}C resonance signal at 143 and 145-146 ppm corresponding to C–4 and C–3 atoms, respectively. The side chains in the PDL macromolecule are weakly oxidized. The average chain length is 1.72 carbon atoms per AR. The number of olefin fragments Ar–CH=CH-R (R≠H) is 11 per 100 AR.

Table 2: The number of main structural units, functional groups and bonds per 100 aromatic rings of the lignin macromolecule (NX = (qX x 6) / fa x 100; q - portion of CX atoms in the 13C spectrum).

Unit, functional group, bond	N_X						
	PDL	1	2	3	4	5	rel. error, %
G	83	87	82	83	84	72	4,2
A′	7	0	0	0	0	0	9,5

Unit, functional group, bond	N_X						
	PDL	1	2	3	4	5	rel. error, %
3,4-dioxyphenyl rings	10	13	18	17	16	28	10,0
Substitution in positions:							
C–2	7	16	5	6	19	n.d.	6,4
C–5	20	43	40	43	41	19	6,4
C–6	11	0	0	0	13	n.d.	6,4
OH_{phen}	20	57	66	52	61	48	7,1
C=O	5-6	5	5	6	12	13	6,2
C(O)H	5-6	0	0	2	3	0	6,5
OCH_3	91	87	82	83	84	72	4,2
OH_γ	40	29	21	25	25	10	7,7
ΣCHO (α, β)	82	77	45	23	42	13	6,4
ΣCH_2O	42	38	24	37	29	13	6,4
-HC=CH-	11	19	23	24	20	28	6,7
CH (β-1)	11	7	10	8	4	6	4,2
$\Sigma C_{side\ shain}$	172	159	124	142	168	123	12,7
C_{Ar}-C	46	48	62	65	67	69	6,7
$C_{CAr\text{-}O\text{-}C}$	103	91	67	88	99	74	-
C_{Ar}-O-C(O)-R	0-5	34	23	28	23	23	-
α,β–O–4	52	45	21	14	18	9	-
C_{Ar}-O-CH=CH-Ar	0	0	14	1	0	0	-
4-O-5	26	6	5	23	25	21	-
C_{Ar}-O-C	78	51	40	38	43	53	-
$f_a = I\ ^{13}C_{TOTAL}/I\ ^{13}C_{Ar}$	0,66	0,68	0,73	0,73	0,70	0,75	4,2

^{13}C chemical shifts (–CH=CH–) occur in the 126-134 ppm range of the ($CH+CH_3$) subspectrum. PDL shows a high degree of condensation: nearly in each second aromatic ring there is an Ar or Alk substituent (–Cap–C–) bond. Substitution of G, G' units in positions C–2, 5, 6 is shown in Table 2. The total number of aromatic ring carbon atoms involved in the formation of etheric arylalkyl and arylaryl bonds in PDL is 103/100 AR ($C_{Car\text{-}o\text{-}c}$, Table 2). The number of α–O–4 and β–O–4 bonds was estimated basing on the content of carbon atoms within the 75-94 range (Table 2). The number of aryl-aryl etheric bonds was estimated as follows: 100 - 52 / 2 = 25,2. Consequently, the total number of etheric bonds in the PDL molecules is 52 + 25.5 = 77.5.

3.2 Chemical structure of lignin preparations 1-5. Etheric arylalkyl and aryl-aryl bonds, phenol OH groups and esteric bonds

By the present time it has been established that the main process responsible for wood delignification is cleavage of the α-O-4 and β-O-4 bonds between phenylpropane structural units of lignin followed by the formation of phenolhydroxy groups (Sarkanen, Ludvig, 1971). This concerns not only conventional methods of soda delignification, but the procedures using catalysts of anthraquinone type. It has been reported that there is a direct relationship between the rate of formation of new phenol OH groups in the lignin macromolecule and the degree of delignification in different methods of soda pulping.

The amount of aromatic ring carbon atoms involved in etheric bonds would seem to be the most reliable parameter for estimating the change of the number of etheric bonds. However, analysis of the ^{13}C NMR spectra of samples 1-5 has shown that the total number of the carbon atoms ($C_{Car\text{-}O\text{-}C}$, Table 2) diminishes only negligible compare with that of the PDL macromolecule. The number of phenol OH-groups in lignins 1-4 and 5 increased 2.6-3.3 and 2.4-fold, respectively, compared with PDL. However, there is no correlation between the increase in the phenol OH group content and the degree of α,β-O-4 bond cleavage (Table 2): The DC additive leads to the most efficient cleavage of α,β–O–4 bonds, but the number of phenol OH–groups in lignin 5 is the lowest one. The same is true with lignin 3. Consequently, in drawing conclusions concerning the degree of α, β–O–4 bond cleavage in lignins from various delignification process, it is not reasonable to start from the content of phenol OH–groups. In soda pulping (240 min) and soda plus elemental sulphur additive vinyl–aryl ethers C_{ar}–C_αH=C_βH–O–Ar are formed in the process of delignification. This is indicated by the presence of

$C_\beta H$ atom resonance signals in the 140-144 ppm range of the subspectrum ($CH+CH_3$) (Sarkanen, Ludvig, 1971). In the ($CH+CH_3$) subspectra of lignins obtained by DDA-catalyzed aspen wood delignification no resonance signals corresponding to vinyl–aryl ethers are observed. These data are in good agreement with the results of studies of the delignification process with catalysts of anthraquinone type. In the ^{13}C spectra of lignins 1-5 there are intense resonance signals of esteric groups, their number being 4.3-6.3 times as high as in PDL. Car–O–C(O)–Alk, Ar rather than Car–C(O)–Alk fragments prevail because in the ($C+CH_2$) subspectra a signal of low intensity arisen from $–O–CH_2$ groups occurs in the 75-71 ppm range. This fact can be explained only by liberation of lignin having a structure different from that of PDL, which also leads to an increase in the Ccar-o-c number. With prolongation of the delignification process the number of esteric bonds decreases.

3.3 Car-C bonds (condensation degree of lignin preparations)

The condensation degree of preparations 1-5increases 1.3-1.5 times compared with the PDL preparation. Analysis of ^{13}C chemical shifts in the 140-163 and 120-140 ppm ranges of the subspectrum ($C+CH_2$) suggests the appearance of a great number of G units substituted in the position C-5 (resonance signals with ^{13}C CS of ~142, 144 and 147 ppm corresponding to C–4 and C–3 atoms, and signals at 125-127 ppm arising from C-5 atoms (Neronov, Chernitsova, Koroleva, Krechetov, 2012)). Calculation of the substitution degree of G units in the positions C–2, 5, 6, based on the number of CH_{ar} fragments has shown that in lignin preparations 1-4 the substitution in positions C-5 is diminished two-fold compared with that in PDL, whereas the substitution in position C–2 increases two- and three-fold in preparations 1 and 4, respectively, and remains practically unchangeable in preparation 5.

The condensation degree of lignin preparations 2-5 are similar, however the lignins from DDA and DC-catalyzed pulping show slightly higher values than lignins 1-3. This provides evidence for the fact that lignin condensation processes do not compete with wood matrix delignification processes in the main pulping stage. The results obtained are in good agreement with the data of investigations of condensation transformations of lignin monomeric models in the presence of anthraquinone (AQ) which, when added as a catalyst to the pulping liquor, did not suppress the condensation processes.

3.4 Side chains

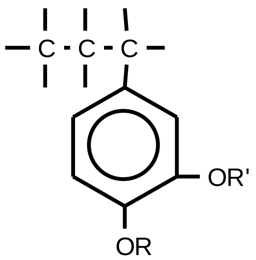
In all the delignification processes the formation of olefin fragments was observed. Compared with DLP the number of fragments increases approximately 2-2.5-fold (^{13}C CS of –CH=CH– and –O–CH=CH– fragments are in the 136-122 and 141-145 ppm regions, respectively (Bruskov, Yaguzhinsky, Masalimov, Chernikov, Emelyanenko, Gudkov, 2015; Neronov, Chernitsova, Koroleva, Krechetov, 2012; Kenessov, Carlsen, 2014), of the subspectrum ($CH+CH_3$).

Particular attention should be given to the length of oxidized side chain in the lignin preparations isolated. In general, the sum of the side chain carbon atoms both bonded to oxygen atoms (C=O, C(O)H, and unbonded ones (–CH, $–CH_2$, $–CH_3$) decreases by a factor of 1,7-4,8 in the process of pine wood delignification. The Largest number of side chain –C–C– bonds is broken in the process of DC-catalyzed pulping (Table 2).

3.5 Functional groups

The content of aldehyde groups in lignins is decreased. Compared with PDL the number of aliphatic $OH\gamma$ groups in lignins becomes 1.6-4 times smaller.

The number of methoxy groups in lignins 1-4 decreases negligibly compared with initial PDL due to removal of structure A. Consequently, demethylation of the G, G' aromatic rings of the lignin high-molecular component does not occur in tests 1-4. However, with DC additive a considerable decrease in the $–OCH_3$ group contents with the formation of ~28/100 structure AR are observed:



, WHERE R' # H, CH_3

Thus, analysis of the chemical structure of lignins from soda delignification processes provides an understanding of the contribution (rel.%) of degradation of the lignin macromolecule (Table 3).

Table 3: Relative number of cleaved bonds in the main stage of pine wood delignification (%) (compared with PDL).

Type of bond	Delignification Method			
	I	II	III	IV
α, β–O–4	60	73	65	83
4–O–5	77	6	0	19
$C_{\grave{a}r}$–O–C(O)–R*	32	18	32	32
C_{β}–C_{γ}	43	12	38	70

* - relative number of cleaved esteric bonds (compared with lignin 1)

4 CONCLUSIONS

In-depth knowledge of the mechanism of reactions allows you to simulate environmentally safe industrial production with less emission of harmful substances into the atmosphere. Analysis of quantitative ^{1}H and ^{13}C NMR spectra of the lignins isolated in the process of soda delignification (I-IV) has shown that in processes I and III delignification occurs as a result of active fragmentation of the lignin macromolecule due to cleavage of arylalkyl etheric and esteric bonds and side chain –C–C– bonds, and in process II cleavage of α–O–4 and β–O–4 etheric bonds and, to a lesser extent, side chain –C–C– bonds and esteric bonds is responsible for delignification.

DC catalyst (IV) facilitates more extensive and efficient (compared with AQ) cleavage of α–O–4, β–O–4, 4–O–5 and side chain –C–C– bonds. All the delignification methods lead to the formation of olefin fragments and a decrease in the content of methoxy groups, however, in method IV these processes are more pronounced. The number of OH groups in lignins cannot serve as an indicator of the degree of cleavage of α, β–O–4 bonds, whereas the reactions of secondary condensation of lignin fragments do not compete with delignification in the major stage.

REFERENCES

Sarkanen, K.; Ludvig, K., 1971. *Lignins;* Wiley Interscience, New York.

Kozlov, I.A., Rubalchenko, N.A., Gogotov, A.F., 2000. Homogeneous catalysis in the processes of lignin oxidation. Proc. IVth International Symposium "Catalytic and Thermochemical Conversions of Natural Organic Polymers". Russia. P. 171.

Kozlov, I.A. Kanitskaya, L.V., 2000. The chemical structure of lignin-natural organic polymer: quantitative ^{1}H and ^{13}C NMR spectroscopy. Proc. IVth International Symposium "Catalytic and Thermochemical Conversions of Natural Organic Polymers". - Russia. P. 182-184.

Kuznetsov, B.N., Kuznetsova, S.A., Kozlov, I.A., 2002. New catalytic processes for a sustainable chemistry of cellulose production from wood biomass. Catalysis Today. № 75. P. 211-217.

Bruskov, V. I., Yaguzhinsky, L. S., Masalimov, Z. K., Chernikov, A. V., Emelyanenko, V. I., Gudkov, S. V., 2015. The continuous generation of hydrogen peroxide in water containing very low concentrations of unsymmetrical dimethylhydrazine. *Biophysics,* 60 (4), 553-558.

Neronov, V. V., Chernitsova, O. V., Koroleva, T. V., Krechetov, P. P., 2012. Contemporary state of vegetation in Baikonur Cosmodrome and estimate of its potential resistance to impact of space-rocket activities. *Arid Ecosystems,* 2 (3), 186-196.

Kenessov, B., Carlsen, L., 2014. Identification (Quantitative Determination and Detection) and Fate of Transformation Products of Rocket Fuel 1, 1-Dimethylhydrazine. *Transformation Products of Emerging Contaminants in the Environment*, 627-648.

Kolumbayeva, S., Begimbetova, D., Shalakhmetova, T., Saliev, T., Lovinskaya, A., Zhunusbekova, B., 2014. Chromosomal instability in rodents caused by pollution from Baikonur cosmodrome. *Ecotoxicology,* 23 (7), 1283-1291.

Developing the Distance Learning System Using the .NET Framework Insights and Methodologies

Maxim R. Volkov[a], Vladislav A. Nikolaev[b], Ivan A. Gulyaev[c], Ilsaf N. Galavetdinov[d] and Elena S. Belashova[e]

Institute of Computer Technologies and Information Security, Kazan National Research Technical University named after A. N. Tupolev – KAI, Kazan, Russia

volkovmaxim02@mail.ru, vanikolaev2002@yandex.ru, ivan.gul.95@mail.ru, ilsaf26052002@gmail.com, bel_lena@mail.ru

Keywords: .NET Framework, Distance Learning, Software Development, Testing Strategies, Real-Time Communication, Educational Technology.

Abstract: This article presents a comprehensive examination of the development and deployment of a distance learning system using the .NET Framework, highlighting its significance in the evolving landscape of digital education. Beginning with an introduction to the necessity and benefits of remote learning platforms in today's digital age, the article delves into the architectural design of the system, emphasizing its multi-tiered structure which ensures modularity, flexibility, and scalability. The core development section details the integration of key .NET technologies – ASP.NET for web application development, Entity Framework for data management, SignalR for real-time communication, and the Identity Framework for secure user authentication and management. A significant portion of the article is dedicated to the meticulous testing strategy employed, covering unit, integration, and system testing phases to ensure the reliability, performance, and user experience of the system. Utilizing the xUnit framework for automated testing, the article showcases how comprehensive testing is instrumental in identifying potential issues early, thereby enhancing the overall quality and stability of the platform. The conclusion synthesizes these discussions, underscoring the system's successful implementation as a testament to the potential of the .NET Framework in creating robust, scalable educational software. The article serves not only as a case study on the development of a distance learning system but also as a guideline for future projects aiming to leverage technology in enriching the educational experience. Through detailed exploration of the system's architecture, development process, and testing methodologies, the article offers valuable insights into creating software solutions that are innovative, user-centric, and impactful in the realm of digital education.

1 INTRODUCTION

In the rapidly evolving landscape of the 21st century, the digital transformation of educational methods has become a cornerstone in fostering inclusive, adaptive, and innovative learning environments. The advent of digitization and globalization has compelled educational institutions and organizations to adopt distance learning, not merely as a temporary solution but as a sustainable and integral part of their educational strategy. This paradigm shift towards remote education is fundamentally driven by the overarching goal to democratize education, making it accessible to students from diverse geographical, economic, and social backgrounds. This article zeroes in on the conceptualization and development of a system dedicated to facilitating remote lessons through the robust and versatile .NET Framework platform.

[a] https://orcid.org/0009-0005-0284-6821
[b] https://orcid.org/0009-0000-1460-1964
[c] https://orcid.org/0009-0004-7667-3102
[d] https://orcid.org/0009-0002-1199-2589
[e] https://orcid.org/0000-0003-4662-185X

Developed and maintained by Microsoft, the .NET Framework stands out as a comprehensive and consistent programming model, renowned for its ability to produce applications that feature visually stunning user experiences, seamless and secure communication, and the flexibility to model a plethora of business processes. It is this versatility and the comprehensive support for development needs that render the .NET Framework an exemplary choice for crafting educational software aimed at not only enhancing learning outcomes but also at engaging students in a meaningful and interactive manner.

The proposed system endeavours to harness the full spectrum of capabilities offered by the .NET Framework to foster an immersive learning environment that transcends the limitations of traditional classroom settings. By intricately weaving together the various technologies under the .NET umbrella – such as ASP.NET for robust web development, Windows Presentation Foundation (WPF) for rich desktop application experiences, and Xamarin for seamless mobile application development – the system aspires to offer a cohesive and responsive learning experience across an array of devices and platforms.

At its core, the system is designed to incorporate cutting-edge functionalities, including real-time communication channels, interactive whiteboards, and comprehensive multimedia content support. These features are meticulously curated to cultivate a dynamic, interactive, and collaborative learning atmosphere, closely mirroring the interactive dynamics of conventional classroom environments. The objective is to maintain high levels of student engagement and motivation by leveraging interactive tools and resources that stimulate participatory learning and critical thinking.

Moreover, the development of this remote learning system, grounded in the .NET Framework, is a response to the urgent demand for high-quality, universally accessible, and flexible educational alternatives. Through an in-depth exploration of architectural designs, development methodologies, and the integration of innovative technologies, this article aims to provide valuable insights and practical guidelines for educators, developers, and stakeholders invested in the future of education. The overarching vision is to pave the way for a future where distance learning is not just a mere adjunct to traditional education but a robust, enriching, and equitable mode of learning in its own right.

2 IN-DEPTH OVERVIEW OF THE .NET FRAMEWORK

The .NET Framework, developed by Microsoft, is a comprehensive software development platform known for its ability to support a wide array of programming languages, including but not limited to C#, F#, and Visual Basic. This multi-language support not only democratizes software development by accommodating a broad spectrum of developers with varying preferences and expertise but also fosters a rich ecosystem of applications ranging from simple desktop utilities to complex, distributed systems.

At the core of the .NET Framework's architecture is the Common Language Runtime (CLR), a sophisticated execution engine that plays a pivotal role in managing the execution of .NET applications. The CLR is responsible for critical system services such as memory management, thread management, exception handling, and security. It also facilitates a seamless interoperability among different .NET programming languages, allowing them to share libraries and object-oriented classes without language barriers. This interoperability is a cornerstone of the .NET architecture, promoting code reuse and modularity.

The Framework Class Library (FCL) is another cornerstone of the .NET Framework, providing a vast repository of pre-coded solutions and libraries designed to tackle a wide range of programming challenges. These libraries cover various domains, including but not limited to graphical user interface (GUI) design, database interaction, web application development, and XML document processing. The FCL significantly enhances developer productivity by offering robust, reusable components that simplify complex programming tasks.

ASP.NET stands as the .NET Framework's answer to the needs of modern web development. It enables developers to build dynamic web sites, applications, and services with a high degree of flexibility and functionality. ASP.NET extends the .NET Framework to the web, providing a rich toolbox of controls and libraries that support the development of sophisticated web UIs and server-side logic. It also introduces powerful features such as web forms, MVC architecture, and secure authentication mechanisms, making it a formidable tool for web developers.

In the realm of data access, ADO.NET provides a versatile and efficient framework for interacting with databases. It is designed to facilitate a wide range of data operations, from simple queries to complex transactions, across different database platforms. ADO.NET emphasizes disconnected data architecture, allowing applications to interact with data sources with minimal reliance on continuous database connections. This design is particularly beneficial for web applications, where scalability and performance are paramount.

For desktop application development, Windows Presentation Foundation offers a unified framework for building visually appealing user interfaces. WPF leverages XAML (Extensible Application Markup Language) to enable developers to define UIs in declarative markup language, separating the presentation layer from business logic. This separation enhances the maintainability and testability of applications. WPF also supports a broad set of media services, including 2D and 3D graphics, animation, and sophisticated typography, making it an ideal choice for creating rich desktop applications.

Windows Communication Foundation (WCF) addresses the need for secure and reliable communication in distributed applications. WCF provides a flexible framework for building service-oriented applications that can communicate across diverse networks and platforms. It supports multiple communication protocols, including HTTP, TCP, and named pipes, and offers extensive security features, ensuring that services are robust and secure.

The .NET Framework's impact on software development is undeniable. Its comprehensive support for multiple programming languages, coupled with a vast array of class libraries and development tools, has positioned it as a leading platform in the industry. The .NET Framework simplifies the complexity of application development, enabling developers to focus on delivering high-quality, innovative solutions. As technology evolves, the .NET Framework continues to adapt and expand, ensuring that it remains a vital and relevant tool for developers worldwide, fostering the creation of software that meets and exceeds the demands of modern users and businesses.

3 DEVELOPING THE DISTANCE LEARNING SYSTEM

The architecture of a system designed for conducting remote lessons is a crucial aspect that dictates its effectiveness, flexibility, and scalability. Utilizing a multi-tier architecture not only facilitates modularity but also enhances the system’s maintainability and future expansion capabilities. This architecture typically comprises three primary layers: the data layer, the business logic layer, and the presentation layer.

1) Data layer: at the foundational level, the data layer encompasses the database and data models that represent key entities such as students, instructors, courses, and educational materials. This layer serves as the backbone of the system, providing structured data storage and retrieval mechanisms that are essential for the operation of the higher layers. Here is a basic representation of how entities like students and courses might be modelled:

```
   public class Student
   {
     public int Id { get; set; }
     public string Name { get; set; }
     public ICollection<Course> Courses
{ get; set; }
   }

   public class Course
   {
     public int Id { get; set; }
     public string Title { get; set; }
     public ICollection<Student>
Students { get; set; }
   }
```

These models facilitate the representation of complex relationships within the educational domain, such as the many-to-many relationship between students and courses.

2) Business logic layer: the core application logic resides within this layer, orchestrating interactions between data entities and implementing the system's functionality. This includes processes such as registration, course management, content delivery, and assessments. The business logic layer acts as a mediator between the data and presentation layers, ensuring data integrity and enforcing business rules.

```
   public class CourseService
   {
     private readonly
ApplicationDbContext _context;
     public
CourseService(ApplicationDbContext
context)
     {
       _context = context;
     }

     public async Task<List<Course>>
GetCourses()
     {
       return await
_context.Courses.ToListAsync();
```

```
    }

    public async Task<Course>
GetCourse(int id)
    {
      return await
_context.Courses.FindAsync(id);
    }
    public async Task<Course>
AddCourse(Course course)
    {
      _context.Courses.Add(course);
      await
_context.SaveChangesAsync();
      return course;
    }
  }
```

This snippet illustrates how a service within the business logic layer manages courses, encapsulating the logic for retrieving, adding, and manipulating course data.

3) Presentation layer: the user interface and interaction are handled by the presentation layer. This layer is responsible for presenting data to users and collecting user inputs, thereby acting as the face of the system. It's designed to be user-friendly, intuitive, and accessible, ensuring a seamless experience for users regardless of their technical proficiency.

```
  [ApiController]
  [Route("[controller]")]
  public class CourseController :
ControllerBase
  {
    private readonly CourseService
_courseService;

    public
CourseController(CourseService
courseService)
    {
      _courseService = courseService;
    }

    [HttpGet]
    public async
Task<ActionResult<List<Course>>>
GetCourses()
    {
      return await
_courseService.GetCourses();
    }

    [HttpGet("{id}")]
    public async
Task<ActionResult<Course>>
GetCourse(int id)
    {
      var course = await
_courseService.GetCourse(id);
      if (course == null)
      {
        return NotFound();
      }
      return course;
    }
    [HttpPost]
    public async
Task<ActionResult<Course>>
AddCourse(Course course)
    {
      return await
_courseService.AddCourse(course);
    }
  }
```

This example showcases a controller in a web API, facilitating operations such as retrieving and adding courses through HTTP requests. This is a crucial component of the presentation layer, linking the user interface with the underlying business logic and data layers.

The development of a distance learning system utilizing a multi-tier architecture enables a clear separation of concerns, which in turn facilitates ease of maintenance, scalability, and flexibility. By segregating the system into distinct layers – data, business logic, and presentation – the design supports robust development practices, ensuring that the system can evolve in response to new requirements or technologies without undergoing major overhauls. This architectural approach lays a solid foundation for building an efficient, reliable, and user-friendly distance learning platform.

The development of the comprehensive distance learning system demanded a strategic selection of technologies and components that align with the goals of scalability, interactivity, and security. The .NET Framework, with its rich ecosystem and robust capabilities, provided the foundational technologies necessary to build a state-of-the-art educational platform. This section delves deeper into the specifics of the development process, highlighting the integration and functionalities of chosen .NET technologies.

The use of ASP.NET was pivotal in constructing both the web application front end and the backend API. This choice was driven by ASP.NET's inherent support for the Model-View-Controller (MVC) architecture, a design pattern that promotes separation of concerns by dividing the application logic into three interconnected components:

- Models represent the data and the business rules that govern access to and updates of this data.
- Views are responsible for rendering the UI, which is generated from the models.
- Controllers handle user input and interactions, manipulate models, and select views to render.

The MVC architecture not only facilitates a modular and organized codebase but also enhances the system’s maintainability and scalability. It allows developers to work on different parts of the application simultaneously without causing conflicts, speeding up the development process.

Entity Framework (EF) was chosen for its ORM capabilities, which abstract the complexities of the database layer, allowing developers to interact with the database using strongly typed objects. This abstraction is beneficial for several reasons:

- Increased productivity: by automating database schema creation and simplifying data operations, EF significantly reduces the amount of manual coding required.
- Data consistency: EF enforces a consistent approach to data access throughout the application, minimizing errors and inconsistencies.
- Performance optimizations: EF provides mechanisms for optimizing data access and caching, improving the application’s overall performance.

The adoption of EF facilitated a seamless interaction with the system's relational database, efficiently managing entities such as users, courses, and content, and automating CRUD (Create, Read, Update, Delete) operations.

SignalR, a library for ASP.NET, was integrated to enable real-time functionalities such as live chat, notifications, and interactive classrooms. This technology is crucial for creating a dynamic and engaging learning environment, closely mimicking the interactive nature of physical classrooms. SignalR works by establishing persistent connections between the client and server, allowing for the instant broadcast of messages and updates. This real-time capability is instrumental in facilitating:

- Live discussions: enabling instantaneous communication between instructors and students during lessons.
- Instant feedback: allowing instructors to provide immediate feedback on assignments and quizzes.
- Collaborative workspaces: supporting interactive sessions where students can work together in real time.

The system's security infrastructure was built using the Identity Framework, which provides a comprehensive suite of functionalities for managing users, authentication, and authorization. The framework supports:

- User registration and management: enabling the creation and management of user profiles, including secure password management.
- Authentication: verifying user identities based on credentials.
- Authorization: granting or denying access to resources based on user roles and permissions.

This framework ensures that the system adheres to best practices for security, protecting sensitive data and maintaining user privacy.

The detailed development of the distance learning system, leveraging key .NET technologies, showcases a well-thought-out approach to creating a robust, scalable, and interactive educational platform. Through the strategic use of ASP.NET, Entity Framework, SignalR, and the Identity Framework, the system not only offers an immersive learning experience but also ensures the highest standards of security and data integrity. This harmonious integration of technologies forms the backbone of a platform that is well-equipped to adapt to the evolving demands of distance education, providing a blueprint for future developments in the field.

4 COMPREHENSIVE TESTING STRATEGY FOR THE DISTANCE LEARNING SYSTEM

The quality assurance phase of the distance learning system was intricately designed to ensure the platform's robustness, functionality, and user experience met the highest standards. The testing strategy encompassed a thorough mix of unit testing, integration testing, and system testing, employing the xUnit framework for its extensive support and flexibility in handling various testing scenarios. This multi-layered approach facilitated the identification and correction of any issues early in the development lifecycle, ensuring a smooth and reliable user experience upon launch.

Unit testing served as the foundation of the testing strategy, focusing on individual methods and functions to ensure their correctness in isolation. This phase targeted the smallest units of code, scrutinizing their behavior under controlled conditions to catch and rectify any logical errors or unexpected outcomes.

```
   public class CourseServiceTests
   {
     private ApplicationDbContext
_context;
     private CourseService
_courseService;

     [SetUp]
     public void Setup()
     {
       var options = new
DbContextOptionsBuilder<ApplicationDbCo
ntext>().UseInMemoryDatabase(databaseNa
me: "TestDatabase")
         .Options;
       _context = new
ApplicationDbContext(options);
       _courseService = new
CourseService(_context);
     }
     [Test]
     public async Task
AddCourse_ShouldAddCourseSuccessfully()
     {
       // Arrange
       var course = new Course { Title
= "Test Course" };
       // Act
       var result = await
_courseService.AddCourse(course);

       // Assert
       Assert.AreEqual(course.Title,
result.Title, "The course title should
match the input.");
     }
   }
```

In the above example, a unit test for the `AddCourse` method is showcased, illustrating how each component's functionality, such as adding courses to the system, is verified independently to ensure they behave as expected.

Following successful unit testing, integration testing was implemented to examine the interactions between integrated components and subsystems. This stage was crucial for identifying issues that occur when individual modules, which function correctly in isolation, are combined. Tests focused on data flow between components, API interactions, and the seamless operation of the front end with the back end, ensuring the integrated components worked harmoniously to perform expected tasks.

Integration testing covered critical paths through the application, such as the process from user registration through to course enrollment and content delivery, to verify that all parts of the system communicated effectively and that data integrity was maintained across different system layers.

The pinnacle of the testing strategy was system testing, wherein the complete, integrated application was evaluated. This phase simulated real-world usage scenarios to validate the entire system’s compliance with specified requirements. System testing encompassed a wide range of tests, including:

- Functional testing: to verify that all system functionalities worked as intended.
- Performance testing: to ensure the system performed well under anticipated user loads.
- Security testing: to identify vulnerabilities and ensure data protection mechanisms were effective.
- Usability testing: co ensure the system was intuitive and user-friendly.

This comprehensive testing phase aimed to affirm the system’s readiness for deployment, ensuring that it could handle real-world operations and provide a seamless experience for end-users.

The detailed and methodical testing strategy employed for the development of the distance learning system underscored the importance of rigorous quality assurance processes in software development. By leveraging the xUnit framework across unit, integration, and system testing phases, the project team was able to ensure a high level of reliability, performance, and user satisfaction. This robust testing approach not only facilitated the early detection and correction of potential issues but also played a pivotal role in refining the system’s overall functionality and user experience, setting a solid foundation for the system’s success in the competitive landscape of digital education platforms.

5 CONCLUSION

The development and deployment of a distance learning system utilizing the .NET Framework represent a significant advancement in the field of digital education. This article has meticulously detailed the processes involved in the conceptualization, architecture design, development, and comprehensive testing of the system. Through the strategic integration of key .NET technologies such as ASP.NET, Entity Framework, SignalR, and the Identity Framework, the platform has been equipped to offer a robust, scalable, and interactive learning environment.

The architectural design of the system, grounded in a multi-tiered approach, ensures modularity, flexibility, and ease of maintenance. By segregating the system into data, business logic, and presentation layers, the design promotes a clear separation of concerns, facilitating efficient development and future scalability. The development process further capitalizes on the strengths of the .NET Framework to implement a secure, user-friendly, and functional platform that caters to the diverse needs of remote learners and educators.

Moreover, the comprehensive testing strategy, encompassing unit, integration, and system testing, underscores the commitment to quality and reliability. Employing the xUnit framework for testing not only streamlined the quality assurance process but also ensured that the system was thoroughly vetted for performance, security, and usability issues before its release. This rigorous testing protocol is instrumental in identifying potential issues early, thereby mitigating risks and enhancing the overall user experience.

The successful implementation of this distance learning system showcases the potential of the .NET Framework in developing complex, high-quality educational platforms. It stands as a testament to the efficacy of using structured development and testing methodologies to create software solutions that are both powerful and user-centric. As digital education continues to evolve, the insights and methodologies outlined in this article offer valuable guidance for future projects aimed at enriching the educational landscape through technology.

In conclusion, the journey from conceptualization to the realization of the distance learning system highlights the importance of a well-thought-out development process, leveraging cutting-edge technologies and best practices. It is a clear demonstration of how technical innovation, when guided by meticulous planning and rigorous testing, can transform educational paradigms, making learning more accessible, engaging, and effective for students around the globe.

REFERENCES

Burris, J. W., 2017. Test-Driven Development for Parallel Applications. In *2017 Second International Conference on Information Systems Engineering (ICISE)*, pp. 27-31.

Yogesh, T., Vimala, P., 2020. Test-Driven Development of Automotive Software Functionality. In *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)*, pp. 1162-1165.

Fontela, C., Garrido, A., 2013. Connection between Safe Refactorings and Acceptance Test Driven Development. *IEEE Latin America Transactions* 11(5): 1238-1244.

Guerra, E., 2014. Designing a Framework with Test-Driven Development: A Journey. *IEEE Software* 31(1): 9-14.

Amrit, C., Meijberg, Y., 2018. Effectiveness of Test-Driven Development and Continuous Integration: A Case Study. *IT Professional* 20(1): 27-35.

Moe, M. M., Oo, K. K., 2020. Evaluation of Quality, Productivity, and Defect by applying Test-Driven Development to perform Unit Tests. In *2020 IEEE 9th Global Conference on Consumer Electronics (GCCE)*, pp. 435-436.

Dookhun, A. S., Nagowah, L., 2019. Assessing The Effectiveness Of Test-Driven Development and Behavior-Driven Development in an Industry Setting. In *2019 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)*, pp. 365-370.

Viktorov, I., Gibadullin, R., 2023. The principles of building a machine-learning-based service for converting sequential code into parallel code. *E3S Web of Conferences* 431: 05012.

Kozlov, E, Gibadullin, R, 2023. Prerequisites for developing the computer vision system for drowning detection. *E3S Web of Conferences* 474: 02031.

Gorodova, J., Pachina, N., Tkachenko, S., Pachin, G., 2021. Digital Literacy in the Aspect of Continuing Teacher's Education. In *2021 1st International Conference on Technology Enhanced Learning in Higher Education (TELE)*, pp. 220-223.

Yoqubjonov, J., Gibadullin, R., Nuriev, M., 2023. Advanced robotic process automation for enterprise efficiency. *E3S Web of Conferences* 431: 07011.

Kondratiev, V., 2020. Fundamental Changes in Mathematics Education in the Context of Digital Transformation. In *2020 Ivannikov Ispras Open Conference (ISPRAS)*, pp. 75-77.

Shakirzyanov, M., Gibadullin, R., Nuriyev, M., 2023. Prerequisites for the development of the system of automatic comparison of video and audio tracks by the speaker’s articulation. *E3S Web of Conferences* 419: 02029.

Chituc, C. -M., 2022. An Analysis of Technical Challenges for Education 4.0 and Digital Education Ecosystems. In *2022 IEEE German Education Conference (GeCon)*, pp. 1-5.

Gibadullin, R. F., Perukhin, M. Y., Mullayanov, B. I., 2020. Optimization of water supply by the method with model predictive. In *2020 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)*, pp. 1-6.

Reflection as Part of a Distance Learning Lesson

Alexander Evdokimov[1][a] and Alena Shashkova[2][b]
[1]Herzen State Pedagogical University of Russia, 48 Moika River Emb., Saint Petersburg 191186, Russia
[2]Admiral Senyavin Maritime Technical Academy of St. Petersburg, 189 Narodnaya Opolcheniya Ave., building 1 lit.B., Saint Petersburg 198260, Russia
evdokimov89@gmail.com, shashkovaad@spbmtc.com

Keywords: Reflection, distance learning, interactive tools, survey tools, digital technologies

Abstract: The paper explores the possibilities of online survey tools in facilitating student reflection in distance learning. Today, reflection is an important part of a lesson plan and interactive tools are an effective alternative to surveys on comprehensive educational platforms. Dedicated survey tools allow to identify reflection as an individual, independent stage of a lesson plan. These tools are numerous due to the advances in digital technologies and free competition this industry offers. They may have some distinctive features, however, by and large, the online survey tools are very similar in interface and functionalities.

1 INTRODUCTION

At present, teaching and learning may be viewed as a synthesis of the 20th century traditional educational practices and dynamic digital environment of today. The effectiveness or even feasibility of this synthesis is evaluated differently by both researchers and agents of education. In spring 2020, almost all teaching and learning had to go online. This brought to light disadvantages as well as prospects for the development of online and distance learning. The paper focuses on reflection as the final stage of a comprehensive lesson plan and its implementation in digital environment. The study explores the possibilities of online survey tools in facilitating student reflection in distance learning. It discusses different survey tools and focuses on their advantages and disadvantages.

As a starting point, it is necessary to define the term "reflection". "Self-reflection" is a term that fits the context of our study. It is defined by the Oxford dictionary as a "serious thought about your own character and actions" (Oxford…, 1997). Pedagogy uses the following definition: "Building conclusions, generalisations, analogies, comparisons and evaluations, and also emotional experience, remembering and solving problems. It also includes addressing beliefs for interpretation, analysis, realisation of acts, discussion or evaluation" (Slastenin, 2002). Another popular definition of the term "reflection" is "building and maintaining awareness of a set of activities taking place during a lesson". Reflection may focus on the activities of a student or any other activities during the lesson, including the relationship between different types of activity. Reflection is different from self-evaluation as it is not limited to an individual's activity alone, instead, it encompasses the whole range of meaningful types of activity (Figure 1) (Hutorskoy, 2001). In modern educational environment reflection is part of the final stage of a lesson. At this stage students evaluate their activity during the lesson and determine if all the set goals have been achieved (Belkina, 2010).

[a] https://orcid.org/0000-0002-8871-4774
[b] https://orcid.org/0009-0005-9811-4675

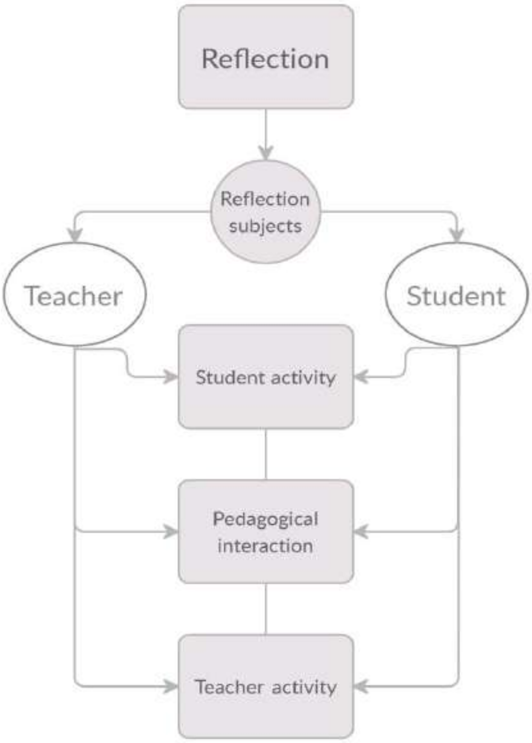


Figure 1: The structure of reflection in the pedagogical process.

2 PROBLEM

The instruments to encourage student reflection at the end of the lesson are diverse. They include "analogue" and digital tools as tests in a certain subject. "Analogue" tests are classroom paper-based tests, whereas digital tests require the use of individual devices and special survey tools that allow for distance testing. There is also a combined testing approach that uses digital technology yet requires students to be present in class. The best examples of the combined approach to facilitate student reflection are such services as Plickers or Classroomscreen (Figure 2) (Evdokimov et al., 2019). Our study focuses most on digital reflection tools applicable in distance and online learning.

Figure 2: ExitPoll Function Appearance (Reflection).

As is said above, reflective surveys in digital environment require two things — a device (usually a smartphone or a personal computer with access to the Internet) and an online platform with a survey developed by a teacher in advance. The evidence from educational institutions during the Coronavirus quarantine (April-June 2020) shows that most of them were unanimous about using a learning platform. In most cases an educational institution had already had some distance learning tools in use before the quarantine, e.g. Herzen University uses the learning platform Moodle. However, at times this centralized approach was breached and the teaching staff had to use other educational tools. As I see it, the major reason for that breach is the absence of a fully-functional, comprehensive virtual learning environment, however, I do not find it necessary to over-criticize such decentralization. Yet, whatever scenario we take, a special learning platform will almost always offer a testing option either to assess student knowledge and level of competences or facilitate reflection. Here, a question arises about whether it is necessary to use special survey tools for student reflection at the end of a lesson. Indeed, there is no specific need for that and the use of such tools is optional. However, using dedicated survey tools may help attain a number of goals, e.g.:

- identifying reflection as an individual, independent stage of a lesson plan;
- setting more clear boundaries between different stages of a lesson plan;
- highlighting optional use of reflection as a stage of a lesson plan.

These goals are not a mandatory part of teaching and learning process. For this reason, the use of independent survey tools is at the discretion of the teacher.

3 RESULTS AND DISCUSSION

Online survey tools that match the set goals are numerous. Below is the list of effective tools to promote reflection in distance and online learning. Functionally, the use of these tools is not limited to distance and online learning alone. They may be equally used in classroom teaching. All the listed tools are available as a free, limited version and a fully-featured paid edition. The tools are listed by popularity and number of hits in global search results.

- **Kahoot!** This is one of the most popular tools among online survey services. Kahoot! can be used to review students' knowledge, for formative assessment, or as a break from traditional classroom activities. Kahoot! also includes trivia quizzes (Evdokimov, 2020). Supposedly, one of the reasons for the popularity of Kahoot! is that it pioneered the market back in March 2013. This also explains why the tool is not free of disadvantages. For example, students cannot see survey questions on their device screens. Questions appear on the teacher’s screen (a projector in classroom teaching or a show-screen function in distance learning). This means that all the students have to answer the survey questions at the same time, which makes the tool applicable only for online learning. In general, the tool has shown to be effective, which explains its popularity in business.

- **Mentimeter.** This is another popular online survey tool. The app enables users to share knowledge and real-time feedback on mobile with presentations, polls or brainstorming sessions in classes, meetings, gatherings, conferences and other group activities (Wang et al., 2007). Mentimeter was launched in 2014, a year later than Kahoot!, and included several improvements to compensate for the disadvantages of the earlier service. Like Kahoot!, Mentimeter has positive reviews from teachers and other categories of users from across the world. I tend to believe that now these two services are top of the popularity ranking. Yet, there are other apps with similar functionalities. Among them are:

- **TallySpace.** Unlike other tools, TallySpace is a paid app (free trial period only). Another distinctive feature is SMS voting in offline mode. This can be convenient if a person, due to some characteristics, cannot fully use Internet applications (for example, due to age).

- **Meeting Pulse**

This is by far an incomplete list of online survey tools. It includes only the most popular services to conduct fast and effective surveys, including reflective surveys, as part of distance learning.

- **IQ Polls**

- **Wooclap**

- **Feedbackr**

- **Classtime**

4 CONCLUSIONS

Analysing student reflection is a complex and effort-consuming task. The results of the analysis depend on multiple factors. Primarily, the lack or presence of self-regulatory competencies in students and their ability of self-reflection guided by a range of question from a teacher. This allows to evaluate both the internal (acceptance, interpretation) and external outcome (a written paper, interaction with the agents of education) of the teaching and learning process (Rudolph, 2018; Karpov, 2003). The most effective forms of reflection combine analogue and digital approaches. However, the combined approach is only possible in classroom teaching. Distance and online learning can either employ digital tools to facilitate reflection or exclude reflection as an independent stage of a lesson plan. My personal experience with different online interactive survey tools, including reflective surveys, drew me to the conclusion that these platforms are very similar in interface and functionalities. The differences, if any, are minor and they are neutralised once teachers start using the tool.

REFERENCES

Oxford English Dictionary Additions Series Vol 3 1997. *The book*, Contains 3,000 new words and meanings from around the English-speaking world. Published by Clarendon Press.

Slastenin, V. A., 2002. Methodological reflection in pedagogical research, *Teacher education and science* 4 28-32.

Hutorskoy, A. V., 2001. *The book,* Pedagogy: a textbook for universities (Saint-Petersburg).

Belkina, V. N., Revjakina, I. I., 2010. Pedagogical Reflection as the Professional competence, *Yaroslavl Pedagogical Bulletin* - Volume II (Psychological and Pedagogical Sciences) 3 203-206.

Evdokimov, A. S., Korsunova, L. S., Orlova, I. A., 2019. Using the plirekrs service to monitor student progress, *Actual problems of chemical and environmental education* 66 83-87.

Evdokimov, A. S., 2020. ClassroomScreen online service at the lesson, *Actual problems of chemical and environmental education* 67 124-127.

Wang, A. I., Ofsdahl, T., Morch-Storstein, O. K., 2007. Lecture quiz-a mobile game concept for lectures International, *Conference on Software Engineering and Application*. IASTED 11 305–310.

Rudolph, J., 2018. A brief review of Mentimeter – a student response system, *Journal of Applied Learning and Teaching* 1 (1) 35–37.

Karpov, A. V., 2003. Reflexivity as a mental property and method of diagnosis, *Psychological Journal* 24 5 45-57.

Private Law Aspects of Personalized Medicine: Digitalization, Big Data, Artificial Intelligence

Inyushkin Andrey Alexeevich[a], Isakova Tatyana Sergeevna[b], Inyushkina Maria Nikolaevna[c], Kudasheva Polina Sergeevna[d], Inyushkin Alexey Nikolaevich[e]
Samara National Research University, Samara, Russia
inyushkin_a@mail.ru, isakova12k@gmail.com, 13lana13@mail.ru, kr-elena1203@mail.ru, ainyushkin@mail.ru

Keywords: healthcare, specialized medical care, personalized medicine, experimental legal regime, artificial intelligence, big data, telemedicine technologies, digitalization.

Abstract: This study examines the current state and prospects for improving the regulatory framework in the field of personalized medical care in the context of the development of advanced technologies and the implementation of new methods of providing high-tech specialized medical care. A system for regulating the provision of specialized medical care is being identified and established through the implementation of digital technologies and telemedicine. The study evaluates the optimization of the regulatory framework in the field of gene therapy and trends in the consolidation of legislation in the field of healthcare. The reasons for adjustments to the regulatory framework are analyzed in detail, and the impact of the application of experimental legal regimes on the field of healthcare is examined. The analysis of law enforcement acts, as well as their impact on the prospects for improving the legal regime in the field of personalized medicine, is provided. Conclusions are drawn about the need to maintain a balance in private and public law relations associated to the provision of specialized medical care, including the use of telemedicine technologies, artificial intelligence, and big data. It is established that the analysis of the practice of applying special legal regimes for the introduction of advanced medical technologies contributes to the development of private law regulation, as well as creates a basis for adjusting related regulations in the field of digitalization and information flow.

1 INTRODUCTION

The development of a personalized medicine system is increasingly causing problems in legal regulation. At the same time, the healthcare system is largely connected with the private law foundations of newly emerging public relations. The emergence of new high-tech means of providing medical care, combined with widespread digitalization, give rise to a set of public relations at the intersection of private and public law. The adopted Decree of the President of the Russian Federation dated February 28, 2024 No. 145 “On the Strategy for Scientific and Technological Development of the Russian Federation” lists the transition to personalized, high-tech medicine, health-saving technologies, including those based on genetic and other technologies, among the priorities of scientific and technological development of the Russian Federation for the next decade. Such long-term tasks require a systematic understanding of the current regulatory framework, its updating to meet the challenges of the time, as well as the formation of conceptually new approaches to contractual structures in the field of healthcare. In the present work, we have made an attempt to analyze the system of private law relations in the field of personalized medicine and establish their relationship with digitalization, big data and artificial intelligence. These technologies are the driver of development in the vast majority of sectors of the economy, including

[a] https://orcid.org/0000-0001-8564-4275
[b] https://orcid.org/0009-0008-2389-2749
[c] https://orcid.org/0009-0001-2959-0150
[d] https://orcid.org/0009-0006-2801-3892
[e] https://orcid.org/0000-0002-3678-2636

the healthcare system. That is why the analysis of legislation in these segments of public relations is one of the priorities for the development of personalized medicine and the healthcare system as a whole.

2 RESEARCH METHODOLOGY

The present study is based on general and special methods of legal research. In particular, when analyzing the private law grounds for the formation of relations in the field of personalized medicine, special industry methods of legal science were used, such as the method of legal modeling and the method of comparative law. When analyzing the system of legal regulation in the field of personalized medicine, formal-logical, historical, systemic and functional research methods are used. In particular, to determine the trends in the development of regulatory framework in the field of digitalization of personalized medicine, a historical method is used, which allows us to trace the adjustment of legal definitions in this area. The main sources of the conducted research include the Civil Code of the Russian Federation, Federal Law No. 149-FZ dated 27.07.2006 (as amended on 12.12.2023) "On Information, Information Technologies and Information Protection", Federal Law No. 323-FZ dated 21.11.2011 (as amended on 25.12.2023) "On the Basics of Public Health Protection in the Russian Federation" (with amendments and additions, entered into force on 05.01.2024), Federal Law No. 258-FZ dated July 31, 2020 (as amended on 02.07.2021) "On Experimental Legal Regimes in the field of digital innovations in the Russian Federation", Federal Law No. 86-FZ dated 05.07.1996, (as amended on 02.07.2021) "On State Regulation in the field of genetic engineering". The systematic research method in this work makes it possible to identify trends and prospects for optimizing legal structures, as well as to establish the main methodological approaches to improving the body of laws. Separately, it is necessary to highlight the use of the method of legal prediction, which made it possible to establish directions for improving law enforcement in the field of digitalization of healthcare and analyze the decisions of executive authorities, in particular the Chamber for Patent Disputes.

3 RESULTS OF THE STUDY

Federal Law No. 323-FZ dated 21.11.2011 "On the Basics of Public Health Protection in the Russian Federation" is a system-forming regulatory act in the field of healthcare of the Russian Federation. Given the public law orientation in the field of regulation, it often undergoes significant adjustments. The latest amendments were introduced by Federal Law No. 678-FZ dated 25.12.2023 "On Amendments to Article 20 of the Federal Law "On the Basics of Public Health Protection in the Russian Federation", which come into force on 05.01.2024. At the same time, a large number of changes in recent years have been associated with the widespread digitalization of various spheres of social and economic relations. The sphere of healthcare regulation is no exception, and the legislative framework for the provision of specialized medical care has undergone significant changes. Among the most significant novelties are the provision of medical care using telemedicine technologies, as well as the provision of specialized high-tech care. Article 36.2 “Features of medical care provided using telemedicine technologies” was introduced by Federal Law No. 242-FZ dated 29.07.2017 and legislated the remote format of providing medical care using digital technologies. The provisions of this article regulate the general procedure for providing telemedicine care, and also establish the circulation of information during its provision, including the obligation to document medical information, maintain medical confidentiality, and protect personal data. The reference provision to Federal Law No. 258-FZ dated July 31, 2020 "On Experimental Legal Regimes in the field of digital innovations in the Russian Federation" is directly fixed. These provisions are built in a system of balancing private and public interest, as they allow, on the one hand, to ensure an appropriate level of medical confidentiality, and on the other hand, to guarantee participants in the healthcare system the formation of a structure of relations based on private law principles. The dispositive principles contained in the legislation on experimental legal regimes form optimal conditions for the legal regime of telemedicine technologies, since they are based on the structure of legal relations characteristic of civil law relations. The subject composition and the system of relationships in the experimental legal regime has a civil law bias. In this sense, the introduction of digital innovations through such a legal structure seems optimal. The allocation of a special legal regime provides a certain set of guarantees for entities implementing telemedicine technologies by establishing clear frameworks for the application of the relevant legal regime. Such guarantees are achieved, in particular, by standardizing the basic definitions for both subjects participating in experimental legal regimes and for the basic elements of the entire legal relationship. The introduction of telemedicine care and the digitalization of the healthcare system have significantly expanded the boundaries of medical care. The public law component, characteristic of the regulatory system in the field of healthcare, is reflected in the regulation of the procedure for providing appropriate medical care. The Order of the Ministry of Health of Russia dated 30.11.2017 No. 965н "On approval of the procedure for organizing and providing medical care using telemedicine technologies" explained in detail the nature of the relationship between the subjects participating in the healthcare system when using telemedicine technologies. It is worth noting the balance in the regulation of these relations and the absence of a public law bias, which is typical formedical law. The use of the existing terminology of the Federal Law dated 27.07.2006 No. 149-FZ “On Information, Information Technologies and Information Protection” is positive when describing relations arising with organizations using information systems in the field of telemedicine technologies. The direct consolidation in paragraph 46 of the Order of the Ministry of Health of Russia dated 30.11.2017 No. 965н "On approval of the procedure for organizing and providing medical care using telemedicine technologies" of the status of an information system operator for consulting medical organizations, as well as for other organizations related to telemedicine, makes it possible to apply all relevant legal guarantees for patients when providing them with medical services in digital form. The use of digital telemedicine technologies creates the need to build a hierarchy of the system of application of regulations in this area. Clause 5 of Article 36.2 of the Federal Law dated 21.11.2011 No. 323-FZ "On the Basics of protecting the health of Citizens in the Russian Federation" regulates the protection of personal data and medical confidentiality when providing medical care. This provision must be taken into account when making audio or video recordings during consultations using information and telecommunications networks, including the Internet. The existence of such records raises the question of their potential use by executive authorities exercising supervisory functions, as well as law enforcement agencies in the exercise of their powers. The absence of a normative distinction between special provisions on medical confidentiality and the body of laws with a public-law orientation related to the investigation and collection of documented information in the criminal law sphere, allows to make a conclusion that there are shortcomings in the established system of legal regulation. It should be noted that there are controversial situations in the private law sphere, which are reflected in law enforcement practice. An example of such situations is the emerging relationship regarding the legal protection of intellectual property in the field of high-tech medicine and the use of telemedicine services. The development of commercial activities in providing paid medical consultations in digital format gives rise to the need for the subjects participating in these relations to secure rights to the means of individualizing their services. From this point of view, the Conclusion of the Chamber for Patent Disputes dated 14.07.2022 (Appendix to the decision of Rospatent dated 07.09.2022 on application No. 2020755569) “On the cancellation of the decision of Rospatent and registration of a trademark”, which considered a dispute over the registration of the AIRADIOLOGY trademark, is indicative. The Federal Service for Intellectual Property refused to register this trademark, since the combination of symbols in the form of the abbreviation "AI" - artificial intelligence and the word "radiology" did not comply with the provisions of paragraph 1 of Article 1483 of the Civil Code of the Russian Federation, since in general they did not have a distinctive ability for the declared goods and services. The formation of a system for protecting intellectual rights to individual medical technologies creates the need to take into account the rights of an indefinite circle of people. This is why the initial refusal of Rospatent in this case seems entirely justified, and the Conclusion of the Chamber for Patent Disputes, which corrected the initial decision of Rospatent on the submitted application, is indicative. Thus, in practice, the balance of private and public interests is ensured, which, with the active introduction of digital technologies in the field of healthcare, poses objective difficulties in legal regulation. The adjustment of legal provisions in the field of regulation of genetic engineering activities of the Russian Federation is also indicative. The adoption of Federal Law No. 643-FZ dated 29.12.2022 "On Amendments to the Federal Law "On State Regulation in the Field of Genetic Engineering Activities" has significantly adjusted approaches to the regulation of gene therapy, which is closely related to the digitalization of the healthcare system. All issues related to the provision of appropriate medical care will be regulated through regulatory acts in the field of healthcare. Thus, one of the trends in healthcare regulation is the consolidation of provisions in the field of medicine in one regulatory act. The adopted changes significantly optimize the issues of circulation of genomic data, which from 1.09.2024 will be recorded in the State Information System in the field of genetic information "National Database of Genetic Information".

4 RESULTS AND DISCUSSION

The results obtained in this work clearly demonstrate the difficulties in building a healthcare regulatory system. Significant problems arise when introducing advanced technologies and providing specialized high-tech medical care. As some authors rightly point out, a telemedicine consultation should be preceded by medical organizations obtaining voluntary consent from patients to provide medical services in digital form with a detailed description of the methods for depositing the information received during the consultation, as well as procedures for maintaining medical confidentiality (Poduzova, 2023; Dikarev, 2009; Solov'ev, 2012). The digitalization of healthcare and the introduction of new methods of providing specialized medical care, including gene therapy, require the improvement of legislation both in the field of genomic data circulation and in the field of information security and big data (Borodin, Inyushkin, 2020; Rassolov, CHubukova, 2020; Lyutov, 2021; Inyushkin, Inyushkin, Ruzanova, Belyakov, Kryukova, 2019). This approach to adapting the system of legal regulation in the field of healthcare to current realities will most likely lead to the formation of an optimal legal regime for the introduction of personalized medicine. Such regulatory trends are typical for any period of the introduction of new technologies and the formation of qualitatively new public relations between medical organizations, doctors and patients. Optimization of the regulatory framework in the field of artificial intelligence, big data, for the needs of personalized medicine, which is going through the stage of experimental legal regimes, seems extremely timely and justified. One should agree with the opinion of individual researchers who describe in detail the need to apply such barriers when adjusting the legislative framework (Dmitrik, 2020; Handrlica, Sharp, Nešpor, 2023; Goo, Heo, 2020; Undheim, Erikson, Timmermans, 2023). The application of experimental legal regimes in the field of medicine has a very positive effect on the development of the technologies analyzed in this work. Thus, the introduction of artificial intelligence systems in the field of medicine is one of the main directions for the development of strong artificial intelligence. Therefore, further research into the regulation of strong artificial intelligence in healthcare seems extremely promising.

4 CONCLUSION

Based on the analysis carried out in this work, it can be argued that the digitalization of healthcare significantly affects the legislative system in this area. The development of personalized medicine forms qualitatively new social relations that require revision in approaches to legal regulation. The acts adopted by executive authorities compensate to a certain extent for the lack of a legislative framework, and the use of experimental legal regimes makes it possible to guarantee a balance between private and public interests in the field of medicine. When forming a system of private legal regulation of relations in the field of personalized medicine and the implementation of related telemedicine technologies, there are regulatory issues related to ensuring the proper level of confidentiality of personal data and medical secrecy. Determining the hierarchy of regulations when systematizing the legal regulation of the healthcare sector, including the provision of high-tech medical care, is a systemic problem that gives rise to reasonable discussions characteristic of various legal systems and states. The development of genetic engineering and its applied medical aspects are significantly related to the digitalization of the healthcare system. The formation of specialized information systems and the development of rule-making in this area make it possible to adapt the legislative framework to the needs of the subjects participating in relations in the field of providing high-tech medical care. The trend towards consolidation of the legislative framework in the field of healthcare within the framework of one single legislative act and the exclusion of regulations related to gene therapy from other federal laws should be recognized as effective. The use of artificial intelligence systems and big data in the field of medicine stimulates a significant increase in digitalization in the field of healthcare. The emergence of new technologies with a private law regime in the public law areas of public relations clearly demonstrates the need to optimize the legislative framework not only in special industry regulations, but also in basic codified ones. Such adjustments will significantly simplify the interaction between participants in the provision of specialized medical care and will allow them to fully exercise their rights.

ACKNOWLEDGMENT

The study was supported by the Russian Science Foundation (Grant No. 23-28-00720).

REFERENCES

Poduzova, E.B., 2023. Ohrana informacii, sostavlyayushchej vrachebnuyu tajnu, v sfere primeneniya tekhnologij iskusstvennogo intellekta v digital-medicine. *Aktual'nye problemy rossijskogo prava*. № 6. S. 68 - 74.

Dikarev, I.S., 2009. Vrachebnaya tajna v ugolovnom sudoproizvodstve. *Rossijskaya yusticiya.* № 4. S. 66 - 69.

Solov'ev, I., 2012. Osobennosti pravovogo rezhima dostupa k vrachebnoj i auditorskoj tajne. *Nalogovyj vestnik.* № 7. S. 52 - 58.

Borodin, S.S., Inyushkin, A.A., 2020. Genomnye issledovaniya i genomnoe redaktirovanie v aspekte formirovaniya effektivnogo pravovogo rezhima. *Pravovoe gosudarstvo: teoriya i praktika*. № 2 (60). S. 19 - 31.

Rassolov, I.M., CHubukova, S.G., 2020. Zashchita geneticheskih dannyh pri geneticheskom testirovanii i genoterapevticheskom lechenii: informacionno-pravovye aspekty. *Aktual'nye problemy rossijskogo prava*. № 5. S. 65 - 72.

Lyutov, N.L., 2021. Zapret geneticheskoj diskriminacii i zashchita geneticheskih personal'nyh dannyh: perspektivy modifikacii norm trudovogo prava. *ZHurnal rossijskogo prava.* № 10. S. 72 - 84.

Inyushkin, A.A., Inyushkin, A.N., Ruzanova, V.D., Belyakov, V.I., Kryukova, E.S., 2019. Circadian genes: information and legal issues. The 21st Century from the Positions of Modern Science: Intellectual, Digital and Innovative Aspects. ISC 2019. Lecture Notes in Networks and Systems, vol 91. Springer, Cham. pp 30 - 37.

Dmitrik, N.A., 2020. Eksperimental'nye pravovye rezhimy: teoretiko-pravovoj aspect. *Zakon.* N 6. S. 64 - 72.

Handrlica, A., Sharp, V., Nešpor, J., 2023. Forum shopping in regulatory sandboxes and the perils of experimental law-making. *Juridical Tribune.* Vol. 13. Issue 3. PP. 408 - 426.

Goo, J.J., Heo, J.-Y., 2020. The impact of the regulatory sandbox on the fintech industry, with a discussion on the relation between regulatory sandboxes and open innovation. *Journal of Open Innovation Technology Market and Complexity*. Vol. 6, Issue 2, 43.

Undheim, K., Erikson, T., Timmermans, B., 2023. True uncertainty and ethical AI: regulatory sandboxes as a policy tool for moral imagination. *AI and Ethics.* Vol. 3. pp. 997 – 1002.

Theoretical Foundations for Analyzing Problems of Macroregional Innovative Development and Ways to Solve Them

Ivanov M.Yu.[a], Lobova V.V.[b]
Bratsk State University, Makarenko St., Bratsk, Russia
libmann.52@gmail.com, varya.lobova.04@mail.ru

Keywords: Economy, Management, Scientifically-Educational Centers, Knowledge, Competencies.

Abstract: The paper presents the results of research into the economic foundations of the creation and development of scientifically-educational centers (SEC) in the global crisis. The prerequisites for the emergence and the role of SEC according to the diffuse model (bell curve) of innovation by E. Rogers are analyzed. It is established that SEC participants and project teams can be a kind of trendsetters (early adopters) between innovators and the rest of the community. The possibility of using the method of determining the technology readiness (maturity) level (TRL) in the development of high-tech knowledge-intensive products is shown, while the drivers and limiters of TRL in Russia, the SEC's area of responsibility according to the TRL levels and the specifics of the implementation of innovative projects in general are revealed. Using the example of the world-class interregional SEC "Baikal" as an example, the principal tasks of SEC functioning for the purpose of perspective transformation of natural and economic potential of the macroregion (Irkutsk region and the Republic of Buryatia) are formulated: motivation of participants, engineering and knowledge ranking, design, assembly and development of competencies in the field of integrated processing of wood and wood waste.

1 INTRODUCTION

It is known that the development and successful activity of any organization or country are largely determined by the strategy adopted in them - a set of methods and means of solving prospective long-term tasks.

The modern global economy, built on a longstanding trend of constantly increasing demand, is not at its best. The vast majority of enterprises are forced to focus not on accumulating and developing their assets, but on finding opportunities to do business in the conditions of falling markets, changing sales channels and production chains.

The cost of making inefficient decisions is also increasing. The main losses of organizations are not from market conditions and external economic factors, but from the mistakes of managers who do not know how to properly allocate available resources and try to "fit" the activities of the enterprise to the framework known only from the position of the standard academic education received earlier.

Managers who develop development strategies do not have the necessary competencies and do not understand how the infrastructure of the global production and consumption system is changing, so they often substitute strategic decisions with situational ones that have only a short-term effect or do not play a role at all, based on the principle of "decision for decision's sake".

The education and training level of classical specialists is not modified for the specifics and needs of the crisis economy. For the development of business strategy it is important to understand how it fits into the global model of demand, how the market will be transformed in the current conditions. After all, the market, according to the liberal model of social policy adopted in developed countries, is the most effective economic mechanism. At present, not only new goods and services are important, but also a competent program of balanced functioning of enterprises and regions (macroregions) (Antipina and etc., 2020), as well as advanced tools for the development of performers' competencies.

[a] https://orcid.org/0000-0003-0538-7083
[b] https://orcid.org/0000-0002-8706-8395

2 RESEARCH METHODOLOGY

System analysis to find out the causes of existing difficulties, setting goals, solving problems of macroregional innovation development by using the potential of SEC. Method of determining the level of readiness (maturity) of technologies to formulate and "repackage" the true objectives of SEC functioning.

3 PROBLEMS AND GOALS OF INNOVATIVE DEVELOPMENT OF REGIONS (MACROREGIONS)

As noted above, the world economy is based on demand, which, in turn, today does not correspond to the level of income of the population.

Monetary and credit emission are the alphabetical ways to solve the crisis, but the effectiveness of these instruments has long been lost. Thus, monetary emission only increases inflation, while credit emission and increase in the bank multiplier contribute to the problem of underpayments.

Today there are affordable loans for small and medium-sized businesses, but the demand for them is still low, because the real capitalization of assets does not coincide with the expectations of their owners. In other words, the assets of enterprises are depreciating, but debts are not.

For example, real estate properties that do not generate income may become unprofitable because there will always be expenses (Bogatyreva and etc., 2022; Zakharov and etc., 2021). It is necessary to pay utilities and taxes in any case, even if no one lives in the hotel or apartment. This results in a paradoxical situation when the cost of credit is decreasing, while debts are constantly growing, because the accumulated debt can only be serviced at a 0% interest rate in a falling market.

If there is no demand for basic product groups, the demand for related services decreases. And along with commodity markets, labor markets are also falling. Employers determine for themselves how much they are ready to pay based on their current capabilities, and are not at all aimed at meeting the real needs of employees. Moreover, "narrow" specialists who possess a limited set of competencies for solving specific tasks are in a special risk group.

In the current situation, the correct goal-setting and diversification of enterprises' assets, i.e. the search for alternative capital, are necessary, since the process of reproduction of traditional capital may be postponed indefinitely or not start at all.

A comprehensive analysis of the problems of the world economy allows us to formulate the following objectives facing the modern management system:

- development of environmentally neutral technological processes of the future ("green" technologies);
- increasing the share of knowledge-intensive products to meet the qualitatively new demands of consumers;
- scientific organization of work and development of production culture, allowing to significantly increase the productivity of enterprises without significant costs;
- more efficient realization of natural and economic potential, through the creation of regional and macroregional associations and clusters (Bovkun and etc., 2020).

It is easy to see that the first two goals require innovation and significant investment. Innovation and investment are known to be closely linked to the size of markets. The larger the market, the more likely it is that investments will pay off. If the market shrinks, then all the sophisticated innovations and knowledge-intensive technologies become of little use.

What are the peculiarities of innovation projects? In addition to the obvious novelty and high degree of risk, there is also a significant problem of changing the required competencies in the course of the full innovation cycle, since its subject is usually a high-tech product. Consequently, the success of a complex innovation project depends not only on investments, but also on the quality of human capital and the implementation of an anthropocentric design approach.

4 SEC POTENTIAL AS A WAY OF INNOVATIVE DEVELOPMENT OF MACROREGIONS

One of the tools for solving the goals set for the modern management system, widely used in recent years, is the creation of SEC.

SEC is an association of leading scientific and educational organizations with the economic sector to provide world-class research and development, obtain new competitive technologies and products and their commercialization, training of personnel to solve major scientific and technological problems in the interests of the development of science and technology industries on the priorities of national technological development.

The reasons and prerequisites for the creation of the SEC are quite diverse. Thus, the traditional provision of science exclusively at the expense of the state does not give the desired effect. Both funds are insufficient, and the results of research and development are not always oriented to the end user. In other words, in the vast majority of cases, the state finances process rather than result-oriented science, which makes it impossible to maintain the required level of the country's development, including through import substitution. The quality of domestic scientific research, no matter how cynical it sounds, should be measured not by the astronomical number of patents and articles, but by the number of results that reached the real sector of the economy. Consequently, researchers should be primarily focused on the possibility of applying the new knowledge obtained, rather than striving for a permanent increase in scientometric indicators.

It is known that fundamental scientific research generates knowledge, and the search for directions of using this knowledge is carried out with the help of applied scientific research. In the past, these tasks were solved with the help of the sector of applied sectoral institutes. Nowadays, the SECs can take over the search for the use of knowledge, acting in highly competitive markets, and doing so on a continuous rather than occasional basis.

SECs are also indispensable in the constituent entities of the Russian Federation, since the regional leadership cannot physically interact with a multitude of science and business organizations, and is in dire need of one consolidated representative.

Returning to the topic of innovation, it should be noted that innovators, due to the lack of necessary competencies, represent only the beginning and the end of the path, and not the entire intermediate chain. When it is said that finances are needed, it is necessary to understand who can provide them. Potential investors often do not see the prospects or have no idea where and at what stage of the innovation process financing is needed.

Thus, the SEC's practical role is to determine the type and level of assistance to developers and corporations, to "deconstruct" complex knots.

It is advisable to develop knowledge-intensive products and breakthrough technologies using internationally recognized methods and tools, which will enable the SEC to participate more effectively in jointly solving the tasks at hand. One such unified tool is, in particular, the TRL method. TRL provides a consistent and uniform discussion of the technical maturity of different types of technologies, examining program concepts, requirements, and demonstrated technological capabilities of a project (Héder, 2017). TRL levels are measured on a scale of one to nine, where level nine demonstrates the most mature stage of technology (Figure 1).

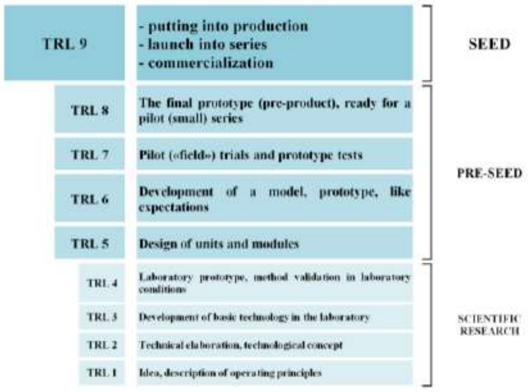


Figure 1: Readiness (maturity) levels of TRL method technologies.

TRL was developed by the National Aeronautics and Space Administration in the 1970s to implement U.S. space programs. Over the years, the method has been modified several times and has become more accessible and versatile. The specificity and complexity of TRL has gradually decreased as its use has expanded beyond its original purpose. The European Association of Research and Technology Organizations recommended in 2010 that TRL be adopted to evaluate innovation projects funded by EU countries (Kasner, 2021). But it was not until 2013 that TRL was formalized by the International Organization for Standardization with the publication of ISO 16290: 2013 (Ribeiro, 2022). It should be noted that some levels of TRL may not be relevant to a single project at all due to the specifics of its implementation.

It is logical to assume that the SEC, by virtue of the purpose of its creation, covers the final two levels of the research and investigation phase and the fully "pre-seed" phase (levels TRL 3 through TRL 8).

SEC also brings together a kind of trendsetters, who play the role of a transmission link or, according to E. Rogers' diffuse model (bell curve) of innovation (Rogers, 2003), early adopters between innovators and the rest of the community (Figure 2). It is the trendsetters who provide the most significant leap and success of knowledge-intensive products in the market as a whole.

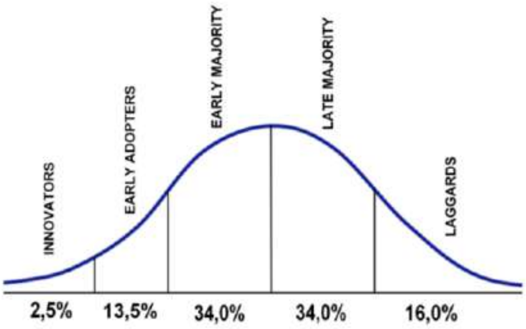


Figure 2: Diffuse model of innovations by E. Rogers.

TRL, in addition to the obvious advantages, has disadvantages, the main of which is that this method is poorly combined with total control, characteristic not only for Russian enterprises in particular, but also for the state in general (Figure 3).

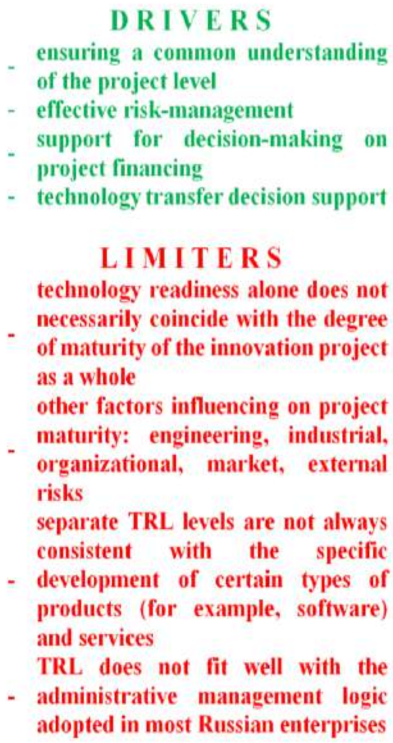


Figure 3: Drivers and limiters of TRL method application.

The SEC's activities should not clearly follow a constructed administrative logic of governance, as the purpose of the SEC is to address the problems of the venture economy (Richardson and etc., 2021; Santoso and etc., 2022), to bring together and ensure the interaction of potential stakeholders of innovative projects.

In view of the above, the principal objectives of the SEC should be considered to be:

- search for the most significant sectoral and regional problems and increase the role of knowledge in their solution;
- structuring the problems of the world economy into a familiar form for scientists;
- knowledge engineering;
- creation of knowledge bases and ranking of knowledge by enterprise and industry problems, management levels and economic effect;
- development of universal rather than highly specialized competencies, as even federal state educational standards do not always offer ready-made competencies capable of "covering" all the problem areas of industrial partners;
- integration of knowledge and competence bases in the SEC's areas of activity;
- assembling and developing competencies;
- motivation and cognitive development of SEC participants, training of project managers and project teams to implement breakthrough technologies.

In 2021, Bratsk State University (BrSU) as a participant of the world-class interregional SEC "Baikal" of the Irkutsk region and the Republic of Buryatia in the following areas of activity started to realize the above tasks:

- integrated wood processing;
- recycling of industrial waste;
- AgroBioPharmTechnologies.

In 2022, BrSU opened the Competence Development Center (CDC), designed to provide analysis of the state and assistance in meeting the future staffing needs of SEC participants and potential external customers of scientific and (or) scientific-technical products, taking into account both current and anticipatory directions of development of socio-economic policy of regions (macroregions).

The scope of CDC activity is participation in the implementation of educational and scientific-technical programs of SEC with the use of network and project forms of training, image building, increasing the intellectual potential of SEC, as well as other educational organizations of higher education, enterprises of the real sector of the economy, state and local authorities.

CDC's main goals are:

- increasing professional and managerial competence of managers of scientific-innovative, scientific-technical projects and laboratories (centers) and the sphere of technological entrepreneurship;

- assisting and advising SEC participants in providing a systematic approach to training motivated leaders and teams to implement complex projects and respond to big challenges;

- generation and ensuring the transfer of new approaches and technologies of training of managerial personnel engaged in research and development.

In 2023, BrSU scientific and pedagogical staff at the CDC implemented additional professional advanced training programs "Integrated wood processing" and "Integrated wood waste processing" and graduated students capable of solving actual problems of the forest industry in Russian regions in the following areas:

- waste and low-quality wood as additional raw materials;
- process wood chips, production of wood chips, requirements for process wood chips;
- additional technological processes of waste utilization, procurement and production of raw materials for the chemical industry;
- ways to quantify additional woody raw material at the harvesting site;
- types of woodworking waste, classification, qualitative and quantitative composition;
- wood-based panel and fiberboard materials;
- wood composite materials and wood polymer-composite materials based on the use of wood processing waste;
- energy utilization of woody biomass.

Currently, thanks to the support of the Fund for Strategic and Innovative Development of the Irkutsk region, which is the project office of the world-class interregional SEC "Baikal", the material and technical equipment of the CDC and the development of new programs for the development of competencies of employees of industrial partners continue.

5 CONCLUSIONS

It is impossible to give an answer to two eternal questions - "who is to blame?" and "what to do?". However, it is no longer important who is to blame. When the ways to resolve the global crisis have been exhausted, only the second question remains relevant - "what to do?".

Russian enterprises in the vast majority of cases cannot rank the existing problems and competently allocate resources for their elimination. Business solves private, not global, problems. Such tactics allow survival, but at the same time deprive them of the opportunity to develop.

Enterprises lack specialists who know how to set tasks correctly. When developing a market strategy, managers appeal to problems rather than to knowledge and competencies.

The way out of this situation may be the maximum use of the results of scientific research to increase productivity, develop the quality of products and services in order to gain a competitive advantage.

The paper considers the background to the creation and prospects for the development of SEC, designed to "plug the hole" between science and business and build a chain, during the passage of which knowledge increases its maturity.

The scientific novelty of the research is the formulated true objectives of SEC functioning in order to ensure macroregional innovation development, and these objectives are taken not on a formal basis from the statutory documents, but "repackaged" based on the state of modern economy.

REFERENCES

Antipina, O.V., Kleymenova, L.V., Deich, V.Yu., 2020. Assessment of the Budget Independence of the Territories. *International Conference "Trends and Innovations in Economic Studies"*. European Proceedings of Social and Behavioral Sciences.

Bogatyreva, M.V., Kudashkin, V.A., Metelitsa, V.I., 2022. Project Funding as an Alternative Way to Attract Investment in the Construction Industry. *AIP Conference Proceedings.*

Zakharov, S.V., Ivanov, M.Yu., ShuiYao, Xu, Rebrikova, A.V., 2021. Special Economic Zones and the Role of Construction Industry Enterprises in their Creation. *Conference Series: Earth and Environmental Science*. Journal of Physics.

Bovkun, A.S., Shupletsov, A.F., Vakhrusheva, M.Yu., Arkhipkin, O.V., 2020. Features of Effective Development and Support of Small Businesses in Single-Industry Towns. *International Conference "Trends and Innovations in Economic Studies"*. European Proceedings of Social and Behavioral Sciences.

Héder, Mihály., 2017. From NASA to EU: the Evolution of the TRL Scale in Public Sector Innovation. *The Innovation Journal*.

Kasner, R. and Bałdowska-Witos, P., 2021. Evaluating the Technology Readiness of a Ribbon-Blade Wind Turbine Using Nasa's TRL Method. *Materials*.

M.E. Ribeiro, Frey, I.A., Azevedo, P., 2022. Classificação das Patentes em Universidades Federais na Escala TRL (Technology Readiness Level): Estudo de Caso a Partir da Norma ISO 16290: 2013. *Cadernos de Prospecção*.

Rogers, E.M., 2003. *Diffusion of Innovations*, Simon and Schuster. New York.

Richardson, M., Gorley, M., Wang, Y., Aiello, G., Pintsuk, G., Gaganidze, E., Rieth, M., Richou, M., Henry, J., Vila, R., 2021. Technology Readiness Assessment of Materials for Demo In-Vessel Applications. *Journal of Nuclear Materials*.

Santoso, S., Siswanti, I., Nurhidajat, R., Isa, S.M., Marfatah, M.R., 2022. Measuring Model of Infrastructure Provision Readiness With Sharia PPP Financing Scheme Using the IRL and TRL Concept Approach. *IQTISHODUNA: Jurnal Ekonomi Islam*.

Sustainable Development Goals: Criteria and Prospects for Economic Growth of Turkmenistan

Shemshat Saparova[a], Yulduz Nurgeldiyeva[b]
Department of Scientific affairs, International university for the humanities and development, Ashgabat, Turkmenistan
scientific.affairs.iuhd@gmail.com

Keywords: Turkmenistan, sustainable development goals, economic sectors, environmental protection.

Abstract: Turkmenistan's economy is undergoing significant changes as it moves towards sustainable development. By aligning with these objectives, Turkmenistan can leverage opportunities for long-term prosperity and environmental stewardship. The country's economic transformation is characterized by a shift towards diversification, innovation, and sustainability. Key factors driving this transition include investment in renewable energy sources, infrastructure development, and the promotion of a more diverse economy beyond traditional sectors. Turkmenistan's commitment to sustainable development is evident in its efforts to reduce carbon emissions, improve resource management, and enhance economic resilience. By embracing a sustainable development framework, Turkmenistan aims to create a more resilient and prosperous economy that balances economic growth with environmental protection, social progress.

1 INTRODUCTION

One of the most important goals of the economic policy of independent Turkmenistan is to stimulate the power of the national economic complex, to maintain its rates at a stable and optimal level. Economic theory develops many dynamic models of economic growth, which help to investigate the conditions for achieving the optimal rate for the country and to develop an effective long-term economic policy.

The construction of any economic model and market transformation begins with the adoption of national plans for the long term and state laws regulating the ongoing innovative economic and social processes. In this regard, it should be emphasized that the wise and far-sighted economic and social policy pursued by Hero-Arkadag Gurbanguly Berdimuhamedov is bringing tangible results. At the Extraordinary Meeting of the Khalk Maslakhaty Mill Gengesh of Turkmenistan held on February 11, 2022, the main directions of development of the state and its institutions for the next 30 years (2022-2052) were considered and approved. This historic Program is a kind of continuation of the chosen path of development of the country on the path of progress. "In the era of new Renaissance and great transformations and the era of might and happiness, we have realized large-scale social, political and economic reforms. In our politically stable and united society, the native people confidently realized the set goals, thanks to which we were able to achieve sustainable political, economic and social development"[2], - noted in his speech Hero - Arkadag Gurbanguly Berdimuhamedov.

Specific tasks outlined in the program document are designed to ensure stable and balanced development of a socially-oriented national economy under conditions of a systematic, soft, and shock-free full transition to market relations. Successful implementation of this Program should contribute to further strengthening of the national economy, its transformation from a raw material economy into an innovative one, based on modernized high-tech industry, which is an indispensable condition for ensuring radical improvement of living conditions and increasing the welfare of the people.

Consistent implementation in modern life of the strategic course on innovative development of all spheres of the economy is a guarantee of the economic independence of the Turkmen State. It has

[a] https://orcid.org/0009-0002-5999-5199
[b] https://orcid.org/0009-0001-0361-8805

become possible in the current conditions of global economic recession, unforeseen and sharp decline in prices for leading energy resources, to maintain competitiveness and steadily develop many sectors of the economy, as well as to create new areas of the national economic complex. At the present stage, the priority task is to continue the consistent implementation of state programs for the production of import-substituting products and to increase the volume of exports of products manufactured in Turkmenistan.

Under the State Program to increase the volume of exports of products, numerous projects are planned to be implemented. New production facilities are being created, aimed at high technological development of the chemical industry, light industry, machine building, agriculture, food and pharmaceutical industries. There is a gradual establishment of processing industrial production based on innovations, integrated use of natural and mineral resources. In this context, a number of industries aimed at the production of import-substituting and export products based on local raw materials are already functioning. Examples include the operation of the world's only plant for the production of environmentally friendly gasoline from natural gas in Ovadandepe, Akhal province, as well as the commissioning of textile complexes in the Kaahki and Babadaikhan districts in 2021 with the participation of foreign companies.

The State Program on production of import-substituting products in Turkmenistan envisages implementation of more than 81 projects. Within its framework, modern enterprises are already being built and put into operation to produce a wide range of construction, chemical, household and other products based on local raw materials. In addition, we can see the results of labor of enterprises for processing and production of various types of meat and dairy products, fruit and vegetable and fish products.

The world community has a rich historical experience of organization of economic life at both macro- and microeconomic levels. The first and most superficial analysis of this experience reveals that the forms of organization of economic life of society at all levels are complex and diverse. In the millennium in which we live, every country, whether developed or developing, strives to achieve an economy that can be called a market economy. In the modern world, it is this type of economy that is considered to be the most successful; it is the market economy that generates powerful economic incentives at the micro level. As far as Turkmenistan is concerned, the development of economy is connected with a number of factors - historical development, peculiarities of national development and mentality of the people, territorial position, as well as state and social factors, foreign policy course of the state. The economic model of Turkmenistan is the result of a long historical process, during which the correlation between the elements of the model was built and the mechanism of their impact was formed. That is why the national economic system is unique and mechanical borrowing of its achievements is impossible. Ultimately, the effectiveness of the model is most fully assessed in the indicators of growth of economic potential and welfare of the population.

In spite of circulation as in itself, market relations include:

- relations associated with the lease of enterprises and other structures of the economy, when the relationship between two entities is carried out on a market basis;
- exchange processes of joint ventures with foreign enterprises;
- the process of hiring and using labor force through the labor market;
- credit relations when loans are granted at a certain interest rate;
- the process of functioning of market management infrastructure, including commodity, stock, currency exchanges and other units.

One of the elements of the economic model of Turkmenistan is the formation of various forms of ownership. Unlike other Central Asian countries, the first stages of formation of the new economic model emphasized support for small and medium-sized enterprises, which became a priority. The creation of new market institutions (banks, financial structures) initiated the privatization of a large share of state-owned enterprises, while denationalization actually covered agriculture, trade and other service sectors. Thus, in agriculture, homestead plots were transferred to the ownership of daihan, and farms (daihan farms) were formed on the basis of former collective farms. Privatization of state enterprises started in Turkmenistan in 1993, thanks to the adoption of a number of fundamental legal acts, including the Law of Turkmenistan of June 12, 1997 "On denationalization and privatization". At that time, the sale of enterprises and facilities in the service sector, retail trade network and public catering, as well as corporatization of various enterprises began.

Hero-Arkadag Gurbanguly Berdimuhamedov notes that the country has achieved dynamic growth of socially-oriented economic sphere, which is based on various forms of ownership and provides for a gradual transition to market relations. A rather powerful non-governmental sector has been formed in our country's economy, market institutions and such a new sector as joint-stock companies, banks, a system of institutional investors and insurance companies have been developed. In addition, legal ownership of privatized property has been distributed, commodity deficit has been overcome and internal conversion of the national currency - manat - has been ensured.

Concerning the public sector of the economy, it is necessary to reconstruct state-owned enterprises and privatize their non-core assets. Therefore, one of the main tasks is to identify non-core assets in state-owned enterprises. This will significantly improve their activity, reduce the burden on them, reduce the state budget expenditures, which will ensure healthier activity of state enterprises.

It is necessary to note the fact of attracting foreign capital both in the form of loans and direct investments from friendly countries, leading large companies with world fame. The large potential of energy resources in the country has provided Turkmenistan with a significant inflow of foreign capital, which largely ensured the development of the economy and high growth rates.

2 MATERIALS AND METHODS

A systematic literature review was conducted for the purpose of this study. In 2003, Turkmenistan joined the Millennium Development Goals Declaration (adopted by the UN in 2000)5 and based on it adopted the "Strategy of Economic, Political and Cultural Development of Turkmenistan until 2020", which emphasizes the improvement of the living standards of the population and the human development index. The Sustainable Development Goals (SDGs) are a set of goals for future international cooperation that replaced the Millennium Development Goals at the end of 2015. These goals are planned to be implemented from 2015 to 2030. The outcome document "Transforming our World: The 2030 Agenda for Sustainable Development" contains 17 global goals and 169 corresponding targets. The concept of sustainable development emerged in the process of combining three main perspectives: economic, social and environmental. Turkmenistan was the first country in the region and one of the few countries that was the first to adapt SDG indicators to the National Programs of Socio-Economic Development. Most of the Sustainable Development Goals and targets have already been incorporated into the main strategic and program documents in Turkmenistan. In each of the individual areas of the Sustainable Development Goals Turkmenistan has shown certain positive development results in recent years, among the most successful ones we can highlight SDG 3 – "Good health and well-being", SDG 4 - "Quality education", SDG 5 - "Gender equality", SDG 6 - "Clean water and sanitation", SDG 7 - "Affordable and clean energy", SDG 8 - "Decent work and economic growth", SDG 9 - "Industrialization, innovation and infrastructure".

Since the adoption of the SDGs, certain positive trends have been observed in Turkmenistan. Let us start with an overview of the results of the social policy pursued by the Government of the country. An active social policy based on the principles of social justice and social security is the best guarantee of stability in society. "The society has come to the realization of national goals rising above the economy," emphasizes Hero-Arkadag Gurbanguly Berdimuhamedov. World practice shows that the model of society's development in the XXI century is the model that ensures sustainable economic, political development of socially-oriented and socially-responsible type".

The Turkmen State is responsible to every citizen and ensures the creation of conditions for the free development of the individual, protects life, honor, dignity and freedom, personal inviolability and the natural and inalienable rights of the citizen. First of all, it is necessary to increase the growth rate of the gross domestic product. The power supply and lighting system in cities and settlements is to be improved. The agricultural sector is becoming a highly profitable industry, where the production of food and agricultural products is increasing at a high rate, gradually replacing the imported products previously imported into the country. The phased implementation of the National Program for the development of villages, settlements and small towns is gaining momentum. One can endlessly enumerate how many kindergartens, general and specialized schools, institutes, health houses, hospitals, sanatoriums and health centers, stadiums and outdoor recreation areas have been built and are currently under construction

3 RESULTS AND DISCUSSIONS

With regard to SDG 3 - "Good health and well-being", the main objective in this area is to ensure healthy lifestyles and promote well-being for all people at all ages. Access to qualified medical care is an inalienable human right. Within the framework of the State Program "Saglyk" modern treatment and diagnostic complexes, health houses, specialized hospitals and sanatoriums of various profiles have been built, the level of which corresponds to the world standards, and the material and technical base of the system is regularly strengthened.

SDG 4 - "Quality Education" is constantly at the top of the priority list of the Government of Turkmenistan. The educational sphere is known to be of paramount importance in achieving the SDGs. Construction of new educational institutions of all levels continues in Turkmenistan. To date, there are successfully functioning institutes and international universities specializing in almost all areas of humanities, economics, sociology, law, as well as in such areas as international journalism, innovative technologies, digital economy. Laboratories of higher schools and specialized secondary educational institutions in various fields, libraries, and classrooms are provided with both internal and external systems of communication with the world community and the necessary material and technical equipment according to high international standards. The digitalization of education, carried out in stages, is gaining momentum. Student youth is actively involved in science and creativity, as science, education and new technologies go in one step, gradually revealing new talents, which are so necessary for the future of our developing state.

In more detail, let us look at SDG 5 - "Gender Equality". Gender equality implies a society in which both women and men have equal opportunities, rights and obligations in all spheres of life. Equality between women and men is when representatives of both sexes can have equal access to education and health care, governance and power, have equal opportunities to achieve financial independence, working for someone else or running their own business, to realize their personal and professional needs and interests. A critical aspect in achieving gender equality is the empowerment of women and greater opportunities in various spheres of society development, as well as the involvement of men in the process of achieving gender equality. As is known, a working group of the Interdepartmental Commission with the United Nations Population Fund has developed a second national plan of action on gender equality for 2021-2025 to ensure Turkmenistan's compliance with its international obligations in the area of human rights and international humanitarian law. Turkmenistan adopted its first National Action Plan on Gender Equality in 2015. With the support of the UN Population Fund UNFPA. The new plan includes the following strategic directions: promoting equal access to education for women and girls; prevention of gender-based violence; economic empowerment of women and girls; active participation of women at all levels, including political and social aspects. Turkmenistan is a country where women occupy a dignified place in society and have equal access and equal opportunities to participate in public and State life. In the traditions of the Turkmen people, whose history dates back more than 5,000 years, the upbringing of a strong and noble generation has always been at the top of the list, and it is the duty of every family to be the successor of this glorious tradition. Turkmen women are able to preserve and protect family values, using the rich experience of raising children and forming new generations accumulated by their ancestors.

SDG 6 is about making water and sanitation available and sustainable for all. Clean and accessible water for all people is an essential part of the world we live in. The planet's freshwater resources are sufficient to achieve this vision. The agricultural sector accounts for as much as 70% of the world's freshwater withdrawal. Saving just a fraction of this water would significantly reduce the pressure on water resources in other sectors of the economy.

In 2010, the Mejlis of Turkmenistan adopted the " On Potable Water Act", aimed at creating State guarantees for the provision of drinking water to the population and defining State requirements for control over the quality of drinking water and its safety for human health, for the protection of drinking water sources and their use. The law establishes the legal, economic and organizational framework for the rational use and environmental protection against pollution, contamination and depletion, as well as for the functioning of drinking water supply systems and the relationship of actors in the field of drinking water supply. The national programs adopted by the Government of Turkmenistan for the long-term perspective assume increase in production of such agricultural and strategic products as cotton, wheat, and this, in turn, requires large expenditures of the country's water potential. Economical and reasonable use of drinking water and wastewater is a priority task in the implementation of the "water" policy. The solution of sustainable development problems is possible only by taking into account the following development components - social, economic, environmental and institutional, which are closely interrelated and cannot be implemented in isolation from each other. The participation of representatives of public organizations and business in the processes of integrated water resources management is considered important in improving the mechanism and procedure for optimizing the water component.

SDG 7 envisions universal access to affordable, reliable, sustainable and modern energy for all that we depend on in our daily lives, as well as uninterrupted operation and intensive development of energy storage rates for all types of energy.In today's world, an imperfect energy supply system is not possible. Absolutely all economic and industrial sector, agriculture, entrepreneurship, development of modern infrastructure with developed communication and high technologies, health care and education are connected with energy supply and assume their careful, reasonable use. It is necessary to move towards the search for renewable energy sources. Taking into account the climatic zone in which we live, with more than two hundred sunny days a year, we have an opportunity to "tame" the sun and use solar-wind energy on renewable resources, as the flow of light is almost constant. They do not need to be mined; they are ready for use without human intervention. Innovative approach, and the development of solar energy leads to a reduction of harmful emissions into the atmosphere from fuel combustion. Due to the application of technologies for converting the energy of light into electric power, the energy consumption of households in almost all spheres of activity is reduced.

SDG 8 is to promote sustained, inclusive and sustainable economic growth and full and productive employment. The systematic, sustainable development of any society is impossible without creating the necessary socio-economic conditions for the realization of the intended goals of sustainable development. As Hero-Arkadag Gurbanguly Berdimuhamedov emphasizes, only a diversified, innovation-based economy will be sustainable in the long term. Therefore, a significant part of capital investments is directed to the development of hydrocarbon raw materials processing, capacity building in the electric power industry, chemical industry and transportation and communication complex. The stability of macroeconomic indicators is characteristic for Turkmenistan developing in the conditions of market relations, which has been repeatedly noted by experts of world financial structures, in particular, the International Monetary Fund.

Building resilient infrastructure, promoting inclusive and sustainable industrialization and innovation - this is SDG 9. Developed infrastructure is of great importance for the functioning of the national economy, representing an integral part of it. Types of infrastructure - production, social, market - have such specific features as ensuring normal human life, reproduction of labor resources in the national economy, increasing the working age of the population, formation of the younger generation. To date, the importance of social infrastructure is fundamentally changing and becoming increasingly important. The shift in the direction of economic growth of the national economy towards improving the quality of life of the population leads to an increase in the volume of investment in this sphere. At the current rate of economic growth and urbanization, there is a need for additional investment in sustainable infrastructure, so that cities can better counteract climate change and contribute to economic growth and social stability in the region.

4 CONCLUSION

As a result of their formalization in the global agenda, the Sustainable Development Goals have become mandatory criteria against which the performance of all organizations, institutions and civil society organizations will be evaluated in the foreseeable future. The SDGs, focused around different sectors, are designed to address global macroeconomic challenges. This trend is quite natural and expresses the call of the world community - the contribution of each person to sustainable development should lie in their very activities. That is why we are now interested in critically assessing our impact on society and the environment, identifying our own long-term priorities in the field of sustainable development and ensuring transparent reporting on the results achieved in this direction.

Turkmenistan's permanent neutrality clearly demonstrates the universal significance of the peace-loving and humanistic traditions of our people, which reflect their desire to preserve peace, resolve issues through negotiations, good-neighborliness and respect for other nations and peoples. The Constitution of Turkmenistan enshrines that the highest value of society and the State is the human being. That is why the main motto of the reform policy of the Hero-Arkadag Gurbanguly Berdimuhamedov is the slogan: "The state is for man!"

Thus, by successfully implementing a constructive foreign policy and foreign economic strategy, our country is making a significant contribution to ensuring universal progress not only in the Central Asian region, but also in the world as a whole.

REFERENCES

Berdimuhamedov, G., 2018. Turkmenistan on the way to achieving the Sustainable Development Goals. p. 14.

Speech by President of Turkmenistan Serdar Berdimuhamedov at the inauguration ceremony (Ashgabat, March 19, 2022). Neutral Turkmenistan newspaper, March 20, 2022.

Voluntary National Review of Turkmenistan. Empowering people and ensuring inclusiveness and equality. – Ashgabat, 2023.

Program "Revival of a New Era of a Powerful State: National Program of Socio-Economic Development of Turkmenistan in 2022-2052", Ashgabat, TGIS. 2022.

"Program of the President of Turkmenistan on socio-economic development of the country in 2022- 2028", Ashgabat, TGIS. 2022.

Sharifi, A., Allam, Z., Bibri, S. E., Khavarian-Garmsir, A. R., 2024. Smart cities and sustainable development goals (SDGs): A systematic literature review of co-benefits and trade-offs. Cities, 146, 104659.

United Nations. Transforming our world: the 2030 Agenda for Sustainable Development. [Online] Available at: https://sdgs.un.org/publications/transforming-ourworld-2030-agenda-sustainable-development-17941 (Accessed: 14 March 2024).

Hossain, M., Uddin, M. S., Rahman, M. M., 2022. Sustainable Development Goals and Challenges in Turkmenistan. *International Journal of Environmental Science and Sustainable Development*. 6(1).

United Nations Development Program in Turkmenistan. Framework Document on Environmental and Social Protection – Ashgabat, 2022.

World Bank. Turkmenistan: Country Partnership Framework for 2020-2024. [Online] Available at: https://www.worldbank.org/en/country/turkmenistan/publication/turkmenistan-country-partnership-framework-for-2020-2024.

Interaction between Ecology and Economics: Total Unity or Antithetical Dissociation

Valeriy A. Yakovlev[1][a]

[1]*Department of Technosphere Safety, North-Eastern Federal University, 58 Belinsky Street, Yakutsk, Republic of Sakha (Yakutia) 677000, Russia*

febra.t@yandex.ru

Keywords: ecology, economics, ecosystem, environmental protection measures.

Abstract: This topic is more relevant than ever, because the ecological system is in a state of crisis. It is closely intertwined with the economic one at the local, regional, national and global levels, and due to the aggravation of socio-economic and political problems, it requests a change in the direction of development of modern civilization. In this paper, the issues of interaction between economics and ecology are considered in detail. The article explores the contemporary ecological situation and economic growth as the cause of crisis and ways to solve environmental problems from an economic point of view. The article reviews and analyzes existing literature on the economic impact of environmental crises, as well as potential solutions to reduce the ecological impact of economic growth. The article finds that the existing economic system exacerbates environmental problems, including desertification, depletion of natural resources, destruction of the ozone layer, acid rain, and others. The primary contradiction between economic and ecological development lies in the fact that economic growth creates harmful environmental consequences. The article emphasizes the need for coordinated action by governments to address environmental problems and find sustainable solutions for effective production, transport, and renewable energy use, as well as waste processing technologies that do not pollute the atmosphere. The article highlights the importance of addressing the ecological crisis and finding a sustainable path forward, which requires coordinated global action to address the economic impact on the environment.

1 INTRODUCTION

Ecology is the natural science of the interactions between organisms and the environment. And ecological research has traditionally been based on the interpretation of the non-human world and has hardly touched upon human society. In this article, ecology will be seen as the biosphere, i.e. the natural environment, and economics will refer to the production, exchange, consumption of goods and services. If we look at the origins of these two concepts, we can see that they share a common root, "oikos", which literally means "home, abode" in Greek.

The concept of economic development refers to economic growth. It is inconceivable without scientific and technological progress, and without securing and maintaining a constant rate of production growth, which implies an increasing dependence on natural resources. Society has always depended on natural resources, but the problem is that this dependence is not taken into account in economics. Man tends to consume rather than conserve. It turns out that the main contradiction between economic and environmental development is that, on the one hand, the economy has to develop, and on the other hand, this development generates detrimental effects on the environment. This article will look at the scale of these impacts in today's realities.

The interaction of ecology and economy is one of the most important problems of our time. On the one hand, economic growth and development require a certain level of use of natural resources, which leads to an increase in the negative impact on the environment. On the other hand, given the growing environmental awareness of society and the need to preserve natural resources, it is important to find a balance between economic interests and

[a] https://orcid.org/0000-0002-3765-5292

environmental protection. This article will consider the problem of interaction between ecology and the economy, explore the possibilities and limitations of the integration of economic and environmental goals, and analyze trends and challenges in this area.

2 THE RELATIONSHIP BETWEEN ECOLOGY AND ECONOMICS

The economy and the environment are linked. They have a significant impact on each other. The relationship between society and nature is a case in point. In the first stage, their commonwealth in environmental protection measures as follows: the increasing consumption of natural resources leads systematically to the depletion of natural resources and the increasing input of waste from human production/living activities into the environment. Virtually everything involved in production eventually returns to the environment in the form of waste. This, in turn, leads to higher costs for natural resource extraction and environmental remediation.

An example of the relationship between economic processes and the environment is the construction of wastewater treatment plants. Most industries disturb the environment, or rather its purity, so they build wastewater treatment plants to avoid polluting the water, the air, etc. These facilities are expensive, and manufacturing companies try to save money by doing harm and pollution.

Due to the increase in gross product, production capacity, the environment is deteriorating. For comparison, production today has increased 20-fold compared to mid-twentieth century figures. Chemical/petrochemical/pulp and paper production, motor transport and mineral extraction companies cause the greatest negative impact on the environment.

Table 1: GDP dynamics for 1950.

Regions, groups of countries, countries	GDP, billion dollars in 1993 prices			Population, million people			Specific gravity, in %			
							in world GDP		in the world population	
	1950	1996	difference factor	1950	1996	difference factor	1950	1996	1950	1996
World, including:	5621	32925	5.9	2510	5771	2.3	100.0	100.0	100.0	100.0
North America	1984	8255	4.2	218	457	2.1	35.3	25.1	8.7	7.9
South America	295	1963	6.7	112	326	2.9	5.2	6.0	4.5	5.6
Europe	2081	8803	4.2	569	793	1.4	37.0	26.7	22.7	13.8
Africa	239	1460	6.1	223	736	3.3	4.3	4.4	8.9	12.7
Asia	941	12015	12.8	1376	3431	2.5	16.7	36.5	54.8	59.4
Australia and Oceania	82	430	5.2	13	29	2.3	1.5	1.3	0.5	0.5
Former socialist countries, including:	857	5236	6.1	875	1757	2.0	15.3	15.9	34.9	30.5
the same without China	707	1809	2.6	331	543	1.6	12.6	5.7	13.2	9.4
China	150	3366	22.4	544	1214	2.2	2.7	10.2	21.7	21.0
USSR	410	897	2.2	180	293	1.6	7.3	2.7	7.2	5.1
Russia	249	585	2.4	102	148	1.4	4.4	1.8	4.1	2.6
Market economies, including:	4764	27690	5.8	1635	4014	2.5	84.7	84.1	65.1	69.6
developed, including:	3644	17347	4.9	546	814	1.5	63.0	52.7	21.8	14.1
USA	1754	6786	3.9	152	266	1.7	31.2	20.6	6.1	4.6
developing, including:	1220	10343	8.5	1089	3200	2.9	21.7	31.4	43.4	55.5
Latin America	396	2794	7.1	159	476	3.0	7.1	8.5	6.3	8.3
countries south of the Sahara	130	607	4.7	164	558	3.4	2.3	1.8	6.5	9.7
energy exporters	127	1234	9.7	79	301	3.8	2.3	3.7	3.2	5.2

Table 2: Evolution of the countries with the highest GDP for 2020-2022, trillion dollars.

№	Country	2020	2021	2022
1.	United States of America	20 893.75	22 997.50	25 346.81
2.	China	14 862.56	17 458.04	19 911.59
3.	Japan	5 040.11	4 937.42	4 912.15
4.	Germany	3 843.34	4 225.92	4 256.54
5.	India	2 667.69	3 177.92	3 534.74
6.	United Kingdom	2 758.87	3 187.63	3 376.00
7.	France	2 621.96	2 935.49	2 936.70
8.	Canada	1 645.42	1 990.76	2 221.22
9.	Italy	1 891.06	2 101.28	2 058.33
10.	Brazil	1 448.55	1 608.08	1 833.27
11.	Russia	1 483.38	1 775.55	1 829.05
12.	Korea	1 638.26	1 798.54	1 804.68
13.	Australia	1 357.32	1 633.29	1 748.33
14.	Iran	938.05	1 426.30	1 739.01
15.	Spain	1 280.46	1 426.22	1 435.56
16.	Mexico	1 087.12	1 294.83	1 322.74
17.	Indonesia	1 059.90	1 186.07	1 289.30
18.	Saudi Arabia	703.37	833.54	1 040.17

It is important to note that an increase in the gross product does not simply lead to the pollution of natural resources, but to their complete depletion. This is due to the fact that most businesses use them irrevocably. Recently, there have been more and more people on the planet, which means that:

- the number of industries is increasing;
- consumption of water, land, biological and mineral resources is increasing;
- more and more waste.

All of the above factors are contributing to an unfavourable environmental situation around the world.

The underlying challenge is to ensure that economic performance advances, but in a way, that does not cause even minimal damage to the global environment. Such a happy outcome, say participants at international conferences, is only possible with a global modernization of production activities.

If there is economic growth and environmental improvement, the researchers estimate that there are two outcomes - favorable and unfavourable. Opponents of economic growth are strongly concerned about the environment. They believe that it, along with industrialization, should be deliberately curbed. This position is close to the "zero-growth theory", according to which the only solution is to stop or stabilize economic growth at an optimal level that does not threaten the natural environment.

Other proponents in defence of economic growth say that the link to the state of the environment is greatly exaggerated. They argue that if one were to abandon economic growth and maintain GDP at the same level, one would still have to choose between different patterns of production.

The concept of sustainable development is based on the idea of sustainable use of the resource base. From an ecological point of view, this principle is fundamental in dealing with environmental issues. The main idea of the concept is the unity and interrelation of economic, social and environmental development. The integration of economic and environmental interests can be achieved by increasing the efficiency of benefit extraction with constant resources. Sustainable development implies meeting the needs of the present without harming future generations. In order to achieve this, environmental legislation must be improved, the gap in living standards between peoples must be narrowed and an environmental mindset must be fostered.

Economic development can aggravate the negative impact on the environment, because it is accompanied by trends of increased consumption, trade and production. All this leads to intensive pollution of the environment and big environmental problems.

It has to be admitted that there can be a positive impact. This condition will be fulfilled if the economic growth is expressed in a higher standard of living, a stable state budget, and a deferred tax system. These factors will increase investment in the environment, the use of quality waste management technology, and the cleaning up of rivers, forests and water bodies.

There are already special nature conservation organizations in certain countries, which are responsible for ensuring that nature thrives and is preserved. These international public environmental organizations include:

The World Wildlife Fund - WWF. It is an independent foundation for the protection of rare and endangered wild animals.

Greenpeace. Greenpeace campaigns for solutions to global environmental problems by bringing them to the attention of the authorities and the public.

Helcom. Helcom (Helsinki Commission): works for the protection of the aquatic environment in the Baltic Sea Region.

The types of international environmental organizations are manifold and can be categorized in many ways. Among the intergovernmental organizations, UN specialized agencies such as:

- UNESCO;
- FAO;
- WHO;
- WMO;
- IMCO;
- IAEA.

Although they have been set up to fulfil other purposes and tasks, the protection of the environment is part of their remit. The International Union for Conservation of Nature and Natural Resources (IUCN), established by a decision of the founding assembly in Fontainebleau in October 1948, tops the list of international non-governmental organizations in the field of environmental protection.

Different countries have their own idea of "cleanliness" and thus of how to combat pollution. Much depends on the location and size of the country, the scale of industrial production and other factors. As a rule, the most favorable situation is observed in the richest countries in Europe and some other countries with a high standard of living, including Australia, New Zealand and Canada. Based on current data from the Environmental Performance Index, developed by scientists at Yale and Columbia University in the US, Table 3 shows the cleanest countries in the world for 2022.

Table 3: Green countries by 2022.

№	Country
1.	Denmark
2.	Luxembourg
3.	Switzerland
4.	United Kingdom
5.	France
6.	Austria
7.	Finland
8.	Sweden
9.	Norway
10.	Germany

3 THE NEED TO CARE FOR THE ENVIRONMENT

Environmental problems directly affect the economy. Therefore, special attention should be paid to them, as they can undermine the development and security of a country and of humanity as a whole. Environmental problems include:

- land crisis;
- water pollution, water bodies;
- demographic problem;

- air pollution;
- shrinking energy supplies;
- deforestation;
- natural disasters;
- loss of flora and fauna;
- major epidemics, serious diseases.

When forests are clear-cut for economic purposes, the state of the ecological system is not taken into account. The permanent destruction of forests has a huge impact on the **ecosystem** as a whole. Destruction of forests leads to a loss of biodiversity (some plant and tree species are already extinct and others are in danger of extinction). Due to the loss of biodiversity of animals and plants, there is a decrease in products such as medicines which are so important for humans.

Industries emit large amounts of carbon dioxide, methane and other heavy compounds into the atmosphere. These substances concentrate and form a veil in the sky that lets in sunlight but traps heat. It contributes to the greenhouse effect and this changes the climate. The changes are manifested in rising ocean levels, thawing permafrost, shifting frosts and thaws, abnormally hot weather, and cataclysms. If no action is taken to reduce emissions, air temperatures will rise by 4.5°C by 2100.

The amount of phosphates, nitrates, carcinogens and other substances is changing the composition of the water. According to the UN, 30 billion tonnes of oil products, 50,000 tonnes of pesticides, 5,000 tonnes of mercury enter the world's oceans every year. It should be known that industry uses millions of cubic metres of water resources. Water is also important for agriculture. For example, the smelting of 1 tonne of steel requires 200 m^3 of water and the production of 1 tonne of synthetic fibre requires between 2,500 and 5,000 m^3. Currently, the world's freshwater resources are only 2.5%, 2/3 of which is from glaciers. At this rate, in 80-100 years' time, there will be no freshwater left at all.

Air and water pollution are occurring at the same time as soil contamination. Industrial emissions are changing the structure of the soil. Chemical fertilizers (aluminium, zinc, lead) kill the humus, disrupt the natural cycle of components of the biosphere. Of the approximately 140 million square metres of land (as of 2022), 23% is degraded and 15% has been completely lost.

Changes in environmental indicators affect the economy in the following ways:

1. The reduction in land resources has an impact on food production.

2. Reduced forest areas are followed by a decline in food, energy resources and other forest products, which affects the economies of most countries in the world. Annually, losses of up to $5 trillion are reported for the destruction of forested areas.

3. Reducing air pollution requires large financial outlays. It requires developing and implementing high-tech processes and moving people towards low-emission products and services.

4. Unless measures are taken to protect, manage and treat water, water scarcity for the population will increase from 40% to 65%. This problem is difficult to solve due to poor economic viability and high costs.

5. In order for the 828,000 people (as of 2022) to avoid hunger, it is necessary to increase production of goods and energy by a factor of 5-10!

We need to pay attention to the environmental friendliness of production. This is important because investing in ecology is an investment in the development of industry and the economy of a country. A good example is the United States, where the Clean Air Act was passed in 1970 and the Environmental Protection Agency was created. During this programme and the introduction of the sulphur dioxide emissions trading system in 1990:

1. Air quality in the country has improved.
2. Number of harmful impurities in the air has been reduced.
3. Standard of living has improved.
4. Country started to attract emigrants.
5. Mortality rates went down.
6. Number of highly skilled people increased.
7. Improved investment attractiveness.
8. Companies involved in the project have received additional money.

It is now necessary not only to remove the effects of pollution, but also to set a goal - to develop a concept that does not involve so much damage to the environment and does not inhibit economic development. In 1987, the UN adopted the concept of sustainable human development, according to which the needs of the present generation can only be met without harming future generations. It suggests that it is necessary to limit not only the pollution affecting the population today, but also the long-term risks for the environment in the future.

Part of the concept of sustainable development is a cluster of green technologies, which minimize human impact on the environment and make it possible to do business responsibly. Clean technology is the world's third-largest investment after IT and biomedical technology. This is one of the most promising sectors for venture capital investment. China, Europe and the US are leading it. Great hopes are pinned on technological breakthroughs: industrial giants are allocating multi-billion dollar budgets

(Figure 1, 2) to develop innovative solutions and buying start-up developments.

rubles.

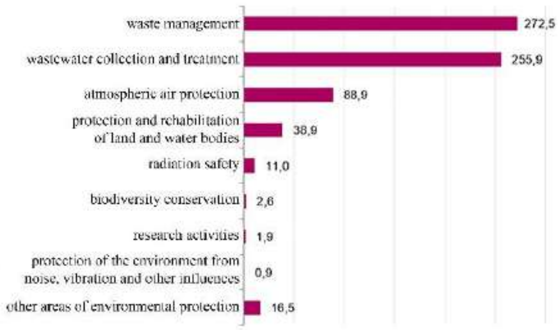


Figure 1: Current spending on environmental protection in Russia (including payments for services and overhaul) in 2021 by area, billion.

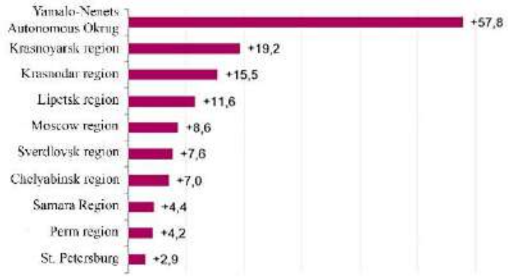


Figure 2: Regions with maximal increase in environmental expenditures in 2021, billion rubles.

Many countries around the world are actively practicing reuse of waste and recycled materials, which saves substantial funds and saves natural resources. In the long term, it is necessary to think about creating low-waste and zero-waste enterprises and technologies.

Reducing water consumption per unit of output for more efficient water management becomes paramount in the problem of water management. The issue of deforestation requires stricter penalties for illegal logging, reforestation and the gradual closure of the gap between harvested and reforested forests, better wood and waste management.

In addition to direct benefits in the form of improved environmental quality, the transformation of a green economy can further increase GDP, create new jobs, shape new industries and services, reduce resource consumption and expand the consumption of by-products, and provide healthier and more equitable living conditions for people.

4 CONCLUSIONS

The world's current economic system is an aggravation of environmental problems of various levels, scales and nature. It must be recognized that the environmental situation on the planet as a whole continues to deteriorate.

The technologisation of the global economy and unrestrained economic growth has led to global problems, such as desertification, depletion of natural resources, ozone depletion, acid rain, etc. The consequences of urbanized economic growth for the natural environment are multifaceted; above all, more intensive use of natural resources places us in danger of exhausting them altogether. At the same time, as the exploitation of natural resources grows, the amount of waste introduced into nature increases.

The main contradiction between economic and ecological development is that, on the one hand, the economy must develop, and on the other hand, this development generates consequences detrimental to the environment.

The paper considered the current environmental situation, economic growth as the cause of the crisis, and ways to solve environmental problems from the perspective of economics. I would like to point out that it focuses on the economic aspects of the environmental problem and the possibility of solving it, leaving out of it all the possible social, political and other consequences, which open the field for other studies.

Economic problems are common to all countries of the world, irrespective of their standard of living and development. Thus, coordinated action by the governments of different countries is needed to improve the situation. Governments need to work together to find options for efficient production, transport and renewable energy, as well as waste-processing technologies that do not pollute the atmosphere.

REFERENCES

Bocken, N. M. P., Bakker, C., Pauw, I., 2019. Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering, 36(3), 374-388.

Schaltegger, S., Hansen, E. G., Lüdeke-Freund, F., 2016. Business cases for sustainability: the role of business model innovation for corporate sustainability. Journal of cleaner production, 163, 34-43.

Stahel, W. R., 2016. The circular economy. Nature News, 531(7595), 435-438.

Geng, Y., Doberstein, B., Fujita, T., 2012. Greening China's cities: framework and performance indicators. Journal of Cleaner Production, 20(1), 17-29.

Luken, R., Mayer, A., Müssigmann, O., 2018. Strategies for the circular economy: innovative concepts for a resource-efficient economy. Springer

Nilsson, M., Mattsson, L.-G., 2016. Circular business models: a review. Journal of Cleaner Production, 127, 153-174.

O'Rourke, D., Connolly, N., 2017. Just sustainability: the emerging discourse of environmental justice in Ireland. Environmental Politics, 26(5), 865-885.

Sustainable Development of Rural Settlement in Modern Russia: the Systematic Approach and the Theory of Centers

Tatiana Yu. Bystrova[a],
Cultural Studies and Design Chair, Ural Federal University named after the first President of Russian Federation B. N. Yeltzin, Mira street, Yekaterinburg, Russia
taby27@yandex.ru

Keywords: rural settlement system, centers theory, systematic approach, sustainable development, urban planning, initial structure, subsystem, landscape.

Abstract: Based on an analysis of developments on the issues about sustainable development of rural settlement system, the author uncovers two significant oversights within the research discourse: firstly, the disregard for the internal organization of rural settlements, often lacking a real centre (quasi-centre); and secondly, the underestimation of individual or local initial subsystems potential within rural settlement system, operating in relative isolation from other components. By addressing these lacunae, we could not only enrich the scientific comprehension of rural settlements, but it also facilitates the formulation of recommendations for territorial planning. An important role is played by the conscious organization of trajectories and communications of residents inside and outside the settlement, since the settlement system is not a mechanical aggregate. elements, but exists due to active connections between them. Such activities serve to mitigate the risk of rural area desertification, thereby averting disruptions within the settlement system. Importantly, the insights gleaned from the Russian experience hold relevance for numerous countries grappling with accelerated urbanization trends and trying to sustainable development of the entire territory in contemporary times.

1 INTRODUCTION

Despite numerous management measures, the rural settlement system of the Russian Federation persists in a unsustainable condition. A significant downturn was particularly evident in the 1960s, attributed to shifting demographic behavior (Cárdenas 2017) characterized by increased life expectancy and dwindling birth rates. During the reform period of the 1990–2000s. the smallest and largest rural settlements turned out to be more stable (+5.3% and -1.0%, respectively). True, the positive indicators of the network of settlements that had over 1000 inhabitants (the number and number of residents changed by 1% and 10.3%, respectively) is due to the fact that in approximately 70% of cases this happened due to the transformation of urban settlements into rural ones. The total number of medium-sized settlements decreased by 2 thousand, or 15.5%. “If we take into account that populated areas of average size are the basis of rural settlement, then the widespread decrease in their number on the territory of European Russia leads to a disruption of the framework of rural settlement,” experts warn (Chugunova 2023). Strengthening sustainability necessitates the exploration of novel methodologies or, as in our context, a more deeply working with existing research methodologies.

The balance of the settlement system is the most important condition for its sustainability. Experts have observed that the agricultural sector's economic upturn, witnessed from the onset of the 1990s to the early 2000s, yielded minimal impact on alleviating the social challenges pervading rural locales, thereby perpetuating rural-urban migration dynamics (Ioffe 2006). Consequently, endeavors aimed at ameliorating the prevailing predicament demand meticulous deliberation and strategic clarity.

The foregoing determines the purpose of the article: to show possible ways to strengthen the sustainability of the rural settlement system of

[a] https://orcid.org/ 0000-0001-6713-6867

modern Russia using system-genetic and system-structural analysis.

2 METHODOLOGY

The definition of a settlement system as a scientific concept is controversial; many positions are given in (Yurkova 2021). We dwell on the fact that this is "a group of territorially close and *functionally connected* settlements" and communications between them. Without taking them into account it is impossible to talk about any "continuum" (A.I. Treivish) or the development synchronicity of settlement and transport networks. The nearest to our position version underlines an interaction as a force for system: this term "suggests that the interactions between places, on the one hand, and, on the other, between the individuals who live in them and their environments constitute a driving force in the evolution of these systems, and notably in the transformations of the related spatial patterns" (Sanders 2021, Chapter 2). But such interpretation is not very widespread, since it requires additional research efforts to take into account the dynamics of systems.

The methodology for studying settlement systems, including rural ones, is currently being developed by A.I. Alekseev, E.A. Antipova, R. V. Keating, A.V. Levchenkov, M.G. Rumyantseva, A. Zavodnik. Since the topic is closely related to the climatic, geographical and economic realities of each individual region and country (Bogglia 2014), we rely mainly on sources from Russian authors. Large-scale scientific reviews are especially useful for studying specific issues, such as in the book by A.I. Alekseev (Alekseev 1990). They make it possible to compare data with modern period and to fit more specific issues into a broad historical and socio-economic context, to isolate the main and secondary issues in local settlement systems.

The literature on settlement systems, depending on the original specialty of a particular author, includes different approaches that we identified earlier (Bystrova 2022): geographical (D.N. Lukhmanov, N.V. Chugunova, Qin Y), historical (R. Drennan, M.J. Haller, L. Sanders with co-authors), mathematical (Yu.R. Arkhipov, F. Bogglia at all.), urban planning (G.V. Mazaev, A.G. Mazaev), economic (E.I. Animitsa, A.I. Treivish), economic-managerial (R. Akchamov), sociological (T.I. Zaslavskaya), demographic (V.V. Patziorkovsky). It seems that specialists from other countries and regions also have a similar specialization, with a general movement towards interdisciplinary methods of study. The connection between the sustainability of the rural settlement system and actions that take into account traditional forms of territory development as much as possible is well shown in (Mouraz 2023), (Nguen 2019), others.

At the same time, one cannot but agree that insufficient attention has been paid to the comprehensive study of rural areas in Russian science: individual aspects have been worked out in depth, and attempts to study rural areas as an integral object are sporadic. The same thing is observed in other countries (Ambrosio-Albalá 2010), (Dwijendra 2021). While studying socio-economic aspects in detail, scientists and practitioners in vain unjustifiably ignore the natural component of the rural settlement system as an important factor in planning and lifestyle. So far, the connection between the rural settlement system and natural conditions has been studied in more detail in the Kaliningrad (A.V. Levchenkov) and Orenburg (I.V. Osipova) regions, as well as Udmurtia (A.L. Lekomtsev).

It is impossible to imagine the processes of rural settlement in the fullness of their connections with the processes of urbanization analyzed in the works of V.L. Glazychev, L.N. Mazur, T. Kümmel, etc. Attempts to connect at the theoretical level the study of the Russian settlement system in the context of issues of strengthening sustainability. Here we name the works of M. Ambrosio-Albala, Yu.A. Arkhipov, E.V. Gorbenkova, P.N. Davidenko, E. Pisani, V.I. Tikhoy and others.

In accordance with the stated approach, we understand the settlement system not only as a "group" of connected settlements, we take into account the essence, intensity and scale of connections and communications between them, both in synchronic and in diachronic aspects. The research program includes references to the theory of centers (Ch. Alexander, N. Salingaros) and central places (W. Kristaller), which allows one to explain the current state of a particular rural area (development or degradation) by the presence or absence of centers and connections between elements (communications). The potential of both approaches is not fully realized today, since the concept of "system" is often used in documents purely nominatively, without taking into account its conceptual depth, and the word "center" is associated only with a position in space. Because of this, "blind spots" arise in the study of processes in rural areas, since: a) not all levels of the settlement hierarchy have been studied and taken into account in management actions; b) external and internal structural connections of elements of rural settlement are considered in isolation from each other, preventing a holistic view.

The peculiarity of the system methodology is to focus on the integrity of the object and the factors that determine it. It allows to identify all the diversity and complexity of connections inherent in an object and present them in real unity. The systems approach does not exist in the form of a strict methodological concept: it performs its heuristic functions, remaining not very strictly bound by a set of cognitive principles, the main meaning of which is the appropriate orientation of specific studies. Finally, the systems approach initially involves not only research, but also the development of a design strategy, which can be carried out at the next stage of work taking into account the developments already made (Shcherbina 2018).

If we use the methodological capabilities of these approaches to the fullest, two interrelated parts of the article naturally arise: analysis of systems (or, more precisely, subsystems) of rural settlement, weakly or minimally connected with other levels of the hierarchy, but having their own logic of organization with which you can work for their conservation or even development; analysis of the internal structure of rural settlements, ensuring their real inclusion in the life processes of larger-scale systems. The problem posed is interdisciplinary, therefore, on the one hand, in the course of the study it is necessary to rely on data from different branches of science, on the other hand, to follow professional town planning and urbanistic discourses, taking into account the specifics of the landscape and the presence of humans in it (Aydin Turk 2017), (Korandei 2021).

To address the topic, the multi-scale study of the subject at different levels of the hierarchy (macro-, meso-, micro-level of rural territory; respectively, federal, regional, municipal, level of individual settlements) and in different aspects (urban planning, economic-geographical, climatic-geographical, socio-cultural) is essential. Along with taking into account the current administrative boundaries of cities, regions, and other territories, we try to take into account historical versions of settlement. The geography of a place and the associated dominant (or determining) socio-economic structure give rise to no less common features in rural settlement systems of different regions than universal socio-political attitudes or socio-economic measures. Knowledge of the processes in their entirety enriches the scientific model of settlement.

3 DISCUSSION

3.1 The uniqueness of rural settlement systems

Unlike the urban settlement system, rural settlement in modern Russian regions is not homogeneous, but consists of a large number of separate local and often unrelated structures, mainly of a linear type.

We initiate from the thesis about the impossibility, or at least ineffectiveness, of studying rural settlement systems by analogy with urban settlement or exclusively in inextricable unity with it. Despite the fact that urbanization changes a lot in the boundaries between city and countryside, it is on the scale of settlement systems that the difference is quite significant (Bystrova 2022). The two types of settlement did not arise simultaneously; initially, a system of rural settlement emerged. Being earlier, it is closely connected with the landscape. The unit of rural settlements was and often remains a “house” or, more often, a “yard” with a whole set of outbuildings; The communal nature of rural life almost does not extend to the structure of the settlement.

The urban settlement system, which gradually evolved within the rural framework, stemmed from its essence and facilitated its own expansion and structural development, thereby broadening the array of potential technological infrastructures within it. It transitioned into complex hierarchical systems, wherein a hierarchy of settlement system elements materialized, giving rise to cores of varying levels, including predominant cores accommodating up to 50% or more of the population. These cores catalyzed the formation of agglomerations, delineating the framework of a settlement system that spanned the entirety of Russia's National Settlement System. Presently, different segments of the urban settlement system are in various stages of development, yet interconnected as a cohesive unit, exhibiting distinct trajectories for future growth, which can be scrutinized and considered by specialists in forecasting and modelling.

Conversely, the rural settlement system, owing to its initial strong ties with natural elements and inclination towards stability, saw minimal development and remained at a rudimentary organizational level. The limited stratification levels preclude the formulation of a unified system model. Despite its expansive geographical coverage, such as within the Russian Federation, it exists as numerous discrete territorial entities, lacking a cohesive structure not only at the national level but also within individual regions.

The classical Russian village is connected with the landscape and natural rhythms; therefore, it has a free layout, far from regularity, the patterns of which are largely determined by the terrain, and perimeter development “around lakes, ponds, ... sources” (E.N. Bubnov). It is difficult to study, and therefore to manage its processes. The situation is aggravated by the classification as rural settlements, which in fact are not rural, but are only located outside the cities and have a small size and number of inhabitants. The settlements of logging workers or railway workers (serving, for example, a semi-abandoned narrow-gauge railway), roadside settlements stretching in a narrow strip along the highway, or settlements of summer residents do not produce agricultural products as the main one. Their choice of place of residence and its logic are not dictated by rural factors themselves, often being based on an external administrative imperative or developing spontaneously. Accordingly, the universal laws of the rural settlement system do not apply to them.

For example, the rural settlements of the Urals have tended towards instability since the 17th century: among the Bashkir population this is caused by the desire to follow cattle; among miners of metal or stone – by searching for new sources of raw materials, etc. Settlements determined by external determinants, by definition, do not have sufficient resources for development and are doomed, unless in the process of existence, especially in new historical conditions, in the settlement itself there will be an initiator or reason - a new craft (ceramics, leather, metal processing, etc.), occupation (growing berry crops, breeding, animal husbandry).

Not any conglomerate of settlements can be considered a system, but only one that is distinguished by integrity, self-organization, the presence of a hierarchical structure, uniform distribution of elements, and irreducibility to the sum of the properties of the elements that make up the system (Enin 2016, 194). The existence of a system cannot be stated: it must be proven by turning these characteristics into criteria for assessing a particular settlement structure.

The reason for repeated unsuccessful definitions and classifications is due to the fact that rural settlement does not form an integrated system as a whole, similar to urban settlement. This is a special type of settlement, consisting of many local formations and “subsystems”, mostly of a linear type, not connected even at close distances, and does not have its own designated centers and, especially, the predominant center of the entire system. The framework of all elements of the system is “external”, developing in addition to the elements of rural settlement. It is represented mainly by municipal and regional roads. This diffuse and discrete settlement has a certain degree of connectivity, but does not form higher organized levels of hierarchy. The stability of such a loosely coupled entity is always in question (Boggia 2014).

Accordingly, management decisions to “enlarge” separate rural settlements and subsystems simplify (rather than complicate) the structure, reducing its already low sustainability.

3.2 Local subsystems of rural settlement: potential for self-organization

In this section, the discussion revolves around the thesis that, due to their initial logic, verified by many generations, local subsystems of rural settlement are capable of developing from within themselves, if their structure is not deformed by actions that are not inherent in them initially. For as overcoming disintegration (Ioffe 2006) as proposals for the sustainable development of rural settlement systems of different scales, it is necessary to follow their own intentions.

3.2.1 Underestimation of the initial organization “rightness” of a rural settlement

Undetected by experts, we label overlooked segments of rural settlements as "blind spots," a phenomenon influenced by various institutional factors.

In a real village, external and internal processes flow into each other, whereas in planning actions or management decisions they are often isolated from each other. This is most clearly noticeable in relation to individual small subsystems, tightly connected within themselves and even among themselves, but without access to other parts in a higher level of scale. The same applies to the officially called administrative and planning centers of settlements, which do not perform the functions of a center in the architectural and urban planning sense of the word, that is, they do not contribute to development and are not the intersection point of many communications and trajectories. According to experts, centers are not just physical focal points, but are deeply intertwined with human perception and experience. In particular, N.A. Salingaros argues that well-designed centers evoke a sense of coherence, harmony and connection within architectural spaces, promoting human activity and social interaction (Salingaros 2006), (A New Pattern... 2020). The opposite is also true: we regard spaces of social interaction as centers. This assessment is not always achieved by simply having a number of required administrative buildings. If they are located among monotonous, homogeneous spaces or form homogeneity, then such an environment contributes to a feeling of desolation and ownerlessness, uncharacteristic of the mentality of rural residents. Oddly enough, for a long time experts did not consider the structure of rural settlements and settlement systems to be factors in strengthening sustainability (Boggia 2014, 161).

Historically, the village had a nonlinear organization, in particular, circular or cumulus, moreover, with a large number of external and internal (natural, pedestrian, transport and other) connections (Mazur 2003, 140-171). It was included in the local subsystems of settlements and often performed an intermediary function in their interaction. Together with the communal way of life of connections, this gave rise to a hierarchy and self-organization of connections, in which, along with the main center of the settlement, there were several centers of a smaller scale. Today, under the influence of external factors, this complexity has been destroyed or is being destroyed.

Speaking about the reduction in the rural population and the degradation of the economic complex of the Russian Non-Black Earth Region in the 2010s in territorial cells of various hierarchical levels, K.V. Averkieva notes that “along with the center-peripheral contrasts, territorial differentiation remains, due to landscape factors and the characteristics of local settlement systems” (Averkieva 2012, 8). However, in management decisions this differentiation is not taken into account; numerous decisions on consolidation, justified from an economic point of view, essentially do not take into account the external and internal organizational complexity of rural settlement systems.

At the same time, such local rural settlement is, as it were, “withdrawn” from general economic processes: for example, when studying disproportions in regional development, speaking about more competitive industrial regions, the authors do not mention their rural component at all (Mironova 2011, 23-34). But it exists, has a natural quality of self-organization for living systems, which is important for stability, as well as a number of other characteristics.

Thus, in rural settlements at a distance from large Russian cities, linear structures of various planning forms can be distinguished. The most common (typical) are linear structures formed by linear objects – rivers and roads. This confirms the analysis of the settlement networks of the Tyumen region, according to which it is the rivers that play the main role in the formation of the network, while the administrative division may not be taken into account by it at all. We see the same on the territory of the Sverdlovsk region (Fig. 1). We see a fairly dense, fractally organized system that takes into account the initial characteristics of the landscape and the river. In addition to paths or grader roads, the river is also a transport connection. It is not too wide, along with steep cliffs, there are places where a boat can land. Their parameters largely coincide with the viable settlement systems identified by historians in different regions with distances of up to 25 km between settlements (though with their own crafts as a basis for centralization) (Drennan 2007, 79). Let us note that in order to move to a higher level of scale, such subsystems lack not only roads (external factor), but also population (internal connections).

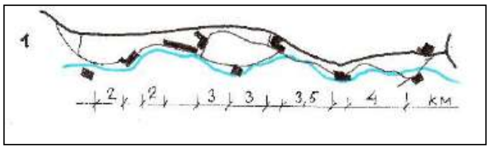


Figure 1: 18 km local linear rural system in the Alapaevsky district of the Sverdlovsk region in Russia: (from left to right) Vogulka, Yaroslavskoye, Kostroma, Vetlugina, Klevakino, Kochneva, Sokhareva, Kuzino, Kostino along the Rezh River. Author: G. V. Mazaev. 2022.

These subsystems have internal connectivity that is not related to the next levels of the hierarchy, for example, regional or federal roads (Wegren 2008). Although the dates of their origin are overwhelmingly not reported in documents and other sources, it can be assumed that they arose in an earlier period and persist to this day, despite the decline in population.

Complicated planning systems are formed by several linear systems. Thus, the layout in the area of the city of Rezh in the Sverdlovsk region of Russia developed in the absence of a clearly defined linear-forming natural element. The main linear system consists of four settlements. Adjacent to it is a smaller system of two elements. The largest population center of the main system becomes the center of a small beam system of two beams. That is, the original linear systems are not static, but are capable of development with the complication of their overall planning structure. Rural settlement acquires the most complex planning forms in the largest agglomeration cities.

Isolating rural settlement systems at different levels with an understanding of their specifics and potential relationships with each other can and should influence the policy in the field of rural-urban settlement, moving away from unification towards a greater variety of planning, architectural, and social solutions. The main attention must be paid to roads and transport communications; local systems are often ruined by their location in a dead end, especially in settlements on the administrative borders of a region or even districts. For example, the village Rastress, built on the famous ancient Babinovskaya road, was one of the largest in the Sverdlovsk region. Later, when the road network changed, all the inhabitants left it.

In recent decades, instead of improving its inherent forms of organization, the task of transforming the rural settlement system into an urban one has been constantly set, primarily through consolidation. Attention to local subsystems shows the unnecessary and even harmful nature of such consolidation. What is convenient in administrative and economic terms is unacceptable from the point of view of urban planning.

It is also necessary to change the research position towards greater flexibility and variability. To increase the sustainability of ecosystems, the designed structure of the territory must be more developed, diverse and more complexly organized than the original one. In urban planning, it is necessary to introduce a concept implying a transition from an industrial agricultural landscape (disproportionate to the natural structure of the area and people) to a biosphere-compatible one (polyzonal, mosaic and polymorphic). What hinders this is that the issues of assessing traditional forms of settlement, understanding their historical and cultural value, and the need for protection by local specialists are not raised at all, although international organizations are already talking about this, as well as specialists in regions with historical background (Wang 2023, 1399). An important criterion for the high assessment of rural settlements is the continuity of the vernacular tradition in their architecture, but the potential and wisdom of vernacular objects and historical settlement patterns are underestimated, and need a special researches (Dwijendra 2021).

3.2.2 Real centers of rural settlements: development potential

Design and practical work with the theory of centers is necessary because in rural settlements today it is possible to record such phenomena as:

- loss of the center, in which the planning structure would coincide with the value-semantic content, or its replacement by a quasi-center (1-2 shops in buildings from the 1970s–2010s) – in 93% of those studied by the author during field expeditions 2022–23s of rural settlements in the Sverdlovsk region in Russia, including those, which are not roadside, but located "in the depths" of the settlement subsystem;
- the emergence of more significant areas for the life of the settlement on its periphery, the inversion of the rural settlement structure;
- loss of status by traditional objects that marked the center (school, monument to soldiers, temple, etc.);
- loss of the integrity of the settlement, which mechanically combines different types of settlement – urban and rural.

V. Kristaller's theory of centers is not extended by specialists to the internal structure of rural settlements. And vice versa, the attitude of specialists based on the ideas of "new urbanism" when developing connections at the lower levels of the hierarchy – between parts or residents – does not reach the meso- and macro-level. In the most favorable situation in real life, a larger-scale center organizes the system so that smaller centers appear in it to support it. For example, public space in the physical center of a village is supported by more local areas within blocks or streets where people are more often to meet.

Thus, located away from the Irbit – Artemovsky highway, the village of Shogrinskoye (former volost village, now Artemovsky district, Sverdlovsk region, about 730 inhabitants according to the 2010 census) provides an example when a restored church, a cultural center and a monument to soldiers standing on one axis, separated from the main routes of movement of residents to the school and kindergarten. Having been founded in 1662, it now suffers from a discrepancy between the original and modern structures. The formal and even semantic center is not associated with the maximum movement and communication of residents. The administration building, despite the significance of its functions, is not surrounded by additional points of attraction and is separated from the rest of the settlement.

As a result, it turns out that points that are "central" in terms of planning and administration do not perform the functions of a center. In many cases, this situation is provoked by the arbitrary transfer of the official center from the original historical one, which can be identified by the church. In turn, the objects in this "center" have partially lost their original meaning. A school or club in only a few villages retains the status of cultural centers; more often there are not many people around them or not at all.

Fences introduced by townspeople significantly destroy the patterns and the hierarchical organization of connections inside and outside the rural settlement. The structure becomes discrete, more one-dimensional, primitive. is accompanied by the appearance of more significant points for the life of the settlement on its periphery. A store, service station, mini-market may be located on the edge, for example, closer to the road. At first glance, there is nothing special about this, but no one takes into account the spatial and value inversion of the rural settlement structure – the important is on the outskirts or to the side, but not in what is called the "center". These phenomena lead to the loss of the original integrity of the rural settlement. It is with them that you need to work, strengthening its stability. Taking into account real communications and movements, eliminating obstacles, and creating points of attraction are the tools of urbanists, which can easily be transferred from cities to elements of rural settlement.

4 CONCLUSIONS

The rural settlement subsystem differs in its properties from the urban one: being much larger in the number of elements, it has a simple type of spatial organization. The level of its stratification is also low, which does not allow the development of level models for constructing a rural settlement system. Being inextricably linked with land as a means of production, it is inert in its development possibilities and can only develop extensively. The very construction of the rural settlement system does not create opportunities for the development of its generalized theoretical models, which leads to the weakness and underdevelopment of the methodological base of the study and explains the "statistical" and abstract-typological options for studying. We could add, that the reduction of small and tiny rural settlements occurs in the 2000s. not only in Russia (Antipova 2012, 132), but it does not follow from this that administrative measures for consolidation will make rural settlement subsystems more stable.

We strive to record the diversity of types of rural settlement and its components with maximum consideration of history, landscape, and economy. However, we are forced to admit that this area of knowledge does not yet have appropriate scientific models, including due to the limited current empirical material and its asymmetry towards quantitative data.

The ideas of consolidation implemented in different periods lead either to the complete destruction and practical disappearance of rural settlements, or to the creation of an ineffective system that does not have an economic basis for existence. The search for new ways and mechanisms that are more adequate to modern realities is impossible without taking into account the uniqueness of individual settlements and their context, which enhances their sustainability.

REFERENCES

A New Pattern Language for Growing Regions: Places, Networks, Processes. A Collection of 80 New Patterns for a New Generation of Urban Challenges, 2020. Sustasis Press, USA.

Alekseev, A.I., 1990. *Many-faced village: population and territory.* Mysl`, Moscow.

Ambrosio-Albalá M., Bastiaensen J. The New Territorial Paradigm of Rural Development: Theoretical Foundations from Systems and Institutional Theories // IOB Discussion Paper. 2010. # 2. 69 p. URL: https://www.researchgate.net/publication/228381936_The_new_territorial_paradigm_of_rural_development_theoretical_foundations_from_systems_and_institutional_theories.

Antipova, E.A., Fakeyeva, L.V., 2012. Settlement System of Belarus. Spatial and Temporal Trends at the End of 20th and the Beginning of the 21st Centuries. In: *Journal of Settlements and Spatial Planning.* Vol. 3. Issue 2. URL: http://www.bsu.by/Cache/pdf/479383.pdf (access 06.04.2024).

Averkieva K.V. *Geography of adaptation processes in rural areas of the Non-Black Earth Region at the turn of the 20th–21st centuries*. Abstract of the candidate's dissertation. specialty 25.00.24, Economic, social and political geography. M., 2012. 24 p.

Aydin Turk, Y., Çifci, A., 2017. The Effects of Landscape Characters on Rural Settlement Patterns. In: *Ecology, Planning and Design.* St. Kliment Ohridski University Press, Sofia. Chapter 34, 349–360.

Boggia, A., Rocchi, L., Paolotti, L., Musotti, F., Greco, S., 2014. Assessing Rural Sustainable Development potentialities using a Dominance-based Rough Set Approach. In: *Journal of Environmental Management*, Vol. 144, 160-167.

Bystrova, T.Yu., Mazaev, G.V., 2022. Features of urban and rural settlement systems at the present stage. In: *Academic Bulletin UralNIIproekt*. No. 3.

Cárdenas, A.G., Nieto, M.A., 2017. Towards Rural Sustainable Development? Contributions of the EAFRD 2007–2013 in Low Demographic Density

Territories: The Case of Extremadura (SW Spain). In: *Sustainability*. № 9. Pp. 1173

Chugunova N., Polyakova T., Naroshnyaya A., Lisetskii F. Current Challenges to the Sustainable Development of Rural Communities in Russia's Central Chernozem Region, 2023. In: *Rural and Regional Development* 1(1). 10001.

Drennan, R.D., Haller, M.J., 2007. The local Village Community and the larger Political Economy Formative and Classic Interaction Patterns in the Tehuacan Valley Compared to the Valley of Oaxaca and the Basin of Mexico. In: *The Political Economy of Ancient Mesoamerica: Transformations during the Formative and Classic Periods*, edited by Vernon L. Scarborough and John E. Clark. University of New Mexico Press, Mexico. 65-82.

Dwijendra, N.K.A., at all. The Effect of Topography on Settlement Patterns in The Nusa Penida Island, Bali, Indonesia. 2021. In: *International Journal of Modern Agriculture*, Vol. 10, No. 2

Enin, A.E., Liventseva, A.V., 2016. Systematic approach to urban planning: history, basic provisions, objects of systemic research. In: *Scientific Bulletin of Voronezh State University of Construction and Architecture*. No. 4(44).

Ioffe, G., Nefedova, T., Zaslavsky I. 2006. *The End of Peasantry? The Disintegration of Rural Russia.* University of Pittsburgh Press, Pittsburgh.

Korandei, F.S., Abramov, I.V., Kostomarov, V.M., Cherepanov, M.S., Sheludkov, A., 2021. Provocative landscapes: a study of everyday cultural landscapes at the outskirts of agglomerations. In: *Vestnik Archologii, Antropologii i Etnografii*. Vol. 3(54). 247-257. 10.20874/2071-0437-2021-54-3-21.

Mazur L.N. *Villages of the Middle Urals in the twentieth century. Statistical and ethnographic description*, 2003. Ural University Publishing House, Ekaterinburg.

Mironova, M.N., Kholina, V.N., 2011. Disproportions in the regional development of Russia: dynamics in the post-Soviet period. In: *Bulletin of RUDN University.* Series: Economics. No. 4. 23–34.

Mouraz, C.P., Ferreira, T.M. & Silva, J.M., 2023. Building rehabilitation, sustainable development, and rural settlements: a contribution to the state of the art. In: *Environ Dev Sustain*.

Nguyen, A.T., Truong, N.S.H., Rockwood, D., Le Tran, A. (2019). Studies on sustainable features of vernacular architecture in different regions across the world: A comprehensive synthesis and evaluation. In: *Frontiers of Architectural Research, 8*(4), 535–548.

Salingaros, N.A., 2006. *A Theory of Architecture*. Umbau-Verlag, Solingen.

Sanders, L. 2021. *Settling the World. From Prehistory to the Metropolis Era.* Presses universitaires François-Rabelais, Tours. URL: https://books.openedition.org/pufr/19610

Shcherbina E.V., Gorbenkova E.V., 2018. Modelling the Rural Settlement Development. In: *Materials Science Forum*. Vol. 931. 877–882.

Wang, X, Zhu, L, Li, J, Zhang, N, Tang, Y, Sun, Y, Wu, H, Cheng, C., 2023. Architectural Continuity Assessment of Rural Settlement Houses: A Systematic Literature Review. In: *Land*. 12(7):1399.

Wegren, S.K., Obrien, D., Patsiorkovsky, V.V. The Economics of Rural Households in Russia: Impact of Village Location, 2008. In: *Eurasian Geography and Economics*, 49, No. 2, 200–214.

Yurkova, O.N., 2021. Rural settlement systems: theoretical analysis. In: *Social consolidation of urban communities: opportunities and limitations in the conditions of digitalization of the urban environment.* Konstanta LLC, Belgorod. 91–95.

Digital Education and the Use of Artificial Intelligence in Education

Grigoreva Marina Nikolaevna[1], Grigorev Artem Leonidovich[2], Borovkova Marina Georgievna[3], Osipov Vladislav Sergeevich Leonidovich[4], Akimova Venera Petrovna[5]
I.N. Ulyanov Chuvash State University, 15 Moskovsky Avenue, Cheboksary, Chuvash Republic, Russia
mngrigoreva@yandex.ru

Keywords: distance learning, e-learning, digital education, education, artificial intelligence.

Abstract: The article discusses digital education, its advantages and problems, and the integration of artificial intelligence. Digital education allows the use of various technologies to improve the quality of education and expand access to it, and the use of next-generation neural networks in the educational process enables the personalization of learning and the improvement of the quality of specialist training. It provides flexibility, interactivity, and accessibility of resources but faces technical problems and security issues. Development prospects are related to technological advancements, integration with the real world, and the creation of effective educational materials.

1 INTRODUCTION

Digital education is becoming increasingly relevant in the modern world. It allows the use of various technologies to improve the quality of education and expand access to it. In this article, we will look at the main advantages and problems of digital education, the prospects for its development, and the integration of artificial intelligence (Akhromeeva T.S., 2017).

2 ADVANTAGES OF DIGITAL EDUCATION

2.1 Flexibility and accessibility

The flexibility and accessibility of digital education are important aspects that determine the possibility of obtaining education at any time and in any place (Maslanov E.V., 2019).

Flexibility in digital education means that students and learners have the opportunity to choose a convenient time, place, and pace of learning. They can study subjects and materials in the order that is most convenient for them and decide for themselves how much time they want to spend studying a specific topic. This is especially useful for those who have other responsibilities and limited time, such as working people who want to get additional education or parents who need flexibility to care for children.

The accessibility of digital education means that electronic educational resources are available to everyone, regardless of their location and physical abilities. With accessible technology such as computers, smartphones, or tablets, students can access online courses and materials from anywhere in the world. This is especially useful for people living in remote or sparsely populated areas, where access to traditional educational institutions may be lacking. Accessibility of digital education can also be important for people with limited physical abilities or disabilities, who may find it difficult to attend regular schools or universities.

One of the key advantages of digital education is its flexibility and accessibility in adapting to the different educational needs of various people. Thanks to digital technologies, education becomes more individualized and customizable to meet the needs of each student. This allows students to receive quality

[1] https://orcid.org/0000-0003-2698-2930
[2] https://orcid.org/0009-0008-8714-3843
[3] https://orcid.org/0000-0002-2433-1053
[4] https://orcid.org/0009-0008-6396-9923
[5] https://orcid.org/0000-0002-9278-3043

education that matches their level of knowledge and interests. Additionally, digital educational platforms also provide the ability to give feedback and assess academic achievements, which helps students develop and track their progress.

However, it should be noted that the flexibility and accessibility of digital education need to be supported by appropriate infrastructure and access to reliable internet. The lack of access to quality internet connections and technical equipment can limit the possibilities of using digital education. Therefore, investment in the development of appropriate infrastructure and technical support is necessary to ensure maximum flexibility and accessibility of digital education.

2.2 Interactivity and personalization

Interactivity and personalization of digital learning are key aspects that make the learning process more interesting and effective (Dubrovsky D.I., 2017).

2.2.1 Interactivity:

Video lessons and presentations. Video lessons and presentations allow for a visual representation of information and make it accessible for perception. This helps students better understand and remember the material.

Online quizzes and simulators. Interactive quizzes and simulators allow students to test their knowledge and identify weak areas. This helps them focus on studying specific topics and improve their skills.

Virtual laboratories and simulators. Virtual laboratories and simulators allow students to gain practical experience without leaving their workplace. This helps them better understand and reinforce the knowledge they have acquired.

Gamification. Using game elements and a competitive spirit makes the learning process more engaging and motivating. This helps students focus on studying the material and achieve better results.

2.2.2 Personalization:

Adaptive learning. Adaptive learning allows the automatic adjustment of educational material to the knowledge level and needs of each student. This helps students absorb material faster and more effectively.

Individualized learning. Digital learning allows students to work on their projects and assignments at their own pace. This helps them develop their skills and learn independently.

Feedback. Digital learning provides students with the opportunity to receive feedback from teachers and other students. This helps them correct their mistakes and improve their skills.

2.3 Accessibility of resources

The internet offers a vast amount of information on various topics. This allows students and teachers to access extensive knowledge bases and use them for learning.

3 PROBLEMS OF DIGITAL EDUCATION

3.1 Technical issues

The technical issues of digital education are related to the development of technology and the ability to use these technologies (Budanov V.G., 2016). They include:

Insufficient technical equipment for teachers and students. Many regions face a shortage of equipment such as tablets and laptops, which hampers learning.

Insufficient technological preparedness of educational institutions. Many educational institutions are not ready for a sudden transition to online learning, leading to many problems such as server crashes and prolonged unavailability.

Lack of clear rules and standards for online education. In the context of digitalization, education lacks established standards and rules, creating problems for educators and students.

Inability to deliver education to the end user. This is related to the lack of normal high-speed internet, equipment for organizing quality education, and the ability to use online learning tools.

Cybersecurity and information hygiene. These aspects play an important role in ensuring safety and confidence in the online environment, especially for educational institutions.

To solve these problems, a comprehensive solution is needed, including technical equipment, the creation of a unified digital educational standard, the definition of a clear agenda and the individuals who will implement the program, as well as the development of a technological base and the creation of a digital learning content base.

3.2 Security and Privacy

Security and privacy issues in digital education include:

Information security threats. Distance learning introduces new threats to the privacy and data protection of participants in the educational process.

Phishing and fraud threats. Distance learning participants should be trained to recognize phishing messages and not respond to them, as well as to update antivirus software and browser extensions to protect against such threats.

Threats from malware and viruses. Distance learning participants should use antivirus software to protect their computers from viruses and other malicious software.

Threats from software vulnerabilities. Software for distance learning should be updated and protected from vulnerabilities to keep the system safe from new types of cybercrimes.

Limitations on the use of equipment. Distance learning participants should limit the use of personal devices when working in the system to prevent infiltration through vulnerabilities on connected devices.

Threats from multi-factor authentication. Distance learning participants should use multi-factor authentication to log into the system to add an additional level of protection.

Threats from unauthorized access. Distance learning participants should limit access to the system only to those users who really need it and set different access levels depending on their role.

Threats from insufficient awareness of participants. Distance learning participants should be informed about basic security measures and personal data protection requirements, as well as the most current protection methods.

4 PROSPECTS FOR THE DEVELOPMENT OF DIGITAL EDUCATION

4.1 Technology Development

The development of digital education technologies is aimed at increasing the efficiency and flexibility of the educational process, as well as personalization and outcome orientation (Macheret D.A., 2019). In Russia, seven tasks of digitalization of education are identified:

Development of material infrastructure: construction of data centers, communication channels, and devices for using digital educational materials.

Implementation of digital programs: creation, testing, and application of educational materials using machine learning technologies, artificial intelligence, and others.

Development of online learning: gradual abandonment of paper information carriers and transition to the use of online courses and platforms.

Development of new learning management systems (LMS): creation of programs for the administration and control of educational courses, ensuring equal and free access of students to knowledge and flexibility of learning.

Development of a universal student identification system: creation of educational institution models that will allow tracking the progress and results of learning.

Improving teachers' skills in digital technologies: training educators to use new technologies and tools to improve the educational process.

Development of new educational institution models: creation of examples of how ideal digital education should work using new technologies and tools.

4.2 Integration with the Real World

The integration of the real and virtual worlds in education opens new horizons for learning and student development. It includes the use of virtual environments, augmented reality technologies, and other digital tools.

Virtual classes allow students to learn from anywhere in the world, interact with teachers and other students. Virtual laboratories provide access to equipment and experiments, as well as reduce the risks associated with conducting experiments.

The development of professional skills occurs through virtual projects, where students apply knowledge in practice. Virtual excursions and travels enrich the educational experience and expand students' horizons.

Virtual reality is used to simulate real scenarios and solve problems, for example, in medicine or engineering. Thus, the integration of the real and virtual worlds contributes to improving the quality of education and forming prepared professionals.

5 IMPLEMENTATION OF ARTIFICIAL INTELLIGENCE

The implementation of artificial intelligence (AI) in digital education can lead to significant changes in the field of education (Petrunin Y.Y., 2018). Here are some of the main directions:

Adaptive learning: AI allows the creation of individual educational programs that take into account the skills, interests, and characteristics of each student.

Gamification: the use of AI to create personalized games and tasks that make learning more engaging and interesting.

Intelligent robotics: the use of robots to solve various tasks in learning, such as programming, designing, and conducting experiments.

Learning to work with AI: developing skills in working with AI for representatives of creative professions, such as designers, artists, and programmers.

Micro- and nano-learning: the use of AI to provide information in the form of short lessons, videos, and exercises that are easily perceived and remembered.

Generative artificial intelligence: the use of chatbots and neural networks to improve the learning process, analyze learning outcomes, and select materials.

Massive Open Online Courses (MOOCs): the use of AI to analyze data and support the educational process on MOOC platforms.

The implementation of AI in digital education contributes to improving the quality of education, the accessibility of education, and the inclusiveness of the educational environment.

6 CONCLUSION

In conclusion, it is worth noting that digital education has a number of advantages, such as flexibility, accessibility, interactivity, personalization, and the ability to apply artificial intelligence to improve the quality of learning. However, to successfully implement and develop digital education, it is necessary to solve a number of problems related to technical equipment, technological preparation, online education standards, and cybersecurity. It is also important to ensure high-quality internet connectivity and technical support to provide maximum flexibility and accessibility of digital education.

REFERENCES

Akhromeeva, T.S., Malinetsky, G.G., Posashkov, S.A., 2017. Meanings and values of digital reality: Future. Wars. *Synergetics. Philosophical Sciences.* No. 6. P. 104-120.

Maslanov, E.V., 2019. Digitalization and the development of information and communication technologies: new challenges or exacerbation of old problems? *Digital Scholar: Philosopher's Lab.* Vol. 2, No. 1. P. 6-21.

Dubrovsky, D.I., 2017. Electronic culture. Who's against? *Philosophical Sciences.* No. 2. P. 50-57.

Budanov, V.G., 2016. The new digital life technosphere – prospects and risks of transformations of the anthroposphere. *Philosophical Sciences.* No. 6. P. 47-55.

Macheret, D.A., 2019. "Digital socialism" or expansion of individual freedom? *Social Sciences and Modernity.* No. 2. P. 54-65.

Petrunin, Y.Y., 2018. Artificial intelligence: key to the future? *Philosophical Sciences.* No. 4. P. 96-113.

A Comprehensive Approach to Fault Diagnosis of Electrical Equipment Based on Color Images

Anna E. Kolodenkova[a], Svetlana S. Vereshchagina[b]
Samara State Technical University, Samara, Russia
anna82_42@mail.ru

Keywords: electrical equipment, thermogram, photograph, black-and-white graphs, convolutional neural network, classification.

Abstract: Electrical equipment plays a critical role in industrial electrical systems, where unexpected mechanical failures during operation can lead to severe consequences, such as disruptions in technological processes, reduced quality and quantity of produced goods, and the occurrence of emergency situations. To ensure the reliable operation of these systems, it is essential to conduct regular inspections and maintenance of electrical equipment using modern computer technologies for the timely detection of faults. To address this issue, a comprehensive approach is proposed, based on the processing of color images obtained from thermal imaging devices, black-and-white graphs generated from sensor data stored in Excel format, as well as simple color photographs. The core of the image, graph, and photograph processing (recognition) lies in artificial intelligence technologies, specifically convolutional neural networks (CNNs). The developed CNN outputs a class number corresponding to the current state of the equipment. Additionally, an algorithm for a comprehensive approach to fault detection in electrical equipment using CNNs is proposed. The results obtained allow for a reduction in the number of unplanned failures by providing early warnings about the development of faults and potential equipment failures..

1 INTRODUCTION

With the rapid development of various industrial sectors, fault diagnosis of electrical equipment is becoming increasingly significant to ensure the safe operation of equipment and production processes. This equipment is prone to frequent premature failures due to potential damage, wear and tear, climatic conditions, and other external and internal environmental factors, making regular inspections and maintenance of electrical equipment (EE) necessary (Shao, Xia, Han, Zhang, Wan, 2020; Cheng, Zixuan, Mingsong, 2021; Kolodenkova, Vereshchagina, 2023).

As traditional periodic inspections can no longer meet the safety requirements of EE operation due to the increasing complexity of these systems, achieving automatic fault recognition now relies heavily on computer technologies and image recognition techniques, particularly those using thermal imaging devices. The advantage of using such devices is the ability to conduct rapid inspections without direct contact with the object.

There is a significant body of work by both international and Russian researchers dedicated to assessing the technical condition of EE using convolutional neural networks (CNNs) (Alvarado-Hernandez, Zamudio-Ramirez, Jaen-Cuellar, Osornio-Rios, Donderis-Quiles, Antonino-Daviu, 2022; Zhen, Zhenbao, Vong, Pecht, 2019; Mingshu, Haiting, Xipeng, 2021).

For instance, the study by Alvarado-Hernandez et al. (2022) discusses the structure and development of an intelligent sensor based on infrared thermography for diagnosing faults in related elements of an induction motor (such as rolling bearings and gearboxes). Significant statistical features are extracted using principal component analysis, which leads to preliminary classification, facilitating the final fault classification with a feedforward backpropagation neural network, ensuring accurate fault categorization.

[a] https://orcid.org/0000-0002-9784-1871
[b] https://orcid.org/0000-0003-0421-309X

In the work by Zhen et al. (2019), a fault detection method based on infrared thermography (IRT) is examined for rotating machinery. First, images of the rotating equipment in various states are captured using IRT, and then two popular feature extraction methods from IRT images—bag-of-visual-words and CNN—are sequentially tested. The extracted features are classified to achieve automatic fault diagnosis.

Mingshu, Haiting, and Xipeng (2021) investigate the diagnosis of thermal faults in electrical equipment at substations based on image fusion. They propose an algorithm for the registration and fusion of infrared images of substation electrical equipment. A model based on mask R-CNN for image segmentation and recognition was developed for these images.

Despite the extensive research in this field, the issue of diagnosing EE faults through thermal imaging remains unresolved. This is because the developed approaches and methods have practical limitations, as they are often tailored to specific equipment.

In light of this, the authors propose a comprehensive approach to EE fault diagnosis, which integrates color images and photographs, as well as black-and-white graphs obtained through various methods, to identify faults in EE under a multitude of factors using convolutional neural networks (CNNs).

2 CHALLENGES IN FAULT RECOGNITION OF ELECTRICAL EQUIPMENT BASED ON IMAGES

For the recognition and identification of color images, Convolutional Neural Networks (CNNs) are most commonly used, as they provide partial robustness to changes in scale, shifts, displacements, rotations, and other distortions (Pekhota, Galushko, Gromyko, 2021; Cheng-Jian, Chun-Hui, Frank, 2023; Bengio, 2009). However, their application presents several challenges, despite their advantages:

1. Requirement for Large Data Sets: This issue arises during CNN training when the amount of available data (labeled data) is limited.
2. Interpretability: This problem is due to the complex mechanisms underlying CNNs, making it difficult to interpret their operations.
3. Computational Complexity: CNNs require significant computational resources for training, particularly powerful processors and preferably GPUs (Graphical Processing Units).
4. High Sensitivity to Changes: This issue can occur if factors affecting the image (lighting, background, viewing angle, weather conditions such as wind, rain, etc.) were not represented in the training data set.
5. Noise Suppression: This problem arises if the image was obtained through digitization. Sources of noise can include imperfect image-capturing equipment (e.g., video cameras) as well as poor shooting conditions (e.g., nighttime photography). Noise suppression is employed to enhance visual perception (e.g., image compression).
6. Overfitting and Robustness: To address these issues, researchers propose data augmentation techniques, which can generate a large number of training data sets.
7. Training CNNs: Training large CNNs can be time-consuming. As a solution, researchers suggest using parallel computing and optimizing model architectures.

Therefore, when diagnosing electrical equipment using thermal imaging, it is crucial to minimize the influence of factors that could introduce errors or inaccuracies in the readings.

3 ALGORITHM OF A COMPREHENSIVE APPROACH

Infrared thermographic imaging is well-suited for detecting faults in electrical equipment, as it allows for diagnostics while the equipment remains in continuous operation. By capturing and analyzing temperature data distributed across the equipment's surface, it is possible to identify localized areas where faults are present and assess the severity of the damage. If the thermal image cannot be fully evaluated by personnel, it can still be used to determine the need for further diagnostics of the equipment.

The idea behind the approach to fault detection in electrical equipment using Convolutional Neural Networks (CNNs) lies in the comprehensive processing of color images, black-and-white graphs, and standard color photographs, as well as the design and training of CNNs. The recognized data must be used to classify the technical condition of the electrical equipment.

Figure 1 presents an algorithm for the comprehensive approach to fault detection in electrical equipment using CNNs, consisting of 7 steps.

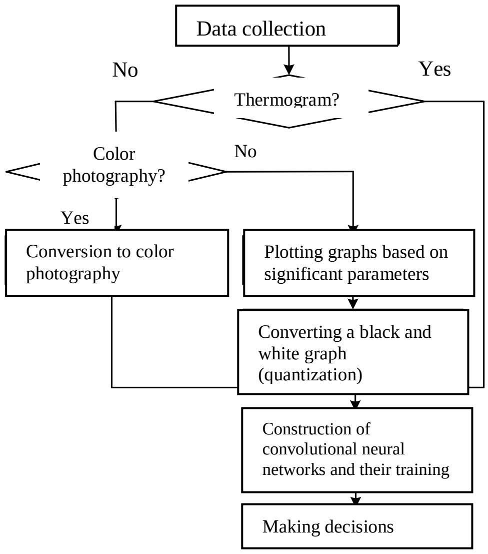


Figure 1. Algorithm of a Comprehensive Approach for Fault Detection in Electrical Equipment Using Convolutional Neural Networks (CNNs).

Step 1: Data Collection

Data can be acquired in the form of color images (thermograms) obtained using a thermal imaging device, black-and-white graphs that characterize changes in various parameters over time based on sensor data stored in Excel format, and standard color photographs. It is important to note that graphs constructed from the electrical equipment's parameter values are used in cases where thermograms or color photographs are unavailable or of poor quality.

Step 2: If the input is a thermogram, proceed to Step 7; otherwise, proceed to Step 3.

Step 3: If the input is a color photograph, proceed to Step 4; otherwise, proceed to Step 5.

Step 4: Convert the color photograph to a black-and-white image.

This conversion is performed using the Niblack method (Saxena, 2019), as it is relatively simple and provides the highest speed for image binarization. The threshold value for the point with coordinates

(m,) is calculated using the following formula::

$$t(m,n)=\mu(m,n)+k\cdot\sigma(m,n)$$

where μ(m,n) is the mean,

σ(m,n) is the standard deviation within the local neighborhood of the considered image point, and

k is a parameter that determines the portion of the object's boundary to be considered as part of the object.

This method, due to its simplicity, enables the highest speed of image binarization. It is most commonly used in practice for the rapid filtering of high-contrast images where there are minimal highly noisy regions with smooth brightness transitions.

It should be noted that there are numerous methods for converting color images to black-and-white (Fedorov, 2018; Israfilov, 2017). Each method has its own advantages and disadvantages. Therefore, before selecting and applying a method, it is advisable to consider the specific domain as well as the image quality.

Step 5: Plotting Graphs Based on Parameter Values

Step 6: Quantization of Black-and-White Graphs (Pekhota, Galushko, Gromyko, 2021). In this step, image quantization is used, where the continuous dynamic range of brightness values is divided into several discrete levels using the Lloyd-Max quantizer:

$$x(i_1,i_2)=\frac{1}{4\pi^2}\int_{-\pi}^{\pi}\int_{-\pi}^{\pi}\frac{1}{\Delta t_1\Delta t_2}\sum_{k_1}\sum_{k_2}X_{\text{н}}\left(\frac{\omega_1+2\pi k_1}{\Delta t_1},\frac{\omega_2+2\pi k_2}{\Delta t_2}\right)\cdot\exp(j\omega_1 i_1+j\omega_2 i_2)\,d\omega_1 d\omega_2$$

,

where $\Delta t1$ and $\Delta t2$ are the vertical and horizontal steps or discretization intervals, respectively;

$k1$ and k2 represent the segment numbers;

Xn is the two-dimensional continuous frequency spectrum;

$\omega1$ and $\omega2$ are the normalized frequencies, and

j=1

The quantization process also takes into account the mean square quantization error, calculated using the following formula:

$$E\{\varepsilon^2\}=E\{x^2\}-\sum_{j=1}^{L}r_j^2\int_{d_j}^{d_{j+1}}w(x)dx,$$

where x is the continuous variable,

dj and dj+1 are the boundary thresholds determined by the dynamic range of brightness;

r is the finite set,

L is the number of levels, and

w is the probability density.

Step 7: CNN Construction and Training

The training of CNNs is carried out using a database of thermograms and graphs based on the parameter values of the electrical equipment.

The convolutional neural network for thermogram recognition is essential for identifying critical or abnormal temperatures, which can be detected in real-time without contact while the equipment is in operation.

The convolutional neural network for simple color photograph recognition is necessary for detecting the contours of equipment parts with temperatures exceeding permissible limits.

The convolutional neural network for black-and-white graph recognition is crucial for identifying faults in the electrical equipment.

Step 8: Decision Making

Each CNN outputs a class number corresponding to the current state of the electrical equipment:

Class 1: The equipment is fully operational.

Class 2: The equipment is operational with minor deviations.

Depending on the class, a list of recommended actions is provided to prevent equipment failure.

4 RESULTS

The research results were obtained during the diagnosis of an asynchronous motor model AIR63A4U1 based on thermograms. The development of the CNN was conducted using the TensorFlow library in the Python programming language. The thermogram database was populated with images captured using a Testo 875-1i thermal imager, which has a thermal sensitivity (NETD) of < 0.05°C at 30°C and an operating temperature range from –15°C to 40°C. Thermal imaging was performed during the spring, summer, and autumn seasons under various climatic conditions (temperature fluctuations, heating). The thermogram database contains 136 images in .bmt format, which include both the real image and the thermogram, with a resolution of 640 x 480 pixels.

When measuring with the thermal imager, the threshold temperature values are set both automatically (continuous automatic adjustment based on current minimum/maximum values) and manually. All temperature measurements below or above the threshold value are displayed in the same color as the threshold value.

Since the number of images representing equipment in good technical condition is much greater than those with faults, the error rate alone cannot objectively evaluate the quality of the CNN. Therefore, its accuracy was assessed as follows:: $P = TP / (TP + FP)$, where TP (*True Positive*) – is the correct identification of a functioning condition as functional, and FP (*False Positive*) – is the incorrect identification of a functioning condition as faulty.

The CNN achieved an accuracy of 96.2%. The equipment was determined to be operational, albeit with minor deviations. Analysis of the thermograms revealed an elevated temperature on the motor housing, which is indicative of winding overheating. Consequently, the following measures were recommended:

Analyze the voltage unbalance coefficient in the zero-sequence component.

Analyze the voltage unbalance coefficient in the negative-sequence component.

Analyze the voltage asymmetry.

5 CONCLUSION

The study proposes an approach for identifying faults in electrical equipment based on the comprehensive processing of input data (thermograms, graphs, photographs). This approach enables faster decision-making regarding the technical condition of the equipment, improves the accuracy of image classification, and reduces the influence of human factors. Additionally, for color images, the varying thermal conductivity of materials (e.g., steel for the housing, copper for the windings, etc.) is taken into account.

ACKNOWLEDGMENTS

This research was supported by the Russian Science Foundation, grant No. 23-29-00415.

REFERENCES

Shao, H., Xia, M., Han, G., Zhang, Y., Wan, J., 2020. Intelligent fault diagnosis of rotor-bearing system under varying working conditions with modified transfer convolutional neural network and thermal images. *IEEE Transactions on Industrial Informatics.* Vol. 17. No. 5. P. 3488–3496.

Cheng, L., Zixuan, Y., Mingsong, Zh., 2021. Research on fault detection method of infrared thermal imaging for power equipment based on deep learning. IOP Conference Series: Earth and Environmental Science. Vol. 714. P. 1–9.

Kolodenkova, A., Vereshchagina, S., 2023. Development of a unified diagnostic complex of electrical equipment for intelligent systems. 2023 International Russian Automation Conference. P. 209–213.

Alvarado-Hernandez, A.I., Zamudio-Ramirez, I., Jaen-Cuellar, A.Y., Osornio-Rios, R.A., Donderis-Quiles, V., Antonino-Daviu, J.A., 2022. Infrared thermography smart sensor for the condition monitoring of gearbox and bearings faults in induction motors. *Sensors.* Vol. 22. P. 1-20.

Zhen, J.I.A., Zhenbao, L.I.U., Vong, C.-M., Pecht, M., 2019. A rotating machinery fault diagnosis method based on feature learning of thermal images. IEEE Access. P. 12348-12359.

Mingshu, L., Haiting, L., Xipeng, Y., 2021. Thermal fault diagnosis of electrical equipment in substations based on image fusion. *Traitement du Signal.* P. 1095–1102.

Pekhota, A.N., Galushko, V.N., Gromyko, I.L., 2021. Tekhnologiya ispol'zovaniya svertochnyh nejronnyh setej pri diagnostike sostoyaniya transformatorov. *Vestnik Polockogo gosudarstvennogo universiteta. Seriya Fundamental'nye nauki.* № 12. S. 63–69.

Cheng-Jian, L., Chun-Hui, L., Frank, L., 2023. Bearing fault diagnosis using a vector-based convolutional fuzzy neural network. *Applied Sciences.* P. 1–11.

Bengio, Y., 2009. Learning deep architectures for AI. *Foundations and Trends in Machine Learning,* P. 1-55.

Saxena, L.P., 2019. Niblack's binarization method and its modifications to real-time applications: a review. Artif Intell Rev 51, P. 673–705.

Fedorov, A., 2018. Binarizaciya cherno-belyh izobrazhenij: sostoyanie i perspektivy razvitiya. [Elektronnyj resurs]. Rezhim dostupa: http://itclaim.ru/Library/Books/ITS/wwwbook/ist4b/its4/fyodorov.htm/ (data obrashcheniya: 01.04.2024).

Israfilov, H. S., 2017. Issledovanie metodov binarizacii izobrazhenij. *Vestnik nauki i obrazovaniya.* №6 (30). C.1-8.

A Measure of the Internal Consistency of Enterprise Digital Twin Data by Control Bsi Method

Masaev Sergey Nikolaevich[a], Valkov Konstantin Vladimirovich[b]
Institute of Informatics and Telecommunications, Reshetnev Siberian State University of Science and Technology, Krasnoyarskii rabochii prospekt, Krasnoyarsk, Russia
Department of Information and Control Systems
faberi@list.ru, prol4588@gmail.com

Keywords: Internal data consistency, BSi method, control, enterprise digital twin, Cronbach's alpha.

Abstract: The research describes internal consistency of data (Cronbach's alpha) so control a digital twin of an enterprise. The British Standards Institution (BSi) method is used for control. It was created in 1901 to set steel standards for British industrialists. The BSi method is evolving to cover information security standards at different levels of availability. The BSi method has not been widely studied as a separate object. This makes it difficult to estimate its impact on the activities of the enterprise. Cronbach's alpha coefficient is used to estimate the consistency of the data in research. It is a widely accepted measure of the internal consistency of the enterprise's data. The research results show the level of internal consistency of the data. The estimation is carried out before the implementation of BSi and after its implementation

1 INTRODUCTION

Cronbach's alpha is a measure of the internal consistency (reliability) of a test or questionnaire. It is used to estimate how internally consistent responses are to various questions or test items. This measure ranges from 0 to 1, with a value closer to 1 indicating higher internal consistency.

The British Standards Institution (BSi) method dates back to 1901, when a committee of engineers set the first steel standards for British industrialists. Since then, this method has developed and expanded, covering standards that ensure the security of information at all levels of access to it.

In the field of control, it is important to study various approaches to analyzing the activities of economic entities, such as inter-industry balances, various modeling and the agent approach. However, the BSi method is not considered as a separate object for research, which creates certain difficulties in estimating its impact on the activities of the enterprise (Vinnichenko, Istomina, 2023; Taranenko, Banzer, 2021).

Various scientists dealt with the issues of control complex systems: V.V. Leontiev, L.V. Kantorovich, A.G. Granberg, A.G. Aganbegyan, V.F. Krotov, M.G. Dorrer, G.A. Dorrer, S.N. Masayev and others (Dorrer, 2023; Dorrer, 2022; Masaev, 2020; Granberg, 2006; Granberg, 2004; Kantorovich, 2011; Krotov, 1990).

Purpose of the work: to measure the internal consistency of the enterprise digital twin data in normal operation and with the implementation of BSi control.

2 METHOD

Cronbach's alpha is calculated using the following formula:

$$\alpha = \frac{N}{N-1}\left(\frac{\sigma_X^2 - \sum_{i=1}^{N}\sigma_{Y_i}^2}{\sigma_X^2}\right), \text{где } X = \sum_{i-1}^{N} Y_i \qquad (1)$$

where N is the number of sample components, σ_X^2— standard deviation of all considered sets, $\sigma_{Y_i}^2$ standard deviation of an individual component.

Table 1: Cronbach's alpha values.

α	Values
> 0.9	very good

[a] https://orcid.org/0000-0002-5825-2708
[b] https://orcid.org/0009-0002-2206-7567

> 0.8	good
> 0.7	sufficient
> 0.6	doubtful
> 0.5	bad
≤ 0.5	Insufficient

2.1 Initial data

The digital twin of an enterprise is characterized by 34 values over 60 periods (t). For this period, the x_4, x_9, x_{10}, x_{11}, x_{15}, x_{20}, x_{21}, x_{22}, x_{24}, x_{25}, x_{26}, x_{29}, x_{33}, x_{34} values in the appendix have zero values, since the table is given partially. In the rest of the table, the values of x_4, x_9, x_{10}, x_{11}, x_{15}, x_{20}, x_{21}, x_{22}, x_{24}, x_{25}, x_{26}, x_{29}, x_{33}, x_{34} in other periods are different from zero. A detailed description of the enterprise digital twin under study can be read in the monograph (Masaev, 2021).

2.2 Computations

Let's calculate Cronbach's alpha for data without using the BSi method:

$$\begin{gathered} N = 60 \\ \sigma_X^2 = 981\ 045\ 998\ 494.74 \\ \sum_{i=1}^{66} \sigma_{Y_i}^2 = 32\ 752\ 955\ 528.32 \end{gathered} \tag{2}$$

Let's substitute the values from formula 2 into formula 1:

$$\frac{60}{60-1}\left(1-\frac{981045998494.74}{32752955528}\right) = 0.982997543 \tag{3}$$

Based on the values in Table 1 and what happened in the computations, we can conclude that the data are in very good agreement.

Let's calculate this coefficient for data using the BSi method:

$$\begin{gathered} \mathrm{N} = 77 \\ \sigma_X^2 = 1\ 227\ 645\ 808\ 383.88 \\ \sum_{i=1}^{77} \sigma_{Y_i}^2 = 36\ 063\ 010\ 941.87 \end{gathered} \tag{4}$$

Let's substitute the values from formula 4 into formula 1:

$$\frac{77}{77-1}\left(1-\frac{1227645808383.88}{36063010942}\right) = 0.983395626 \tag{5}$$

The data from the obtained result are also in very good agreement.

When using the BSi method, the Cronbach's alpha coefficient was higher, which suggests that the data using the BSi method fit better than those without.

3 CONCLUSIONS

Cronbach's alpha coefficient values were obtained. For data without using the BSi method, 0.982997543 and for data using the BSi method, the value is 0.983395626. Both coefficient values exceed 0.9, indicating very good internal consistency of the data in both samples. The coefficient value for data using the BSi method is slightly higher. It’s a higher degree of internal data consistency across the enterprise.

REFERENCES

Representation of the British Standards Institution in Russia, URL: https://www.bsigroup.com/ru-RU/

Vinnichenko, A.V., Istomina, Y.P., 2023. Cronbach's alpha for reliability analysis in prediction of machine learning models. Alfa Cronbach for reliability analysis in forecasting machine learning models. In *XXVI International Scientific Conference Proceedings*, **3** (Saint Petersburg: Saint Petersburg State University of Aerospace Instrumentation) 151-155 pp.

Taranenko, E.Yu., Banzer, E.A., 2021. Development of the system of quality indicators to improve the competitiveness of the enterprise. *Competence* **8** 36-41 pp.

Dorrer, M.G. et al 2023. *Web of Conferences* **390** 03011.

Dorrer, M., 2022. Implementation of the digital twin of educational business processes on the ELMA BPMS platform. *Proceedings II International Scientific Conference on Advances in Science, Engineering and Digital Education* (Krasnoyarsk: AIP) **2647** 40088. DOI 10.1063/5.0104164.

Masaev, S.N. et al 2020. *J. Phis.:Conf. Ser.* **1679** 022091.

Granberg, A.G., 2006. Vasily Leontiev in world and domestic economic science *Electronic journal* VSHE **3** 471-91.

Granberg, A.G., 2004. *Fundamentals of Regional Economics* **4** (Moscow: GU VSHE) p. 495.

Kantorovich L.V., 2011. *Mathematical and economic work* (Novosibirsk: Nauka press) p. 760.

Krotov, V.F., 1990. *The Basics of Optimal Control* (Moscow: Vysshaya shkola) p. 430.

Masaev, S. N., 2021. *Algorithms and programs of complex control of activity parameters of cybernetic system of sets* (Krasnoyarsk: SFU) p. 436 ISBN 978-5-7638-4458-0.

APPENDIX

Table 1: Data on the digital twin of an enterprise without the BSi method.

	t								
values x_n	1	2	3	4	5	6	7	8	9
x_1	0.00	0.00	9682.44	9682.44	7546.65	16843.74	16843.74	16843.74	16843.74
x_2	0.00	0.00	0.00	120.94	603.89	7263.85	4349.36	1127.44	5167.66
x_3	0.00	0.00	43939.12	43939.12	13384.41	66167.10	66167.10	66167.10	66167.10
x_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_5	0.00	0.00	0.00	0.00	7761.26	7774.52	7787.78	7801.04	7814.30
x_6	23574.51	23754.74	23754.74	23754.74	21204.40	44015.85	44015.85	44015.85	44015.85
x_7	3064.69	3088.12	3088.12	3088.12	2756.57	5722.06	5722.06	5722.06	5722.06
x_8	8015.33	8076.61	8076.61	8076.61	7209.49	14965.39	14965.39	14965.39	14965.39
x_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{10}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{11}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{12}	0.00	0.00	7251.17	7251.17	9386.96	89.88	89.88	89.88	89.88
x_{13}	0.00	0.00	0.00	1072.22	4772.72	3031.11	3422.58	0.00	1780.84
x_{14}	0.00	0.00	22331.71	22331.71	68326.34	15543.65	15543.65	15543.65	15543.65
x_{15}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{16}	0.00	0.00	8852.85	8871.14	1128.18	1133.21	1138.25	1143.28	1148.32
x_{17}	34705.99	35214.50	35214.50	35214.50	37764.84	14953.39	14953.39	14953.39	14953.39
x_{18}	4511.78	4577.88	4577.88	4577.88	4909.43	1943.94	1943.94	1943.94	1943.94
x_{19}	11800.04	11972.93	11972.93	11972.93	12840.05	5084.15	5084.15	5084.15	5084.15
x_{20}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{21}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{22}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{23}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	819.01
x_{24}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{25}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{26}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{27}	0.00	0.00	2136.24	0.00	0.00	6278.01	0.00	0.00	6081.94
x_{28}	0.00	0.00	0.00	0.00	0.00	533.69	0.00	0.00	533.69
x_{29}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{30}	0.00	0.00	415.82	571.18	571.18	571.18	571.18	571.18	571.18
x_{31}	0.00	0.00	0.00	901.86	455.11	896.95	1521.26	540.96	1043.11
x_{32}	0.00	0.00	1582.16	2086.16	2086.16	2086.16	2086.16	2086.16	2086.16
x_{33}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{34}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2: Data on the digital twin of an enterprise using the BSi method.

	t								
value x_n	1	2	3	4	5	6	7	8	9
x_1	0.00	0.00	9607.54	9607.54	7471.75	16768.84	16768.84	16768.84	16768.84
x_2	0.00	0.00	0.00	120.94	603.89	7263.85	4349.36	1127.44	5167.66
x_3	0.00	0.00	41929.57	41929.57	11374.87	64157.55	64157.55	64157.55	64157.55
x_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_5	0.00	0.00	0.00	0.00	7761.26	7774.52	7787.78	7801.04	7814.30
x_6	23574.51	23754.74	23754.74	23754.74	21204.40	44015.85	44015.85	44015.85	44015.85
x_7	3064.69	3088.12	3088.12	3088.12	2756.57	5722.06	5722.06	5722.06	5722.06
x_8	8015.33	8076.61	8076.61	8076.61	7209.49	14965.39	14965.39	14965.39	14965.39
x_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{10}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

x_{11}	0.00	0.00	0.00	0.00	200.00	0.00	0.00	0.00	0.00
x_{12}	0.00	0.00	7251.17	7251.17	9386.96	89.88	89.88	89.88	89.88
x_{13}	0.00	0.00	0.00	1072.22	4772.72	3031.11	3422.58	0.00	1780.84
x_{14}	0.00	0.00	22331.71	22331.71	68326.34	15543.65	15543.65	15543.65	15543.65
x_{15}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{16}	0.00	0.00	8852.85	8871.14	1128.18	1133.21	1138.25	1143.28	1148.32
x_{17}	34705.99	35214.50	35214.50	35214.50	37764.84	14953.39	14953.39	14953.39	14953.39
x_{18}	4511.78	4577.88	4577.88	4577.88	4909.43	1943.94	1943.94	1943.94	1943.94
x_{19}	11800.04	11972.93	11972.93	11972.93	12840.05	5084.15	5084.15	5084.15	5084.15
x_{20}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{21}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{22}	0.00	0.00	0.00	0.00	600.00	0.00	0.00	0.00	0.00
x_{23}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	819.01
x_{24}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{25}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{26}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{27}	0.00	0.00	2136.24	0.00	0.00	6278.01	0.00	0.00	6081.94
x_{28}	0.00	0.00	0.00	0.00	0.00	533.16	0.00	0.00	533.16
x_{29}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{30}	0.00	0.00	415.82	571.18	571.18	571.18	571.18	571.18	571.18
x_{31}	0.00	0.00	0.00	901.86	455.11	896.95	1521.26	540.96	1043.11
x_{32}	0.00	0.00	1582.16	2086.16	2086.16	2086.16	2086.16	2086.16	2086.16
x_{33}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{34}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The Role of Hard and Soft Law in Securing Sustainable Investment in the Russian Federation

Churilov Aleksei Yurievich[a]
judicial science candidate, Senior Researcher, Laboratory of Infrastructure of the Far North and the Arctic of Tomsk State University of Architecture and Building, Tomsk, Russia
Lefikantor@yandex.ru

Keywords: Sustainable Development, ESG, Arctic zone, Corporate Governance, Hard Law, Soft Law, Investment Strategies, Environmental Sustainability, Russian Legislation.

Abstract: This article examines the complex relationship between sustainable development, climate change, and the evolving landscape of investment, particularly through the lens of ESG (Environmental, Social, and Governance) principles. With an emphasis on the legal frameworks and soft law practices that govern sustainable investment, the study highlights the pivotal role of incorporating ESG factors into corporate governance and investment decision-making to foster environmental sustainability and social equity. It examines the legislative acts at both global and national levels, with a specific focus on Russian law and its application in areas like the Arctic zone, where sustainable investment regulations are crucial. The paper also critically assesses the terminological ambiguities surrounding sustainable development and ESG investing, pointing out the challenges of achieving a universally accepted definition and the potential implications for policy and practice. Through a detailed exploration of hard and soft law mechanisms, the study underscores the significant impact of non-binding guidelines and ethical standards in shaping investment strategies that prioritize long-term sustainability over short-term gains.

1 INTRODUCTION

Issues of sustainable development and combating climate change are increasingly coming under the purview of executive authorities and financial market regulators across various nations. The prevailing paradigm in investment currently favors a goal-setting approach known as investing for sustainability impact (hereafter IFSI). This approach mandates that in making investment decisions, investors and entrepreneurs should aim to achieve outcomes from investment projects that not only yield maximum positive effects for both the investor and the environment, including communities of indigenous and minority peoples residing in the regions of investment project implementation, but also, in the long term, reduce the overall negative impact from the project's realization (UNEP FI, 2021). The Sustainable Development Agenda up to 2030, adopted by the resolution of the United Nations General Assembly on 25 September 2015, and the Paris Agreement of 12 December 2015, ratified by the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change and signed on behalf of the Russian Federation in New York on 22 April 2016, have established a legal and ideological foundation for a new global redistribution of capital flows in favor of markets that promote sustainable development goals.

In this context, the field known as "Law of Sustainable Entrepreneurship" (Czarnezki, 2023), which is grounded in the core principles of ESG investing, gains popularity, details of which will be elaborated upon subsequently. In many major legal firms, departments dealing with sustainable business development and sustainable investing are being established (Myers, 2022). Indeed, sustainable investing necessitates the consideration of environmental, social, and governance factors in decision-making processes to better manage risks and ensure sustainable and long-term investment returns, as well as to effect positive social change and achieve socially beneficial objectives (Belitskaya, 2023).

[a] https://orcid.org/0000-0001-9435-1626

The incorporation of ESG factors and sustainable development issues into corporate governance and in the formation of value chains enhances business resilience to market volatility in the short, medium, and long term. Consequently, companies can protect and strengthen their market positions, create added value for themselves and stakeholders, increase sales, develop new market segments, enhance brand reputation, improve operational efficiency, foster product innovations, and reduce staff turnover.

This work will primarily explore ESG investing as the most adaptive and accurate concept underlying investment decision-making.

2 METHODOLOGY

The methodology encompasses an examination of legal frameworks and statutes that govern sustainable investment, as well as the application of soft law practices, including guidelines, advisory directives, and best practices. This analysis scrutinizes pivotal legislation delineating the parameters of sustainable development and investment at both global and national levels, incorporating international treaties and standards, alongside Russian legislation. A particular focus is given to the evaluation of hard law norms, such as federal laws that regulate investment activities within Russia's Arctic zone, and legislation aimed at territorial development and urban planning within the Russian Federation. Additionally, considerable attention is devoted to the analysis of soft law, exploring its role and significance in the regulation of sustainable investment. Examples of soft law are examined, including corporate codes of ethics, ethical standards, as well as recommendations and advisory directives from authoritative bodies and international organizations, with an emphasis on adapting the text to align more closely with the style of a native English speaker.

3 RESULTS OF RESEARCH

3.1 Terminological Considerations

It is pertinent to note that the term "sustainable development" has increasingly found its way into both academic discourse and the texts of legislative acts. Despite its inaugural usage in 1987 within the United Nations General Assembly's report "Our Common Future", which articulated humanity's capacity to forge development in a sustainable and enduring manner, meeting the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, 1987), a consensus on a unified interpretation of this term remains elusive. This conceptualization of sustainable development globally implies a model of progress that satisfies current demands without detriment to future generations' capacity to fulfill their needs.

A similar state of ambiguity surrounds ESG investing. This term, too, lacks a homogeneous and universally accepted definition across both international and national contexts. For instance, the Russian standard GOST R 70339-2022 provides a definition of ESG as environmental and social factors, along with corporate governance elements, observed by companies and organizations of all ownership types, which are considered by institutional investors and financing entities in their investment strategies and credit policies. Meanwhile, the Russian Central Bank's roadmaps interpret ESG as sustainable development principles related to environmental (including ecological and climate change-related), social, and corporate governance aspects. Frequently, terms such as "factors", “standards” (Posulikhina, 2022), "principles" (Majorina, 2021), and "strategies" (Baranina, 2022) used with the ESG acronym.

ESG encompasses non-financial foundations potentially impacting companies' financial outcomes and, in a more traditional sense, sustainable development measures, along with practices in ecology, social responsibility, and corporate governance. It is elaborated that ESG, particularly for regulatory purposes, should broadly include "all information on ecology, social sphere, or governance that is or could become significant to the reporting company or its investors." (Pollman, 2021) This distinction is drawn between ESG, which is perceived as pertaining to risk management, and CSR, which relates to ethical and moral social obligations of a corporation, though ESG is sometimes also linked to social benefits.

Highlighting that adherence to ESG principles or the consideration of ESG factors in investment decision-making is not a panacea is crucial, as the concept itself is not devoid of drawbacks, which can be categorized into intrinsic or substantive and external or introduced shortcomings. The intrinsic flaw is identified as the absence of objective and reliable data on ESG efficacy. Some studies suggest that organizations considering environmental, social, and economic factors in responsible investment implementation demonstrate superior operational performance (Arabesque, 2015). However, it is evident that not all organizational activities are subject to public reporting, leading to speculation about compliance with many ESG elements. Moreover, the relevance of qualitative versus quantitative indicators is not always clear, potentially leading to an "imbalance" in assessing these principles' effectiveness, favoring formal over substantive indicators.

The external deficiency manifests as more organizations adopt ESG approaches, resulting in an increasing number of metrics and criteria for their effectiveness. Presently, a plethora of organizations assess compliance with ESG principles, including Bloomberg ESG Disclosure Score, FTSE Russell ESG Rating, MSCI ESG Ratings, Refinitiv ESG Scores, EcoVadis CSR Rating, ISS-Oekem Corporate Rating, RobecoSAM Corporate Sustainability Assessment, Sustainalytics Company ESG Ratings, and TruValue Labs Insights360 Scores, among others. The surge in popularity of sustainable investment and the implementation of ESG principles has led to a second introduced flaw - a political one. For instance, Texas has enacted legislation prohibiting public authorities from conducting business with organizations guided by ESG principles in their operations, largely because the oil industry in Texas does not fit within these rules, thus deterring investors from engaging with organizations in this sector within the state. Similarly, in Florida, pension fund managers are prohibited from considering ESG factors in their investment policy choices. This limitation must be considered by organizations intending to operate in these states or with entities registered within them (McGlashan, 2022).

3.2 Regulation of ESG Investing in accordance with Russian Law

In its broadest sense, the concept of ESG pertains to the measurement and verification of organizational effectiveness, with each constituent element of the acronym—Environmental (E), Social (S), and Governance (G)—denoting distinct aspects that organizations are expected to consider in their decision-making processes. These aspects are regulated by both 'hard' and 'soft' law, reflecting a balance between binding legal norms and non-mandatory guidance.

Emerging from established practices, the Environmental (E) component assesses how organizations contribute to sustainable development from an ecological perspective. Environmental factors in this category account for a company's use of natural resources and the impact of its activities on the environment. Companies committed to implementing ESG principles gather and benchmark their performance metrics against ESG indicators, which may include the use of renewable energy sources, climate change risks, regulatory risks, and more.

The Social (S) dimension evaluates an organization's long-term positioning, the reputational value derived from its market conduct, the stability and effectiveness of its workforce over the long haul, potential costs of labor disputes, political risk of community conflicts, and legal and reputational risks associated with employment practices within its supply chain, among other factors. The social aspect of ESG concerns how a company manages its relationships with employees and local communities, for instance, in the context of the Arctic region, with indigenous and minority peoples.

Governance (G) refers specifically to corporate governance, encompassing decision-making factors and consideration of the interests of participants/founders of the organization, as well as how the company is managed.

Concluding this section, it can be noted that ESG analysis is associated with identifying environmental, social, and governance risks that could influence decision-making at the organizational level. This process can be facilitated through two distinct yet interconnected regulatory mechanisms: hard law and soft law. It is rightly observed in the literature that contemporary issues of sustainable development and investment are regulated by virtually all branches of law, from competition law to corporate law, underscoring the comprehensive legal engagement with sustainability and governance (Lights, 2019).

3.2.1. The Framework of Hard Law

Hard law represents the conventional "positive" law that regulates specific aspects of ESG investing. When referring to "hard" law, it entails universally binding, formally defined rules of conduct that all entities engaged in investment activities must comply with.

In the Russian Federation, hard law in the sphere of sustainable investment regulation, for example in the Arctic region, is primarily represented by the Federal Law of 13.07.2020 No. 193-FZ "On State Support for Entrepreneurial Activities in the Arctic Zone of the Russian Federation." The main aim of this law is to establish an economic basis for accelerated social development and improved quality of life in the Arctic Zone of the Russian Federation. This law also establishes a special managing company responsible for receiving applications for investment activity agreements, concluding investment activity agreements, and maintaining the registry of Arctic Zone residents, among other duties.

Furthermore, the Federal Law of 29.07.2017 No. 218-FZ "On the Public Law Company 'Fund for the Development of Territories' and on Amendments to Certain Legislative Acts of the Russian Federation" established the Territory Development Fund (hereinafter referred to as the Fund). One of the Fund's objectives is to facilitate sustainable socio-economic development, attract investments for the development of existing and the creation of new productions, develop transportation and other infrastructures, construction, and enhance the living standards and quality of life of citizens in accordance with this Federal Law, other federal laws, and regulatory acts of the Government of the Russian Federation.

Significantly, the Urban Planning Code of the Russian Federation consolidates the overarching statutes for territorial development aligned with sustainable growth objectives. Infractions of these statutes may precipitate the annulment of land allocations to developers. Judicial precedents have demonstrated instances where planning documentation for territories, ostensibly crafted not to fortify sustainable territorial development but to restrict the permissible utilizations of auctioned land plots, was adjudged, rendering the land allocation auctions null and void.

Regulation through hard law also occurs at the level of sub-legal acts. For instance, the Order of the Ministry for the Development of the Russian Far East No. 110 of 13.08.2020 "On Approval of the Model Form of Agreement on Investment Activity in the Arctic Zone of the Russian Federation" established the form of agreement on investment activity, the principal provisions of which lay the foundation for future investment agreements. By Order of the Government of the Russian Federation No. 1912-r of 14.07.2021 "On Approval of the Goals and Main Directions of Sustainable (Including Green) Development of the Russian Federation," with the aim of developing investment activity and attracting non-budgetary funds to projects aimed at achieving the national development goals of the Russian Federation in the field of green financing and sustainable development, the attached goals and main directions of sustainable (including green) development of the Russian Federation were approved.

Acts of the subjects of the Russian Federation also play a significant role, as authorities at the level of individual subjects can more specifically assess which directions of sustainable investment regulation are relevant for them. For instance, the active Law of Saint Petersburg of 19.12.2018 No. 771–164 "On the Strategy for Socio-Economic Development of Saint Petersburg for the Period up to 2035" sets as a goal the improvement of the physical culture level among Saint Petersburg residents and the development of a reserve training system for Russian national sports teams. Indicators include the proportion of Saint Petersburg residents regularly engaging in physical culture and sports and the satisfaction level of the population with the conditions for such activities, with the latter indicator measured solely through sociological methods of interaction with the population. It should be noted, however, that such an indicator of achieving sustainable development goals is unlikely to reflect the actual situation of strategy implementation.

Thus, one of the key challenges in regulating investment activities in the Russian Federation is undoubtedly the lack of sufficiently developed legal regulation of investment activities at the level of laws and sub-legal regulatory acts.

3.2.2 The Domain of Soft Law

In this regard, soft law assumes a critical role in facilitating judicious investment practices. This genre of law, comprised of acts and documents, is characterized, as scholars have observed, more by its moral and political force than by its juridical clout (Davydov, 2022). The notion of "soft law" was originally conceived in the United States to describe forms of secondary regulation such as the United States Code or model codes (Lyubchenko, 2017). Soft law does not necessitate formal recognition or incorporation into the legislative framework of a given state; rather, the entities concerned determine the significance and potential utility of adopting such behavioral norms, including states which are guided not by the explicit legal force of these norms but by moral and political considerations. In one of the most authoritative works dedicated to the regulation of sustainable investment at the organizational level - "Private Environmental Governance" authored by Michael P. Vandenbergh in 2013 - it is noted that environmental regulation has evolved from primarily positive state law to private law established by organizations (Vandenbergh, 2013).

Typically, soft law is crafted by the subjects of investment activity themselves (though it may also be developed at the recommendation level, issued by authorized bodies), emerging from an extensive development of behavioral models and so-called "best practices" that inform the creation of soft law. Adherence to the behavioral model devised by its architects is ensured not through the compulsion of state enforcement but through the authority of the community that has established the pertinent soft law instrument. Soft law has gained considerable traction in the investment sphere, especially in regions inhabited by indigenous and minority peoples, including the Arctic region. Additionally, corporate law acts, such as codes of professional ethics, can potentially be classified under soft law (Kasatkina, 2022). The literature highlights that the presence of such a "soft" governance tool within a corporation indicates a well-established system of corporate governance and a commitment to the norms of fair business conduct. Essentially, soft law reflects the narrative of the business community at large, addressing current investment issues and the implementation of the sustainable investment concept (Goncharova, 2022).

However, it is imperative to acknowledge that, given the nascent state of investment entrepreneurship in Russia, soft law embodied in recommendations and methodological guidelines issued by authorized bodies acquires significant importance.

For example, the Bank of Russia advises investors to consider:

a) Among environmental factors, this includes data on greenhouse gas emissions, energy consumption, water usage, waste generation, information on water management and waste treatment, the company's environmental protection policy, and its expenditures in this sphere, etc.

b) Among social factors, this encompasses working conditions of employees, payroll expenses, average salary levels, staff turnover, occupational safety measures, data on accidents, expenditures on employee training, violations of workers' rights, approaches to human capital formation, contributions to regional development, and philanthropy.

c) As for corporate governance factors, consideration should be given to the organization's capital structure, the presence of controlling parties, the history of the organization's management, its role and place in the state's economy, the safeguarding of securities holders' rights during corporate actions, the effectiveness of the management system, including the composition and the results of the effectiveness evaluation of the board of directors' activities, the implementation of internal control and risk management, internal audit, and so forth.

Additionally, the Bank of Russia has developed a checklist for assessing the quality of the developing (or developed) sustainable development strategy (SDS) and/or climate transition strategy (CTS), which is as follows:

Table 1: Sustainable Development (SDS) and Climate Transition (CTS) Strategy Evaluation Checklist.

No.	Element	Yes/ No
1	The SDS and/or CTS include(s) a justification for the integration of sustainable development and/or climate change issues into the Organization's activities and the development of the SDS and/or CTS.	
2	The SDS and/or CTS align(s) with the corporate-wide strategy and other strategic planning documents of the Organization.	
3	The SDS and/or CTS set(s) goals and timelines for their achievement.	
4	The SDS and/or CTS establish(es) ambitious goals (compared to industry-average indicators) within the scope of the SDS and/or CTS.	
5	The SDS and/or CTS are developed taking into account scientifically based forecasts and scenarios of events, the most current scientific data and results recognized at the national and international levels.	
6	The SDS and/or CTS provide for the timelines and circumstances under which a review of the performance indicators, the list of initiatives included therein, and the planned measures for their achievement is carried out.	
7	The SDS and/or CTS take into account a list of significant risks and opportunities related to sustainable development for the Organization.	
8	The SDS and/or CTS reflect the potential negative effects of implementing the goals set forth therein.	
9	The SDS and/or CTS contain a description of the impact of the implementation of the SDS and/or CTS for both stakeholders within the Organization and for external interested parties.	
10	The SDS and/or CTS describe how the Organization integrates issues of sustainable development and climate change in organizing corporate governance. These issues can also be integrated into other documents, e.g., a sustainable development policy.	
12	The implementation plan contains a description of how the Organization plans to implement relevant internal policies and requirements into its operational activities, minimize risks and maximize opportunities associated with sustainable development, ensure the implementation of technological solutions for sustainable development and climate change, ensure sufficient levels of financial, personnel, and other resources to achieve the goals of the SDS and/or CTS, implement climate projects	

	where applicable, align the SDS and/or CTS with other strategic documents and policies of the Organization including investment policy and asset management policy, build the organization's capacity in the field of sustainable development or climate change, and enhance the relevant qualifications of employees, organize a system of employee motivation for achieving the Organization's goals in sustainable development and climate change, and interact with counterparties to increase the effect of implementing the SDS and CTS.	
13	The implementation plan is developed for the period of the SDS and/or CTS implementation, and if the timelines for achieving the final values of target performance indicators of the Organization's activities in sustainable development or climate change exceed the traditional time horizons of strategic planning, then for a shorter period with the indication of the terms for its update.	

These acts are not universally mandatory but rather recommendations that should be taken into account by organizations seeking to attract investment, including foreign investment.

4 CONCLUSIONS

It is to be concluded that presently, organizations are increasingly inclined to utilize soft law instruments in the implementation of investment projects and in the development of investment policies. Organizations engaged in investment are paying more attention to whether their potential counterparts consider the agenda of sustainable development and climate change, and whether they ensure informational transparency of activities in terms of parameters related to sustainable development.

An illustrative example of the implementation of soft law norms is demonstrated by Schroder Investment Management, which offers its clients the creation of a "sustainable development budget"—i.e., investing in green projects as part of the diversification of investment projects. Thus, indirectly encouraging, firstly, investment in environmentally safe and clean enterprises by investors and, secondly, by entrepreneurs—to implement projects considering ESG factors in decision-making.

In conclusion, it should be asserted that although regulatory acts play a significant role in regulating and ensuring responsible and environmental investing, their importance is secondary to soft law, which predominates in the investment sphere.

ACKNOWLEDGEMENTS

This work was carried out within the government contract FEMN-2022-0003 of the Ministry of Science and Higher Education of the Russian Federation.

REFERENCES

UNEP FI, RPI Report: A Legal Framework for Impact: sustainability impact in investor decision-making. Freshfields Bruckhaus Deringer, commissioned by The Generation Foundation, UNEP FI, and PRI Association, 2021. London: Freshfields Bruckhaus Deringer. 558 p.

Czarnezki, J.J., Galperin, J., Grimes, B., 2023. Teaching Sustainable Business Law & the Role of ESG Lawyers. *Environmental Law Journal, NYU.* Vol. 31, No. 3. pp. 285–348.

Myers, C., Czarnezki, J.J., 2022. Sustainable Business Law? The Key Role of Corporate Governance and Finance. *Environmental Law.* Vol. 51, No. 4. pp. 991–1040.

Belitskaya, A.V., 2023. Legal incentives for investing in sustainable development. *Law and Business,* No. 1. pp. 5–11.

United Nations, 1987. Report of the World Commission on Environment and Development: "Our Common Future" [Brundtland Report]. New York: UN. 374 p.

GOST R 70339–2022. National Standard of the Russian Federation. "Green" standards. Financing of construction activities for sustainable development. Framework foundations and principles. Approved and introduced by the Order of Rosstandart No. 885-st dated 07.09.2022.

Bank of Russia, 2018. Roadmap for the development of financing for small and medium-sized enterprises. Approved by the order of the Bank of Russia No. OD-2387 dated 13.09.2018.

Bank of Russia, 2021. Information Letter No. IN-06-28/96 "On recommendations for the board of directors of a public joint stock company to consider ESG factors, as well as sustainable development issues".

Posulikhina, N.S., 2022. ESG Standards and Evaluation (Expertise) of Comprehensive Project Safety. *Current Problems of Russian Law,* No. 8. pp. 104–110.

Majorina, M.V., 2021. ESG Principles in International Business and "Sustainable Contracts". *Current Problems of Russian Law,* No. 12. pp. 185–198.

Baranina, E.Yu., 2022. Investment Strategies of ESG: Legal Regulation, Problems, and Prospects. *Banking Law,* No. 5. pp. 69–76.

Pollman, E., 2021. Corporate Social Responsibility, ESG, and Compliance. In The Cambridge Handbook of Compliance. Eds. Benjamin van Rooij & D. Daniel Sokol. Cambridge: Cambridge University Press. 800 p.

Arabesque Asset Management, 2015. From the Stockholder to the Stakeholder: How Sustainability Can Drive Financial Outperformance. Oxford: Arabesque Asset

Management & the Smith School of Enterprise and the Environment, University of Oxford. 60 p.
McGlashan, R., 2022. The Rise of State Anti-ESG Legislation. *Fordham Journal of Corporate & Financial* Law, No. 11.
Light, S.E., 2019. The Law of the Corporation as Environmental Law. *Stanford Law Review*, Vol. 71. pp. 137–213.
Supreme Court of the Russian Federation, 2023. Judgment No. 309-ES22-29786 in case No. A60-66538/2021.
Davydov, E.Yu., 2022. The concept of indigenous small-numbered peoples in international law and domestic legislation: theoretical and methodological aspects. *International Public and Private Law,* No. 4. pp. 23–26.
Lyubchenko, M.Ya., 2017. Judgments of the European Court of Human Rights as "Soft Law". *Herald of Civil Procedure,* No. 3. pp. 256–270.
Vandenbergh, M.P., 2013. Private Environmental Governance. *Cornell Law Review,* No. 1. pp. 129–199.
Kasatkina, A.S., Ruderman, I.F., 2022. Codes of Corporate Ethics of Transnational Companies: A Comparative Legal Analysis. *Russian Legal Journal*, No. 5. pp. 131–140.
Goncharova, V.A., Ivanov, V.V., Trubnikova, T.V., Churilov, A.Yu., 2022. A narrative approach in legal research: Purpose and methodology. *Vestnik Tomskogo gosudarstvennogo universiteta – Tomsk State University Journal.* 483. pp. 240–252.
Bank of Russia, 2020. Information Letter No. IN-06-28/111 "On recommendations for the implementation of principles of responsible investment".
Bank of Russia, 2023. Information Letter No. IN-02-28/76 "On recommendations for public joint stock companies and issuers of issued securities on the development of a sustainable development strategy and a climate transition strategy".
Schroder Investment Management case study. Available at: https://www.unpri.org/strategy-policy-and-strategic-asset-allocation/introducing-a-sustainability-budget-to-asset-allocation-decisions/6181.article (accessed 14.03.2024).

The Role of Mamun University in the Sustainable Economic Development of Khorezm Region

Arslon Nurjanov[1], Alisher Sherov[2], Ergash Ibadullaev[3], Alibek Rajabov[4], Muzaffar Yakubov[5]
"Mamun university", 220900, Qibla Tozabog, Khiva, Uzbekistan
mamuntm@mamunedu.uz, sherov_alisher@mamunedu.uz, ibodullaev_ergash@mamunedu.uz, rajabov_alibek@mamunedu.uz, yakubov_muzaffar@mamunedu.uz

Keywords: economic development, education, Linear trend model, ARIMA model, GNP, Mamun.

Abstract: This paper discusses the scientific research related to the evaluation of the impact of the activities of Mamun University on the economy of the region is reflected. According to the results of the research, the total number of students studying at the university (both full-time and part-time courses), the total income of the university, the total number of professors, teachers, supervisors and workers who are employed at the university were found to have a positive effect on the GNP of the region. Also, in the research work, the results of forecasting the total number of university students for the next three-year period were developed. In addition future prospects of the university have been explained and strategies that will play important role in the development of both university and the region's economy have been developed and discussed.

1 INTRODUCTION

In an era characterized by rapid technological advancement, globalization, and dynamic economic landscapes, the role of universities in shaping regional economies has become increasingly prominent. Universities serve as multifaceted institutions not only dedicated to the pursuit of knowledge and academic excellence but also as key drivers of economic growth, innovation, and prosperity within their respective regions. This paper delves into the intricate relationship between universities and regional economies, exploring the diverse ways in which higher education institutions contribute to the socio-economic fabric of their surrounding communities (Yusupova et.al 2022). Universities are often regarded as the cradles of knowledge, fostering intellectual curiosity and academic inquiry. Beyond their traditional role as centers of learning, however, universities play a pivotal role in nurturing human capital, fostering innovation, and catalyzing economic development. Through their education and training programs, universities equip individuals with the skills, knowledge, and competencies necessary to thrive in today's increasingly competitive and knowledge-based economy. By producing a skilled workforce adept in critical thinking, problem-solving, and technical expertise, universities contribute directly to the productivity and competitiveness of regional industries. Moreover, universities serve as engines of innovation, spearheading groundbreaking research and development initiatives across a myriad of disciplines (Kuziboev et.al 2024). The research output generated by universities not only expands the frontiers of knowledge but also serves as a catalyst for technological advancement and commercialization. Through collaborations with industry partners, technology transfer initiatives, and entrepreneurship programs, universities facilitate the translation of academic research into tangible products, services, and businesses that drive economic growth and job creation within the region.

[1] https://orcid.org/0009-0009-3303-071X
[2] https://orcid.org/0000-0001-7383-6229
[3] https://orcid.org/0000-0002-7059-2510
[4] https://orcid.org/0000-0002-5252-6456
[5] https://orcid.org/0000-0001-6009-0384

In this paper we analysed the role of newly founded university of Mamun in the economic development of Khorezm region. This university was founded in 2021 by Nurjanov Arslon in historical city of Khiva, Khorezm region. This region is situated in Uzbekistan one of the fastest growing country of Central Asia. For the past four years the university became one of the main part of the region's economy. In 2021 only 83 students were accepted and the university began its activity. As a result of reforms carried out by the staff the university achieved the belief of the population of the region and in 2024 the total number of students reached 7067 and for the being time this organization employed around 300 staff members and it should be stated that this indicators are increasing. The university offers education services on 7 direction such as economics, accounting, English language, psychology, pedagogy, history and Russian language. The university has been expanding its main campus is situated in Khiva city and also 2 campuses in Urgench city, it means that the students can choose their studying places according to their wishes. The unique thing of the university is that it has the biggest, modern library with variety of printed and electron books and this library could be visited not only by students but also is open for locals who are interested in doing researches. Distinctive features of Mamun University are the unique career-relevant, high quality and inclusive educational programs, which are internationally recognized and accredited. That in turn allows our graduates can easily enter universities around the world. In addition, Mamun University cooperates with a number of national universities, where students can continue their studies by immediately enrolling into the 2nd year of the selected major. The strong core of Mamun University is its teaching staff. All teachers have undergone specialized trainings and some of them studied at foreign universities abroad. Our teachers are ready to provide comprehensive support in the educational process for better assimilation of knowledge and development of the potential of our students. Mamun University also supports talented students by providing scholarships for education, motivating them towards further achievements. Furthermore, the university is trying to combine the theoretical knowledge with practical activities. In order to achieve this goal the following strategies have been developed:

- **business incubator** - this center is a center that works mainly for the purpose of supporting new ideas, start-up projects;

- **business accelerator** - in this center, in order to further develop their activities, consulting services and educational courses, training and seminars in business, psychological and personnel management areas are provided to business entities in order to further develop their activities;

-**business clinic** provides various services to business entities that are on the verge of bankruptcy and helps them to resume their business activities and carry out effective activities.

2 LITERATURE REVIEW

Universities have been playing an important role in the economic development of the region for a long time. The relationship between education and the region's economic growth has been studied by several researchers so far. According to Pal (2023) the most crucial instrument for a nation's socioeconomic progress is education and it serves as a catalyst for increasing production and advancing technology. The stages of economic growth and education levels are positively correlated, as is evident. Paper by him demonstrated how education may have a transformative effect on promoting equitable and sustainable economic growth. By embracing new inputs and technology, education also plays a critical role in increasing agricultural and industrial production, which raises worker salaries. Ziberi et.al (2022) quantified how public spending on education affects North Macedonia's ability to thrive economically by using secondary data from the World Bank Indicators covering the years 1917–2020. This study indicates that North Macedonia's economic growth will be positively impacted by a one-point increase in public spending on education also the results concludes that in North Macedonia, economic growth will increase with a one-point increase in unemployment and a one-point decline in employment. Rajabov et.al (2023) examined the relationship between education and the economy, the role that education plays in economic development, and the effects that education has on the economy. The impact is more pronounced in places with a high proportion of educated individuals who can apply their knowledge to take practical steps that advance the local economy than in places with a lower proportion of educated individuals. One crucial foundation that supports society in all of its forms is education. Through this lens, the impact of public investments in elementary, secondary, and higher education on economic growth is a matter of discussion (Kuziboev et.al 2023). If public spending on education is beneficial, it is most likely done so under the guise of investing in human capital, but this has negative consequences on economic growth and merely influences the factorial equilibrium (Ibadullaev et.al 2024). In a research published in 2019, Marquez-Ramos and Mourelle examine the existence of nonlinearities in the direction of the causation that explains the relationship between economic growth and education in the context of Spain. It implies that, under certain situations, a higher level of education has a favorable impact on GDP development. The World Economic Forum identified three ways that education influences a nation's productivity: it makes the labor force more capable of completing tasks collectively and more quickly; secondary and higher education, in particular, facilitates the transfer of knowledge about new information, products, and technologies created by others (Barro and Lee, 2010); and it increases a nation's capacity to create new knowledge, products, and technologies by fostering greater creativity (Saidmamatov, 2021). In the IMF paper "Boosting job growth in the Western Balkans," Kovtun et al. (2014) examine which Balkan nations have the highest rate of youth unemployment and longest duration of any EU nation. The authors came to the conclusion that the Balkan labor markets' subpar performance is a significant societal issue that simultaneously jeopardizes medium- and long-term economic growth and presents a significant obstacle for decision-makers. Valero and Reenen (2018) created a new dataset on the locations of around 15,000 universities in roughly 1,500 regions spread over 78 nations, some of which date back to the 11th century by using UNESCO source materials. The number of universities is positively correlated with future GDP per capita growth, according to fixed effects models we estimate at the sub-national level between 1950 and 2010 (and this relationship is robust to controlling for a host of observables, as well as unobserved regional trends) (Kuziboev et al (2024). According to our projections, an area's future GDP per capita is predicted to improve by 0.4% for every 10% increase in the number of universities per capita in that region.

3 METHODOLOGY

Correlation analysis is based on determining correlation coefficients and evaluating their importance and reliability. If the links are linear, then the correlation coefficient can be used to estimate the link density:

$$r_{Y/X} = \frac{\overline{X*Y} - \bar{X}*\bar{Y}}{\sigma_X*\sigma_Y} \quad (1)$$

In this place, σ_X and σ_Y respectively X and Y the mean squared deviations of the variables, and they are calculated using the following formulas:

$$\sigma_X = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n}} = \sqrt{\overline{X^2} - \bar{X}^2} \quad (2)$$

$$\sigma_Y = \sqrt{\frac{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}{n}} = \sqrt{\overline{Y^2} - \bar{Y}^2} \quad (3)$$

Also, the following modified formulas for calculating the correlation coefficient can be used:

$$r_{Y/X} = \frac{\sum_{i=1}^{n}(X_i - \bar{X})*(Y_i - \bar{Y})}{n*\sigma_X*\sigma_Y} = \frac{n*\sum_{i=1}^{n} X_i*Y_i - \sum_{i=1}^{n} X_i*\sum_{i=1}^{n} Y_i}{\sqrt{[n*\sum_{i=1}^{n} X_i{}^2 - (\sum_{i=1}^{n} X_i)^2]*[n*\sum_{i=1}^{n} Y_i{}^2 - (\sum_{i=1}^{n} Y_i)^2]}} \quad (4)$$

The coefficient of determination is equal to the square of the correlation coefficient. The correlation coefficient $r_{Y/X}$ ranges from -1 to +1. If $r_{Y/X} = 0$, there is no relationship between the factors, if $0 < r_{Y/X} < 1$, there is a positive relationship, if $-1 < r_{Y/X} < 0$, there is a negative relationship, if if $r_{Y/X} = 1$, there is a functional relationship.

Generally, correlation analysis is a statistical method that helps to define any dependency between variables and its strength using correlation coefficients. Its results can be interpreted using the Chaddock (1925) scale (Table 1)

Table 1: Chaddock scale for interpretation of correlation analysis results.

Absolute Value of Correlation, $\lvert r_{Y/X} \rvert$	**Interpretation**
$0.00 - 0.30$	Negligible correlation
$0.30 - 0.50$	Weak correlation
$0.50 - 0.70$	Moderate correlation
$0.70 - 0.90$	Strong correlation
$0.90 - 1.00$	Very strong correlation

Regression analysis determines the effectiveness of the factors influencing the outcome. The term regression is associated with the names of the founders of correlational analysis, F. Galton (1886) and K. Pearson (1903).

Regression analysis makes it possible to assess the effectiveness of the characteristics that affect the resulting characteristic with sufficient accuracy in practice. With the help of regression analysis, it is possible to estimate the prediction values of socio-economic processes for future periods and determine their probability limits.

In regression and correlation analysis, the regression equation of the relationship is determined and it is estimated with a certain probability (confidence level), and then an economic-statistical analysis is performed. Often, several functions are suitable to represent the correlation pattern at the same time, so it is better to finally justify the choice of functions to represent the pattern of correlation on an alternative basis. Usually, the following functions are used in the study of connections between socio-economic processes (Dougerti 2009):

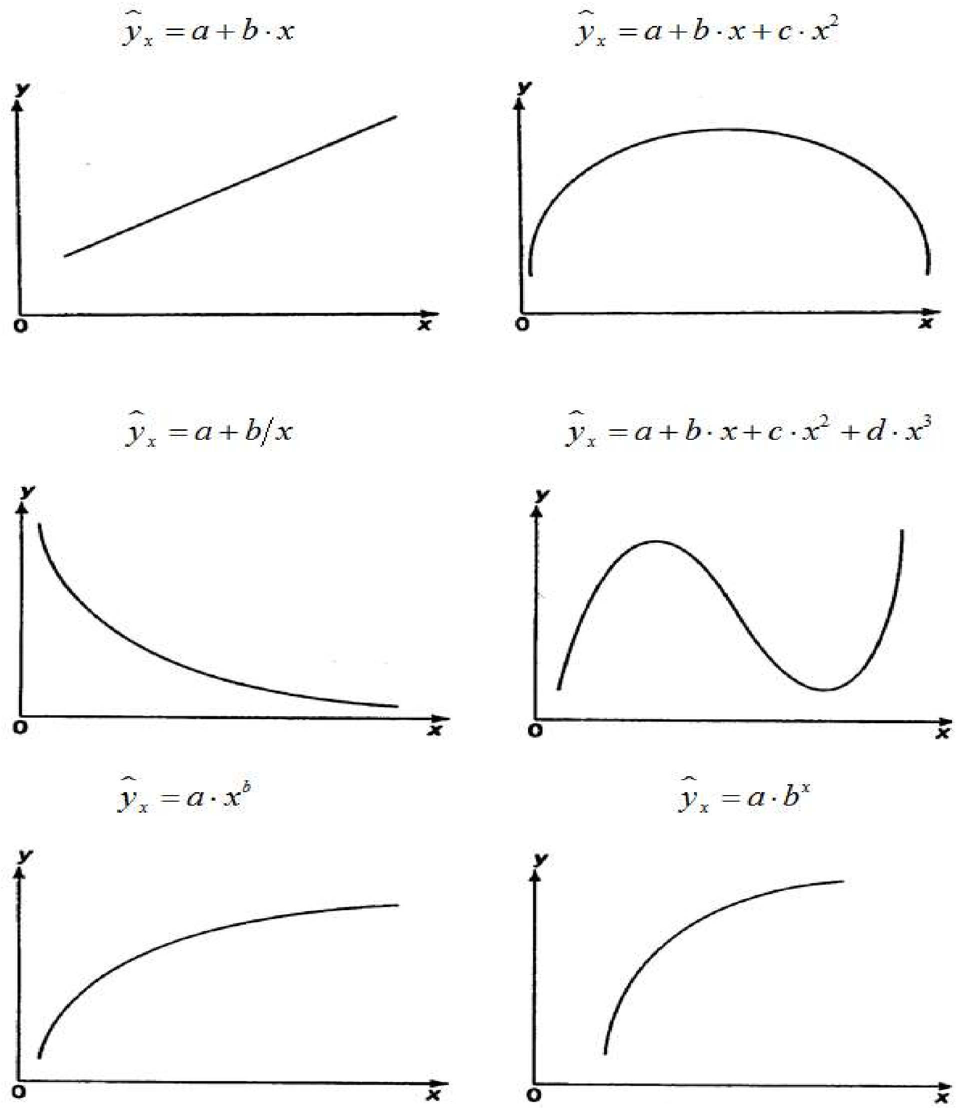


Figure1: Functions used to express connections between socio-economic processes.

The linear form of regression is the simplest form in terms of understanding, interpretation and calculation techniques. A linear pair regression equation generally looks like this:

$$\hat{Y}_i = \hat{\beta}_1 + \hat{\beta}_2 * X_i \text{ or } \hat{Y}_i = \hat{\beta}_1 + \hat{\beta}_2 * X_i + \hat{u}_i \quad (5)$$

here, $\hat{\beta}_1, \hat{\beta}_2 -$ model parameters, $\hat{u}_i -$ error term.

Estimation of model parameters $\hat{\beta}_1$ and $\hat{\beta}_2$ is carried out by the method of ordinary least squares (OLS). The essence of (OLS) is that, Y_i is calculated according to the regression equation of the actual (true) values of the resulting character. It is found that the sum of the squared deviations from the (theoretical) values of $\hat{Y}_i$ will be the smallest, i.e.:

$$F = \sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2 = \sum_{i=1}^{n} \hat{u}_i{}^2 \rightarrow min \quad (6)$$

It can be seen in thus graph:

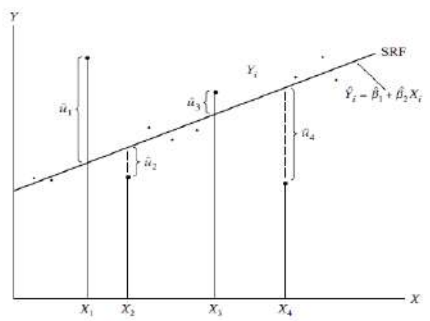


Figure 2: Ordinary Least-squares criterion.

(5) in order to find the parameters $\hat{\beta}_1, \hat{\beta}_2$ in the linear regression equation, it is equal to 0 by taking the 1st derivative (first differentiation) of these parameters from the function (6). Then the following formulas for finding the parameters $\hat{\beta}_1, \hat{\beta}_2 2$ in the regression equation are created:

$$\hat{\beta}_2 = \frac{n*\sum_{i=1}^{n} X_i * Y_i - \sum_{i=1}^{n} X_i * \sum_{i=1}^{n} Y_i}{n*\sum_{i=1}^{n} X_i{}^2 - \left(\sum_{i=1}^{n} X_i\right)^2} = \frac{\sum_{i=1}^{n}(X_i - X)*(Y_i - \bar{Y})}{\sum_{i=1}^{n}(X_i - \bar{X})^2} \quad (7)$$

$$\hat{\beta}_1 = \frac{\sum_{i=1}^{n} X_i{}^2 * \sum_{i=1}^{n} Y_i - \sum_{i=1}^{n} X_i * \sum_{i=1}^{n} X_i * Y_i}{n*\sum_{i=1}^{n} X_i{}^2 - \left(\sum_{i=1}^{n} X_i\right)^2} = \bar{Y} - \hat{\beta}_2 * \bar{X} \quad (8)$$

Forecasting is considered based on the ARIMA (Autoregressive integrated moving average) model. In order to understand the ARIMA model in detail, it is necessary to first consider the "Autoregressive Process" and "Moving Average Process" processes.

Autoregressive Process: Let Y_t t be the volume of GDP per capita at time t. We can express Y_t as follows:

$$(Y_t - \delta) = \alpha_1(Y_{t-1} - \delta) + u_t \quad (9)$$

where $\delta -$ is the average value of Y_t, $u_t -$is related to σ^2 with zero mean and constant variance the concept of non-random error. The value of Y at time t depends on its value at the previous time and random error; Values of Y are expressed as deviations from their mean.

Now we can express the appearance of the model (9) in a different form, that is

$$(Y_t - \delta) = \alpha_1(Y_{t-1} - \delta) + \alpha_2(Y_{t-2} - \delta) + u_t \quad (10)$$

Based on (10), Y_t is called a second-order autoregressive or $AR(2)$ process. Values of Y are plotted around their mean values δ.

And in general

$$(Y_t - \delta) = \alpha_1(Y_{t-1} - \delta) + \alpha_2(Y_{t-2} - \delta) + \ldots + \alpha_p\left(Y_{t-p} - \delta\right) + u_t \quad (11)$$

(3.3.3) is a p-order autoregressive or $AR(p)$ process.

Moving Average Process: Autoregressive Process is not the only mechanism that generates Y. That is, we can express Y in a different way

$$Y_t = \mu + \beta_0 u_t + \beta_1 u_{t-1} \quad (12)$$

where μ is constant and u is the white noise stochastic error term as before. Y is the moving average of the constant and past error terms at time t. Thus, in the present case, Y is said to obey a first-order moving average or MA (1) process.

(12) we change the appearance of the model to a different form, i.e

$$Y_t = \mu + \beta_0 u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2} \quad (13)$$

Based on (13), Y_t is called a second-order moving average or $MA(2)$ process.

In general

$$Y_t = \mu + \beta_0 u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \cdots + \beta_q u_{t-q} \quad (14)$$

(14) is a $q -$order moving average or $MA(q)$ process.

Based on the above, the ARIMA model has the order (p,d,q), where p represents the autoregression parameter, d represents the integration part, and q represents the moving average parameter. An overview of the ARIMA model will look like this:

$$Y_t = \mu + \alpha_1 Y_{t-1} + \cdots + \alpha_p Y_{t-p} + u_t + \beta_1 u_{t-1} + \cdots + \beta_q u_{t-q} \quad (15)$$

It is known that the meaning of d-integration is to monitor the difference between the values of variables in the current period and their values in the past period.

4 RESULTS AND DISCUSSION

The method of correlation-regression analysis was used in this research conducted in order to determine the impact of Mamun University's activities on the economic development of the region. In our opinion, the total number of students studying at the university (both full-time and part-time), the total income of the university, the total number of professors, teachers, managers and employees working in the university and a number of other factors affect the GNP of the region.

Based on the above ideas, in order to create a multi-factor econometric model representing the impact of the activities of Mamun University on the economic development of the region, the following indicators covering the period 2021Q1 - 2024Q1 were selected as the resulting and influencing factors: the resulting factor - the volume of regional GNP (billion soums) - (Y), the total number of students studying at the university (person) — (X1), the total income of the university (million soums) — (X2), the total number of professors, teachers, supervisors and workers working at the university (person).

Since the units of measurement of the variables are different and to better explain the interpretation of the multifactor econometric model, we will logarithmize the values of all factors. Before creating a multi-factor econometric model, let's consider the statistical description of the factors (Table 1).

The average value (mean), bisector value (median), maximum and minimum values (Maximum, minimum) for each factor, as well as how much each factor differs from the average value (Std. Dev (Standard Deviation)) are given in the table. In addition, in the table, the asymmetry coefficient (Skewness — S), which indicates that the theoretical distribution curve of each factor is located on the right side (S>0) or on the left side (S<0) compared to the normal distribution curve, and the theoretical distribution curve of each factor is a normal distribution curve The kurtosis coefficient (Kurtosis - K), which means that it is located higher (K>0) or lower (K<0) compared to the line, and the Jarque-Bera criterion test, which is conducted to confirm the compatibility of each factor with the normal distribution, are mentioned.

Table 1: Statistical description of factors.

	LNY	LNX_1	LNX_2	LNX_3
Mean	10.33266	6.308823	9.631225	4.405371
Median	10.34595	6.973543	10.04481	4.564348
Maximum	10.59443	8.863191	11.25234	5.616771
Minimum	10.08110	2.564949	7.193032	2.995732
Std. Dev.	0.162270	2.132877	1.421243	0.864933
Skewness	0.059506	0.570203	0.470473	0.281333
Kurtosis	1.817789	1.891000	1.770989	1.760144
Jarque-Bera	0.764718	1.370637	1.297752	1.004161
Probability	0.682250	0.503930	0.522633	0.605270
Sum	134.3246	82.01469	125.2059	57.26983
Sum Sq. Dev.	0.315980	54.58996	24.23919	8.977314
Observations	13	13	13	13

Source: Authors' estimations

Whether the factors are stretched to a normal distribution is considered using the coefficient of asymmetry, the coefficient of kurtosis and the Jarka-Bera criterion. If we pay attention to the numerical values in the table, the coefficient of asymmetry, the coefficient of kurtosis and the indicators of the Jarka-Bera criterion have small values, in this case, it can be estimated that the known factors are close to the normal distribution. On the contrary, large values of asymmetry, kurtosis, and Jarka-Bera criterion indicate that the factors deviate significantly from the normal distribution.

A correlational analysis is necessary to select factors for a multifactor econometric model. For this, pairwise correlation coefficients are calculated between the factors. According to the results of the correlation analysis, it is shown that there is a close relationship between the resulting factor (LnY) and the influencing factors (LnX1, LnX2), that is, the value of the pair correlation coefficients is greater than 0.8.

The results of the analysis of the matrix of pair correlation coefficients $ln(x_i)$ $(i = \overline{1,3})$ and $ln(x_i)$ $(i = \overline{1,3})$factors cannot be recognized as collinear. Because, if $r_{\ln(x_i),\ln(x_j)} < 0{,}8$and the determinant of matrix $X'X$ is not close to zero, then this indicates the absence of multicollinearity. Therefore, the pairwise correlation coefficients between the factors took numerical values smaller than 0.8. Therefore, the correlation coefficients between the factors included in the multifactor econometric model meet the requirements for the calculated value and probability of the t-Student criterion. Based on these factors, it will be possible to create a multi-factor econometric model of the total volume of products produced in the regional industrial network and the factors affecting it.

The results of the calculation of the unknown parameters of the multifactor econometric model are presented in Table 2 below.

Table 2: Calculation results of multifactor econometric model parameters.

Dependent variable: LNY				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNX_1	0.029222	0.003774	7.742663	0.0000
LNX_2	0.011072	0.001463	7.567057	0.0000
LNX_3	0.273710	0.008035	34.06512	0.0000
C	9.417863	0.020977	448.9544	0.0000
R-squared	0.899782	Mean dependent var		10.33266
Adjusted R-squared	0.879709	S.D. dependent var		0.162270
S.E. of regression	0.002766	Akaike info criterion		-8.694888
Sum squared resid	6.89E-05	Schwarz criterion		-8.521057
Log likelihood	60.51677	Hannan-Quinn criter.		-8.730618
F-statistic	13759.98	Durbin-Watson stat		1.962346
Prob(F-statistic)	0.000000			

Source: Authors' estimations

The calculated multifactor econometric model shows that a 1% increase in the total number of students studying at the university leads to an increase in the region's GDP by 0.02%. Also, a 1% increase in the total income of the university and the total number of professors, managers and employees working in the university can lead to an increase in the regional GNP by 0.01% and 0.27%, respectively.

The coefficient of determination, standard errors, F-Fisher, t-Student, Akaike, Schwartz criteria in Table 2 show the statistical significance and adequacy of the multifactor econometric model.

In addition, in our research work, the forecast values of the total number of students at Ma'mun University for future periods were developed. Forecast values were formed using "Linear trend model" and "ARIMA" models.

The calculation results of the "Linear Trend" model are presented in Table 3 below.

Table 3: Calculation results of the "Linear trend" model.

Dependent variable: Total_number_of_students					
Variable	*Coefficient*	*Std. Error*	*t-ratio*	*p-value*	
Const	−1694.85	547.567	−3.095	0.0102	**
time	509.363	68.9870	7.383	<0.0001	***

Mean dependent var	1870.692	S.D. dependent var	2174.624
Sum squared resid	9527935	S.E. of regression	930.6857
R-squared	0.832101	Adjusted R-squared	0.816837
F(1, 11)	54.51543	P-value(F)	0.000014

Log-likelihood	−106.2273	Akaike criterion	216.4547
Schwarz criterion	217.5846	Hannan-Quinn	216.2224
rho	0.794324	Durbin-Watson	0.543568

Source: Authors' estimations

The calculation results of "ARIMA" are presented in Table 4 below.

Table 4: Calculation results of the "ARIMA (0; 1; 1)" model.

Dependent variable: (1-L) Total_number_of_students					
Variable	*Coefficient*	*Std. Error*	*z*	*p-value*	
Const	647.503	255.773	2.532	0.0114	**
theta_1	0.518221	0.303703	1.706	0.0879	*

Mean dependent var	587.8333	S.D. dependent var	681.2546
Mean of innovations	15.28233	S.D. of innovations	594.3855
R-squared	0.968998	Adjusted R-squared	0.968998
Log-likelihood	−93.83396	Akaike criterion	193.6679
Schwarz criterion	195.1226	Hannan-Quinn	193.1293

Source: Authors' estimations

The coefficient of determination, standard errors, F-Fisher, t-Student, Akaike, Schwartz, Hannan-Quinn criteria in tables 3, 4 show the statistical significance and adequacy of the "Linear trend" and "ARIMA" models.

Based on the calculation results of the above "Linear trend" and "ARIMA" models, the comparative forecast values of the total number of students at Ma'mun University for future periods were developed (Table 5).

Table 5: Comparative results of econometric models based on forecasting the total number of students at Mamun University.

Years	**Predictive value**	**Standard error**	**95% interval**
According to the linear model			
2024	7474	1228,28	(4770,3; 10177,1)
2025	8492	1317,99	(5591,5; 11393,3)
2026	10530	1519,28	(7185,9; 13873,8)
According to the ARIMA model			
2024	9959	1407,83	(7199,5; 12718,1)
2025	12549	2288,96	(8062,5; 17035,1)
2026	15139	2914,91	(9425,7; 20851,9)

Source: Authors' estimations

According to the comparative results, the total number of students according to the "Linear trend" is expected to increase by 1.5 times compared to the current period by the end of 2026, and by the end of 2026 according to the "ARIMA" model, it is expected to increase by 2.1 times compared to the current period. So, based on our forecast results based on the two models developed in our research work, it can be seen that the total number of students at Mamun

University NTM has a possibility to increase by 1.5-2.1 times from the current period to 2026.

5 CONCLUSION

In general, in recent years, special attention has been paid to raising the higher education system to a new level of quality, further developing the system of higher educational institutions, eliminating existing problems in the field, and ultimately turning them into large centers of science. The level of coverage of the population with higher education is constantly increasing. In this regard, new non-state higher education institutions are being established in our country.

These non-state educational institutions make a significant contribution to the socio-economic development of not only the country, but also the regions.

According to the results of the research carried out by Mamun University as part of the object, the total number of students studying at the university increased by 1%, the regional GNP increased by 0.02%, the total income of the university and the total number of professors, teachers, managers and employees working at the university increased by 1%. and it was found that the increase of 0.01% and 0.27% can lead to the growth of regional GNP, respectively.

Also, in the future according to the results of "Linear trend" and "ARIMA" models by expanding the number of existing educational courses at the university and opening two new educational buildings in the center of the region, it is possible to increase the total number of university students by 1.5-2.1 times from the current period to 2026. Overall, the university plays a vital role in the economic development of the region, serving as catalysts for innovation, entrepreneurship, and talent development. By leveraging its academic expertise, research capabilities, and institutional resources, Mamun universitiy can make significant contributions to building resilient, inclusive, and sustainable economies that benefit society as a whole.

REFERENCES

Lakshman Ch.P., 2023. Impact of Education on Economic Development. Available online at: http://journal.uinsgd.ac.id/index.php/kp Khazanah Pendidikan Islam, Vol. 5 No. 1: 10-19.

Ziberi, B.F., Donat, R., Xhemazie, I., Besnik, A., 2022. Empirical Analysis of the Impact of Education on Economic Growth. Economies 10: 89.

Rajabov, A., Ibadullaev, E., Egamov, B., Zaripov, X., Qosimov, J., 2023. Empirical analysis of determining the influence of the level of innovative development on the economy of world countries. E3S Web of Conferences 449, 02001.

Kuziboev, B., Ibadullaev, E., Saidmamatov, O., Rajabov, A., Marty, P., Ruzmetov, S., Sherov, A., 2023. The Role of Renewable Energy and Human Capital in Reducing Environmental Degradation in Europe and Central Asia: Panel Quantile Regression and GMM Approach. Energies 2023, 16, 7627.

Ibadullaev, E., Rajabov, A., Matyakubova, D., Yakubov, A., Yusubov, I., 2024. Empirical analysis of renewable and non-renewable energy resources consumption impact on economic development in Uzbekistan. BIO Web of Conferences 82, 050 (2024) MSNBAS2023.

Marquez-Ramos, L., Mourelle, E., 2019. Education and economic growth: An empirical analysis of nonlinearities. *Applied Economic Analysis* 27: 21–45.

Saidmamatov, O., Matyakubov, U., Khodjaniyazov, E., Day, J., Ibadullaev, E., Chuponov, S., Bekjanov, D., Matniyozov, M., Matyusupov, B., 2021. Analiza TOWS możliwości zrównoważonego rozwoju ekoturystyki i pomocy państwa w czasie pandemii – region Jeziora Aralskiego w Uzbekistanie. Turyzm, 31(1), 47–57.

Barro, R., Jong W.L., 2010. A New Data Set of Educational Attainment in the World, 1950–2010. Cambridge: National Bureau of Economic Research.

Kovtun, D., Cirkel, A.M., Murgasova, Z., Smith, D., Tambunlertchai, S., 2014. Boosting Job Growth in the Western Balkans. Washington, DC: International Monetary Fund.

Valeroa, A., Van Reenenb, J., 2018. The economic impact of universities: Evidence from across the globe. The economic impact of universities: Evidence from across the globe.

Yusupova, S. B., Sultanov, O. R., Baltayev, R. S., Bekchanov, F. A., 2022. The Advantage of Using e-Learning in Teaching Students Programming Languages. 2022 IEEE International Multi-Conference on Engineering, Computer and Information Sciences (SIBIRCON), Yekaterinburg, Russian Federation, 2022, pp. 1910-1913.

Chaddock, R.E., Principles and Methods of Statistics, 471 p., Houghton Mifflin Co., New York,1925.

Kuziboev, B., Rajabov, A., Ibadullaev, E., Matkarimov, F., Ataev, J., 2024. The role of renewable energy, tax revenue and women governance in environmental degradation for developing Asian countries. Energy Nexus 13 (2024) 100262.

Galton, F., 1886. Family Likeness in Stature. Proceedings of Royal Society, London, vol. 40, 1886, pp. 42–72.

Pearson, K., Lee, A., 1903. “On the Laws of Inheritance,’’ Biometrika, vol. 2, pp. 357–462.

Dougerti, K., 2009. Introduction to Econometrics: Textbook, 3, M.: INFRA – M,. – 47 p.

Kuziboev, B., Vlach, J., Rajabov, A., Ibadullaev, E., Matyakubov, U., Nazarov, M., Mirkhoshimova, M., 2024. Quantile and Threshold Effect of Electricity Consumption on Happiness in Central Asia. *International Journal of Energy Economics and Policy*, 14(1), 321-328.

Impact of Capital Expenditures on Final Consumption and Productivity of the Region's Economy

Vladislav Gusev[a]
Trapeznikov Institute of Control Sciences, Moscow, Russia
gusvbr@ipu.ru

Keywords: Final consumption, fund formation, reserve of production resources, productivity of reproduction system.

Abstract: The reproduction model is intended to address the problem of material provision of state programs or other needs. It allows estimating necessary changes of output, gross product, the maximum possible volume of final consumption of different sectors of economy, as well as estimation of actual and equal productivity. One way to manage reproduction is to change the cost structure and final consumption. This means that a certain amount of productive resources is available. In the case of a shortage of production resources, the process of changing the control parameters in parallel with reproduction starts a slow process of forming additional production capacity. The capital formation process can be stimulated by an increase in the share of final consumption in output, which in turn can be achieved by stimulating the corresponding final demand. Balanced funding helps to maintain final consumption. On the other hand, starting at a certain level of the latter, equilibrium mode productivity begins to exceed its achieved level.

1 INTRODUCTION

The management of the structure of the reproductive system of the region allows to significantly increase its productivity, which can be defined as the ratio of gross value added (GRP) W to the gross volume of intermediate costs Z:

$$\pi = W / Z \ .$$

Denote V - gross output, then the coefficient of intermediate consumption is equal a = Z/V, gross output V = W + Z, hence π = 1/a - 1. If purposeful restructuring of the technological core of the reproduction system is aimed at increasing its productivity, its transition to the equilibrium structure can ensure the stability of the economic system.

Let the volume of output of the i-th branch V_i of the multisectoral economic system having n branches forms a vector $\mathbf{V}$. The change of prices and volumes of output is defined by vectors of price indices p and output indices v. $\left[X_{ij}\right]$ - the matrix of volumes of resources spent during reproduction $, \ i, j = 1,..,n$. Here j is the number of the industry engaged in the production of resource i, $\mathbf{X}$ - the vector of direct costs,

$$X_i = \sum_{j=1}^{n} X_{ij} \ .$$

Unit cost coefficients (material intensities) are calculated using the formula

$$a_{ij} = X_{ij} / V_j \qquad (1)$$

and form a matrix of unit costs $\mathbf{A} = \left[a_{ij}\right]$, having spectrum S. Matrix A defines the structure and state of the technological core of the reproduction system (Leontief, 1990). We assume that output costs, including fund formation, final consumption, net exports, are linearly dependent on output and prices.

$$X_i = \sum_{j=1}^{n} a_{ij} V_j \qquad (2)$$

[a] https://orcid.org/ 0000-0001-7936-180X

2 LOCAL EQUILIBRIUM REPRODUCTION MODE MODEL

The article considers locally stable mode of reproduction of technological core of economy. The local nature of management is that the industry's output is increased by its own added value. Equilibrium output and price indices are the eigenvectors of the technology matrix and the transposed technology matrix respectively. To calculate the eigenvector and frobenius eigenvalue of the positive shura matrix **A** (Ashmanov, 1984; Poljak, 2019) it is convenient to use its stability in the construction of a convergent iteration procedure (Gusev, 2021):

$$\mathbf{x}^{0} = (1,1,\ldots,1),$$

$$\mathbf{y}_k = \mathbf{A}\cdot\mathbf{x}_k \qquad (3)$$

$$\mathbf{x}_{k+1} = \mathbf{y}^k \frac{\|\mathbf{x}^k\|}{\|\mathbf{y}^k\|},\ k = 0,1,2,.. \qquad (4)$$

If interpreted x^k , as a vector of output indices or prices for a moment *k*, the process (3), (4) simulates an uncontrollable process of approaching a locally stable equilibrium reproduction mode for the technological core of the economy. Thus, the output of industries and prices change proportionally to intermediate costs, that is, locally, depending on the available funds of industries. Eigenvalue of matrix **A**, calculated as a limit value:

$$a^* = \lim_{k\to\infty} \frac{\|\mathbf{y}^k\|}{\|\mathbf{x}^k\|}$$

is the largest of all its own numbers (Poljak, 2019). This value determines the local equilibrium productivity $\pi^* = 1/a^* - 1$. It is obviously less than the productivity obtained as a result of optimization processes (Gusev, 2022).

Deformation (1) of matrix **A** as a result of change in final consumption results in change in local equilibrium productivity π^*.

3 BALANCE-SHEET MODEL OF FINAL CONSUMPTION IMPACT ON REPRODUCTION

Let $\mathbf{C}$ - the vector of final consumption, $\mathbf{R}$ - the vector of accumulation (including fund formation and net exports). The equation of balance is like

$$\mathbf{V} = \mathbf{X} + \mathbf{C} + \mathbf{R},$$

Let $\mathbf{V}_c$ - a vector of output that takes into account the provision of growth of final consumption by volume c. It is necessary to calculate the vector of balanced output as a function of the cost of additional consumption. The increase in the output vector $\Delta\mathbf{V}_c = \mathbf{V}_c - \mathbf{V}_0$ under the additional fund formation of Rc is due to the growth of the final consumption equation:

$$\Delta\mathbf{V}_c = \mathbf{B}(\Delta\mathbf{C} + \mathbf{R}_c / f_0),$$

where the $\mathbf{B} = (\mathbf{E} - \mathbf{A})^{-1}$ - matrix of total costs (Leontief, 1990), f_0 is the ratio of investment productivity, which means the volume of production capacity per unit value. $\mathbf{R}_c / f_0$ - costs of capacity building.

End-use growth has a pattern $\mathbf{d} = \mathbf{C_0}/\|\mathbf{C_0}\|$:

$$\Delta\mathbf{C} = \mathbf{d}c,$$

where $\mathbf{C_0}$ is the initial final consumption of the sector in question.

Let eps - the ratio of reserve of production, labor and material resources, then restrictions on output without taking into account the growth of capacities have the form

$$\mathbf{V}_c \le \mathbf{V}_0 \cdot (1 + eps).$$

Given the availability of reserve resources, capacity shortfalls offset by additional output are

$$\begin{aligned}\mathbf{R}c &= \max(0, \mathbf{V}_c - \mathbf{V}_0 \cdot (1+eps)) \\ &= \max(0, \Delta\mathbf{V}_c - eps \cdot \mathbf{V}_0)\end{aligned}. \qquad (5)$$

We shall introduce the reserve volume $\mathbf{R} = \mathbf{R}c * q$ adjusted in accordance with the social orientation of economic policy, where the multiplier q is selected so that the dependence of the growth of final consumption on the planned growth of final consumption with was monotonous, which is required. Then we shall

$$\Delta\mathbf{V}_C = \min(\mathbf{B}(\Delta\mathbf{C} + \mathbf{R} / fo), \mathbf{R} + \mathbf{V}_0 \cdot eps). \qquad (6)$$

In the solution of the system of equations (5), (6), it is assumed that the deficit is covered by the internal product generated in the reproduction cycle over the corresponding period of time. The initial approximation $\mathbf{R}$ can be calculated using the formula

$$\mathbf{R}c = \max(0, \mathbf{B}\Delta\mathbf{C} - eps \cdot \mathbf{V}_0) / (1 + eps).$$

The value added vector (domestic product) due to change in final demand is equal to

$$\mathbf{W}_c = \mathbf{V}_c - \mathbf{X}_c = \mathbf{V}_c - \mathbf{A}\mathbf{V}_c.$$

The corresponding final consumption growth vector is equal to

$$\Delta\mathbf{C} = \mathbf{W}_c - \mathbf{R}_c / fo$$

As a result of the increase in final consumption, and due to the piecemeal linear dependence of parameters on the initial output $\mathbf{V}_0$, there is a change in the intermediate costs ΔX_{ij} of product i in industry j, caused by a change in output corresponding to the growth of the final consumption vector . The unit cost matrix coefficients then change as follows:

$$a_{ij}^* = (X_{0ij} + \Delta X_{ij})/V_i \\ = (X_{0ij} + a_{ij} \cdot \Delta C_j)/V \quad . \tag{8}$$

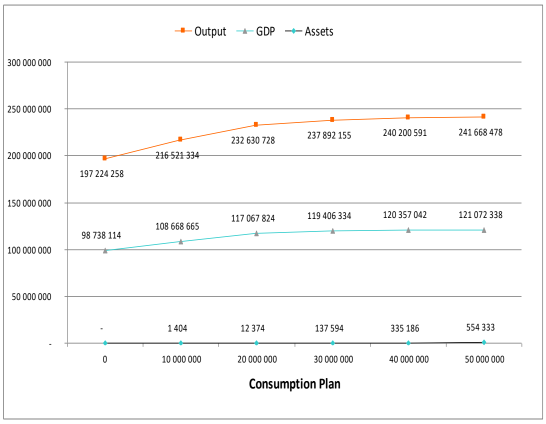
Transformation of matrix A as a result of change of final consumption leads to change of productivity π as well as its own values and, therefore, this transformation can be called deformation of technological core. Such a distortion can occur both locally funded and centrally funded.

4 CALCULATION RESULTS FOR REPRODUCTION MODELS

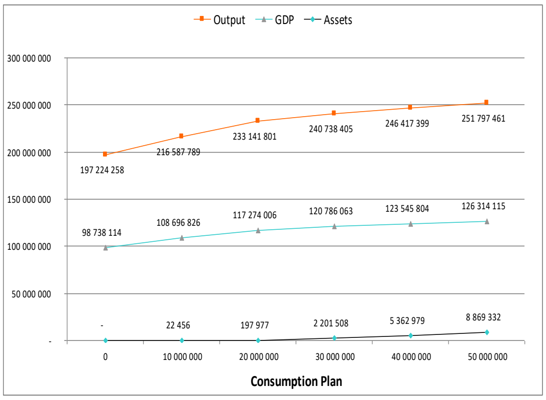
The Tables of Supply and Use of Goods and Services of the Russian Federation for the year 2020 were used to demonstrate the modelled approach and to obtain qualitative conclusions for the regional economy. This table, as well as the Rosstat tables of previous years, contains the same number of industries and types of products, and it can be distinguished symmetric subtface. To calculate the unit expenditure matrix A, this part of the table was used, corresponding to the intermediate consumption of industries, and in addition, a row containing the industry output vector. The statistical data allow estimating the share of unladen production industries about 25%, and the average ratio of fund productivity fo about 0.5.

The values of output V , GRP W , fund formation R, final consumption C, productivity π for declared final consumption c (in table (Tablicy, 2020) for total final consumption expenditures) were calculated. The following results (fig. 1, 2, 3) were obtained for two modes: A - limited funding generation ($q = eps^3$).and B - excess funding ($q = eps$)

All volume indicators are measured in mln. rubles.

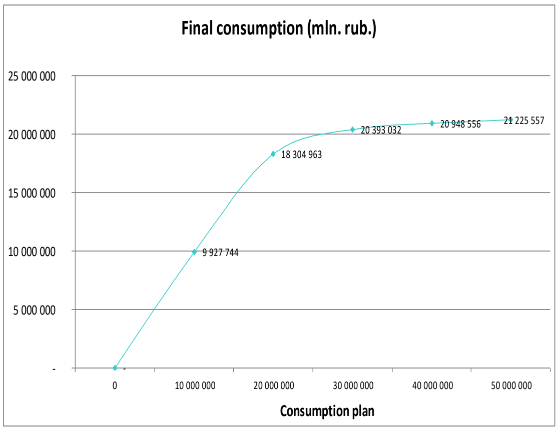


A

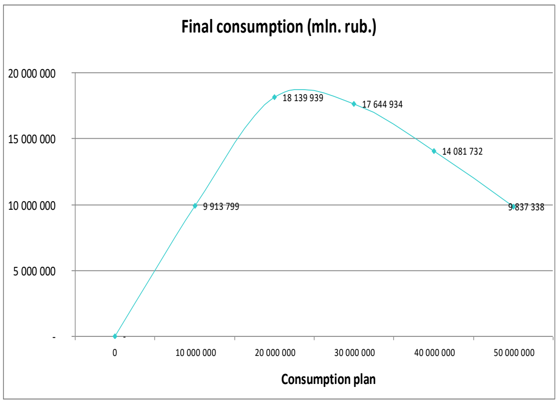


B

Figure 1: Dependence of macro indicators on planned consumption of sector «final consumption expenditure».



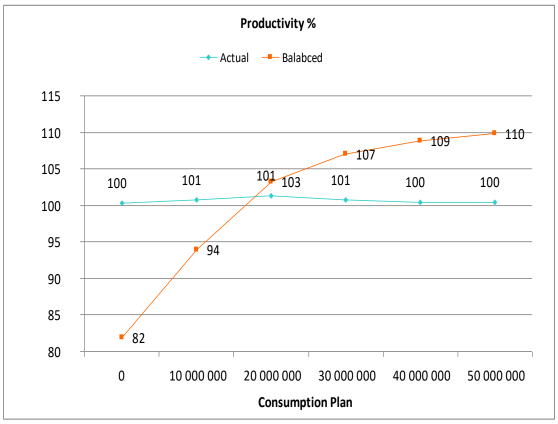
A



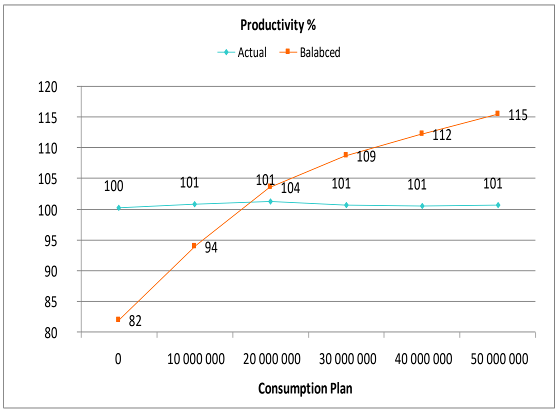
B

Figure 2: Dependence of current final consumption on planned consumption of sector «final consumption expenditure».

The resulting output grows with added consumption nonlinearly, as it takes into account the build-up of fixed assets. If it is large enough, additional constraints on labour must be taken into account. When there is excess funding, final consumption decreases because there is a shortfall in funds. But gross value added increases.



A



B

Figure 3: Dependence of current and equilibrium productivity on planned consumption of the sector «final consumption expenditure»

Equilibrium productivity is calculated by procedures of search of local equilibrium and recalculation of technological matrix (8). Graphs of actual and equilibrium productivity intersect with the volume of final consumption 17 trillion. rub. at the level of 101%. This consumption is a point of bifurcation, with the property that the equilibrium economy is inferior to the uncontrolled economy in terms of productivity, and higher in terms of final consumption. In addition, in excess fund formation, equilibrium productivity is slightly higher than in limited fund formation.

In this case, for sufficient final consumption, actual productivity increases to an amount comparable to that achieved with optimal consolidated management (Gusev, 2022). But equilibrium productivity is much lower than for final consumption expenditure.

4 CONCLUSIONS

The main conclusion is that the multisectoral economy of the region, which has no institutional system of coordination of participants, tends to a state of local equilibrium with minimal equilibrium productivity of the system of reproduction.

The developed model showed a number of reproduction process features associated with the burden of the economic system by the output of end-use products:

Final consumption growth less than or equal to planned volume.

An increase in final consumption, with its corresponding structure, leads to an increase in equilibrium productivity that is achievable in a local control situation. This increase in equilibrium productivity (as opposed to the optimization model of consolidated management) is irreversible, as it is due to a change in the technological structure of reproduction.

When the final consumption threshold is exceeded, the economy achieves a stable state, where local control allows to ensure a value of equilibrium productivity greater than its initial value. That is, after overcoming the specified threshold of final consumption, the local equilibrium economy sustains it.

The maximum possible increase in final consumption is directly dependent on the reserve ratio eps.

Given the local nature of reproduction management, the Russian economy has minimal efficiency, but is stable and uneven income. If each industry, in cooperation with others, only manages its own resource for investment, then the economy is in balance with minimal productivity. The growth rate of such an economy depends on final consumption. The trap is the inability to break the poverty line with low end consumption. A centralized reserve is needed to increase economic productivity.

The obtained results testify to the prospect of development of institutes of management of development of technological infrastructure of the Russian economy (Gusev, 2022a; Gusev, 2007; Antipov, 2019). The models can be used to refine the programs of medium-term development of the Russian economy, including the project of basic unconditional income (Bobkov, 2021), as well as to solve the problems of material provision of CBO. The obtained solutions represent the framework values of economic indicators within a given technological base.

The formulation of economic development plans along with their sustainability (Chen, 2024) should take into account the impact of household final consumption on the external environment (Nágela, 2020) as well as be consistent with natural resource management policies (Smith, 2021).

REFERENCES

Antipov, V.I., 2019. "GOSPLAN. Vchera, segodnja, zavtra" - M.: Konceptual. 208 s.

Ashmanov, S.A., 1984. Vvedenie v matematicheskuju jekonomiku. Glavnaja redakcija fiziko-matematicheskoj literatury. 296 s.

Bobkov, V.N., Antipov, V.I., Kolmakov, I.B., Chernyh, E.A., 2021. Modelirovanie scenariev preodolenija absoljutnoj monetarnoj bednosti v Rossii na osnove koncepcii bezuslovnogo bazovogo dohoda. Uroven' zhizni naselenija regionov Rossii. Tom 17. №2. S. 204–215.

Chen, C-W., 2024. A Framework of Hybrid Method for Developing Optimal Sustainable Product Strategies and Sustainable Product Roadmap. Sustainability. 16(4):1374.

Gusev, V.B., 2021. Jekstremal'nye harakteristiki modeli tehnologicheskogo jadra krupnomasshtabnoj jekonomicheskoj sistemy. *Problemy upravlenija*. № 6. S. 30-39.

Gusev, V.B., 2022. Binarnaja model' upravlenija restrukturizaciej tehnologicheskogo jadra jekonomiki. *Problemy upravlenija*. № 6. S. 14-25.

Gusev, V.B., 2022. Metod planirovanija restrukturizacii i perehoda k jekonomicheskomu rostu v uslovijah sankcij. *Matematicheskie metody v tehnologijah i tehnike.* № 11. S. 84-87.

Gusev, V.B., 2007. Indikativnoe planirovanie i provedenie regional'noj politiki. M.: Finansy i statistika. 368 s.

Leontief, V.V., 1990. Jekonomicheskie jesse. Teorii, issledovanija, fakty i politika. (Essays ineconomics. Theories, theorizing, facts, and policies) Perevod na russkij jazyk: V.G. Grebennikov, I.I. Andreeva, Ju.M. Dyhanov, N.V.Pavlov, N.A. Ranneva. Obshhaja redakcija perevoda S.S. Shatalina i D.V.Valovogo.

Nágela do Prado, Gustavo Hermínio Moraes, 2020. Environmental awareness, engaged consumption and organic products consumption. Revista Pensamento Contemporâneo em Administração. V 14.

Poljak, B.T., Hlebnikov, M.V., Rapoport, L.B., 2019. Matematicheskaja teorija avtomaticheskogo upravlenija. M.: Izdatel'stvo URSS. 500 c.

Smith, B., Waldner, D., 2021. Rethinking the Resource Curse. Cambridge University Press.

Tablicy resursov i ispol'zovanija tovarov i uslug Rossijskoj Federacii za 2020 god (v tekushhih cenah, mln. rub.) Opublikovano Rosstatom 26 janvarja 2022 goda. https://rosstat.gov.ru/storage/mediabank/tri-2020.xlsx

Integration Processes in Universities

Aleksandrova E.V.[a], Vorozhikhin V.V.[b], Petrov A.M.[c]
Plekhanov Russian University of Economics, Moscow, Russia
Aleksandrova.EV@rea.ru, Vorozhikhin@mail.ru, Petrov.AM@rea.ru

Keywords: Education, science, development, integration, ecosystems, innovations.

Abstract: The relevance of the topic is expressed in the reform of the higher education system, associated with the acceleration of scientific and technological development, increasing competitiveness, the development of human resources, etc. The purpose of the article is to study the prospects for the development of higher education in Russia until 2040:- analysis of integration alliances - consortia and universities as ecosystems, the development of innovative models in universities. The main objectives of the scientific work are - to study the current problems of development and opportunities for improving higher education in Russia; - to form and substantiate the directions of the long-term development of higher educational institutions of the Russian Federation for the period up to 2040. The novelty of the research is to develop an image of the infrastructure of higher education-2040; Research methods. The article applies the methods of comparative analysis, forecasting and generalization, comparisons and analogies, methods of classification and expert assessments, as well as the principle of historicism, concretization.

1 INTRODUCTION

Active attempts of reforming systematization of higher education in Russia have been made since 2004. There are certain results, however, in a period of significant acceleration of scientific, technological and socio-economic development of world leaders, it is necessary to find a possible solution to achieve the competitiveness of higher education within the short period of time. Maintaining the gap in the era of technological singularity will lead to this gap fixation and the exclusion of Russia from the ranks of both an international competitor and a significant partner in development, will put Russia in front of the fact that it is impossible to guarantee a favorable (better) future of the country (Vorozhikhin, 2020).

Today, society is trying to get rid of ageism, when the criterion of scientific significance of activity is replaced by age criteria - someone is too young, someone is too old to have adequate ideas and modern knowledge. Every year the role of man and science increases, requiring attention to value ideals that lead to certain criteria for decision-making (Vorozhikhin, 2020).

[a] https://orcid.org/0000-0002-8365-2279
[b] https://orcid.org/0000-0003-3361-1425
[c] https://orcid.org/0000-0003-4582-8066

2 RESEARCH MATERIALS AND METHODS

Research materials and methods are approaches related to the use of system analysis and synthesis, structural-logical and economic-statistical analysis, comparative and retrospective analysis, methods of forecasting and generalizations, comparisons and analogies, methods of classifications and expert assessments.

3 ROBLEM STATEMENT

Scientific education is a constantly developing field necessary to identify and promote existing abilities. Each area of interest or subject plays a role in creating a favorable future. Education of future specialists is very important for the sustainable development of society, therefore it is reasonable to equip students with the necessary knowledge to solve tasks set.

Scientific education has led to the emergence of new technologies and the ability to explain scientific concepts and processes. It is believed that this is necessary for technological progress, as it is a dynamic, progressive and collaborative human enterprise that "causes excitement" as a result of interest and curiosity.

Technology and innovation have been vital throughout human history, and will continue in future. While the energy of water and steam was the source of the first industrial revolution, electricity for mass production formed the basis of the second, and electronics and information technology influenced the third, which led us to the fourth. The boundaries between the physical, biological and digital spheres are blurred during the Fourth Industrial Revolution against the background of advances in artificial intelligence, quantum computing, the Internet of things, nanotechnology and advanced materials. Countries around the world should try to implement policies that promote this innovation and integrate it into their development (successful efforts made by developing countries around the world were highlighted by the United Nations Conference on Trade and Development). Innovations should be adaptive and step-by-step and based on the country's special potential to develop technological and scientific solutions to local problems with possible global impact. In addition, innovation is necessary in an effort to adapt solutions developed elsewhere to local needs. Such problems may be always opportunities to promote innovation. For example, in many low-income countries, mobile devices and wireless Internet connectivity have proven invaluable in meeting the needs of public, information and utility services.

Science has been declared a national project in Russia for the first time. By 2025, Russia should - enter the top five countries in priority areas of science; - make work in Russia attractive for Russian and foreign scientists, as well as - ensure a faster growth in domestic research costs compared with the growth of the country's GDP. Worldwide, the education sector is facing technological changes to meet the growing demand of the 21st century. These changes have opened up wide opportunities for scientific and pedagogical personnel to integrate technology-supported materials into research and teaching practices through the use of information and communication technologies (ICT). Currently, ICTs create opportunities that provide valuable assistance in improving the task, smoothing the teaching and learning process, and enriching the goals of education. The integration of ICT into the research-learning process has mainly increased the efficiency and effectiveness of these processes. The modern complex dynamic world is developing in conditions of global hypercompetition for the future, which is realized in complex forms of competitive partnership, when agents, competing in some markets, influence the others, and over time this picture changes or repeats. In this world, it is impossible to separate development and security management (risks) – risks accompany any processes and technologies, any activity carried out at different levels of the economic system. Development goals are formed on the basis of vision of the desired future, and the area of safe development is based on acceptable deviations from the trajectory of its achievement. Security in a dynamic system is defined as a goal-result – a favorable future – and the process of achieving it. The current changes in the speed of development of public institutions lead to a change in the development leader. The business leader, who has been permanent for decades, transfers this role to universities, i.e. universities assume the role of ensuring strategic economic security of business. The development and safety of universities require the formation of scientific research, on the basis of which unique courses are created, traditional and distance, with the right internal and external positioning, while developing a unique brand. Universities are forced to use complex forms of partnership in the context of global hypercompetition, attract talents – both students and teachers, participate in the economy of the territories of their presence, interact with all stakeholders, finding a balance of interests not only in the short term, but also in the strategic period. Graduates should be ready for lifelong learning and be able to repeatedly master new specialties at different stages of their activity. Another important factor of influence is the adequacy of criteria for evaluating projects, processes, results, texts, and research. The system of priorities and criteria of each decision-maker is based on his personal system of knowledge, skills and experience. From the perspective of assessing complex experience, it is necessary to go beyond assessing the economic effectiveness of a particular project, taking into account changes in potentials at all levels of the system being evaluated, up to the global one. The system of indicators for a comprehensive assessment of the state of complex systems, strategies, programs, and projects for their development requires a multi-vector, multi-level, multi-network description. The normalization of the weights of indicators requires regular correlation with the level of global development. The development assessment should be based on an integrated assessment of megaproject implementation scenarios, differentiated for internal projects. The type of project significantly changes the impact of external factors on efficiency. Depending on the type of project, it is necessary to evaluate the integrated effectiveness. A comprehensive system of evaluation criteria allows evaluating heterogeneous projects included in a single megaproject on a single methodological basis, taking into account the importance of each project for the overall result. At the same time, an integrated assessment of all changes in development potentials (opportunities) for each level of the system is required, which with different weights contribute to the integral indicator of development potential at the global level – taking into account contributions to global knowledge chains, technologies, cost, value, as well as positions in global markets. Their ratio will also change rapidly, taking into account the digital speeds of development and changing positions.

4 FORMATION OF THE ECOSYSTEM OF HIGHER EDUCATION

We live in a system of growing socio-historical demands of modern post-industrial society. One of the fundamental paradigms of its improvement is cooperation of all who are interested in its prosperity. For this, the integration of the customer and the contractor, the development of hyper-actualized, incredibly active projects becomes inevitable. And it is necessary to start with the education quality improvement, the most important lever of socio-economic and political development, the processes of integration of which with the outside world are diverse, voluminous and multidimensional. If we talk about truly modern education, then we must first of all talk about an ecosystem in which all sides of the process are interconnected – an educational institution, a consumer of knowledge, skills and competencies, a customer of a future specialist and, of course, the state and society as a whole. At the same time, it is the educational link of the ecosystem that is associated with scientific, industrial, innovative, and entrepreneurial activities, since it unites the requests of all interested parties (Fig. 1).

In the structure of the university as a key link of the ecosystem, such levels can be distinguished:

• intra-university cluster as a set of communicating units;

• high educational platform is an environment for the integration of its infrastructure and organizational culture;

• the network is a means of intra–university communications that contributes to the effectiveness of educational and management processes;

• incubator is a subsystem for supporting the organization of intra–university projects and programs, including in the field of R&D.

Ecosystems:

– contribute to the creation and development of social and cultural innovations;

– promote technological innovations, including the development of teams of technology entrepreneurs and developers;

– create equal opportunities in conditions of gender, economic, and ethnic inequality.

– become part of social development to empower young people to receive profound education.

Advantages of educational ecosystems:

1. A variety of resources and routes.
2. The possibility of competent, full-fledged use of resources and their exchange to create new methods and ways of learning.
3. Dynamism, changeability, adaptability to different conditions of knowledge transfer.
4. The presence of formal and informal learning processes.
5. A decentralized management system.
6. Student-centricity (or the presence of a student-oriented "change leader").
7. Focus on solving urgent socio-economic problems (Titova, Shishkin, 2023).

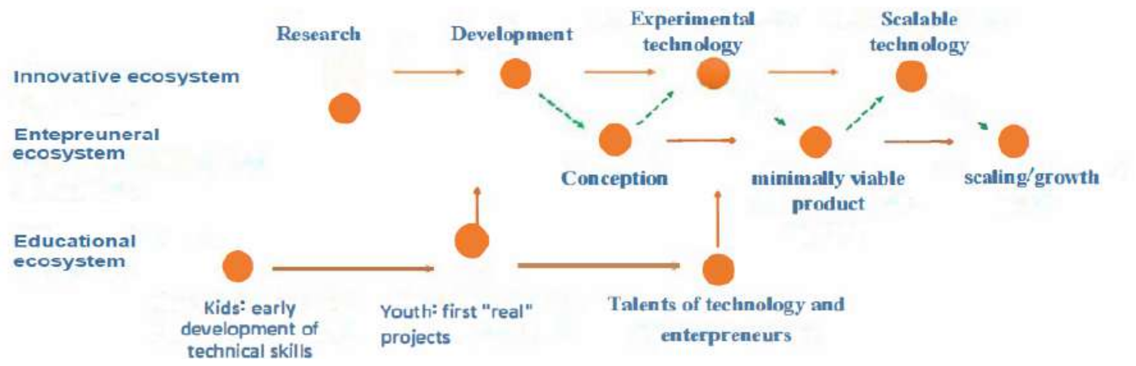


Figure 1. The place of education in the ecosystem of society.

Such structure as the National Research University can be named a classic way to integrate science and education. This cohort of federal and research universities, for which indicators have been developed and control programs have been drawn up for the entire educational system and in which serious resources are invested, have been identified as "locomotives", flagships of education.

But one cannot solve the problem with the state efforts only. Therefore, a public-private partnership system is absolutely necessary. It is important to take into account the opinion of the professional community, representatives of universities, employers, and society as a whole. Another promising type of integration alliances is consortia: an association in which the processes, roles and functions of the participants are established through agreements reached (Fig. 2).

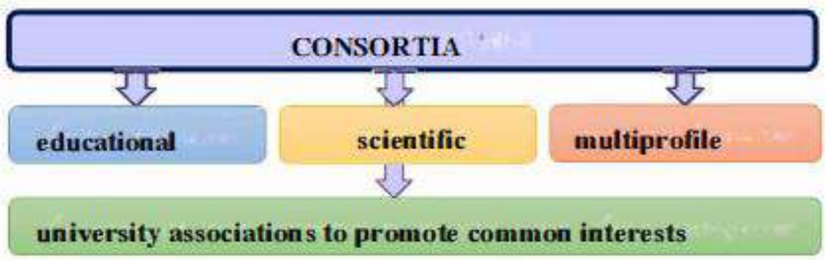


Figure 2: Types of consortia united by a common goal.

The most significant of them involve integration: (Titova, Shishkin, 2023).

1. The Russian higher education system in the global educational space and the global system knowledge.

2. Higher education with business (production);

3. Science and higher education. 4. Universities in the regional economy.

5. Universities in the national knowledge structure.

Increasing the integration potential of universities is a factor of competitiveness. Integration processes in higher education (Fig. 4) are aimed at combining the resources of universities to increase their competitiveness at the global and national levels, which creates a synergy effect. These processes are multidirectional, including the unification and standardization of educational norms and traditions, the preservation of one's own uniqueness and identity in the field of education, and the achievement of common goals and objectives through maximum academic profit. Cooperation can take place not only within the framework of joint educational programs, but also scientific, innovative and social projects.

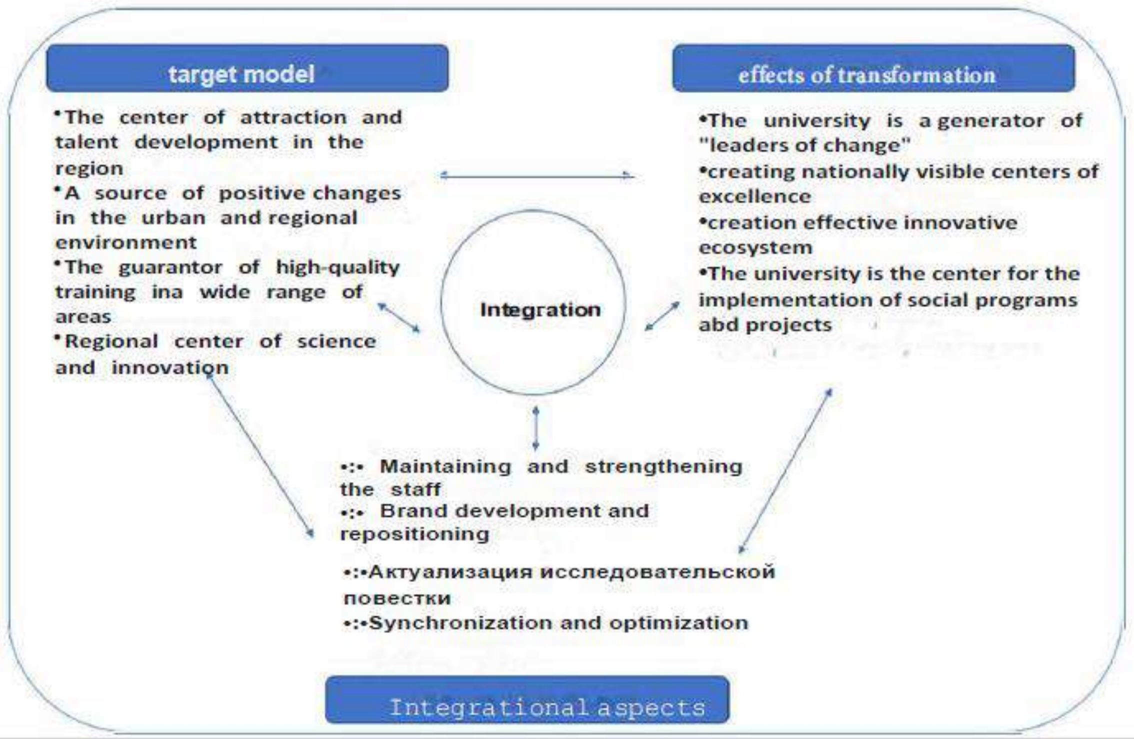


Figure 3: Integration processes in higher education.

The network organization makes it possible to eliminate barriers to scientific communication, which is necessary for exchanging of superdiscipline, transprofessional knowledge. Strong networking is also manifested in paying attention to certain competencies – the level of teaching a foreign language, computer literacy – regardless of the chosen specialty.

The network organization makes it possible to eliminate barriers to scientific communication, being a necessity for the exchange of superdiscipline, transprofessional knowledge. Strong networking is also manifested in paying attention to certain competencies – the level of teaching a foreign language, computer literacy – regardless of the chosen specialty.

In addition, one of the tasks of the Ministry of Education and Science of the Russian Federation starting from 2024 is the introduction of network educational programs of technological master's degree in leading universities. It should be noted that the Master's degree programs are interdisciplinary. For example, "applied linguistics" combines a humanitarian component with mathematical methods of analysis and computer science. Specialists in this field are in great demand by those companies that are engaged in developments in the field of Internet search, creation of new programming languages, machine translation, etc.

Discoveries and breakthroughs are possible today, mainly at the junctions of sciences. The examples most often cited are physics, nuclear energy, IT, as well as biophysics, biology, biotechnology, medicine – everything related to living organisms, and this is where Russia has made especially significant progress.

Many universities have been developing for a long time not at the expense of paying students, but at the expense of income from science. New rules for financing scientific research are being formed on the basis of modern "measurement tools" of their effectiveness. One of them is publication activity. It is it that influences the scientometric indicator "Hirsch Index".

New federal educational standards should also be integrated into the existing system of interaction, in which it is necessary to strengthen the professional component and integrated curricula.

The integration of universities into the regional economy requires that the content of vocational education takes place in accordance with the needs of the labor market. It's time to break the stereotypes that peel off from real life. Universities need to be combined with industrial complexes.

Thus, the educational process can help to increase the profitability, efficiency and profitability of the enterprise. There must be an understanding: even if it is a private enterprise, the mission is of national importance. And the specialists "motivated" for its production will eventually bring even more profit to the owner.

The trend of modern life, when the educational process is transferred to the enterprise of business partners, is symbolized by the so-called dual education system, the meaning of which is to "bind" theoretical knowledge to the realities of a high–tech production process. The basic principle of the dual training system is that part of the educational process – lectures, laboratory work – takes place on the basis of a university or college, and the "fine–tuning" of a specialist, industrial training - at industrial enterprises. The evaluation criteria needed by the business community should be incorporated into this system. And they will depend on a set of professional competencies dictated by business requirements.

Such a training system can be divided into 3 parts. If, for example, we are talking about production, then this is theory; training on special simulators that allow you to qualitatively simulate a modern expensive CNC machine – in fact, a computer combining software with a mechanism of execution; and, in fact, the practical part, reflecting the trend of modern life, when the educational process is transferred to an operating enterprise business partners to perform real production tasks.

Close cooperation takes place in two directions: business forms an order, and educational institutions make plans, programs, create joint laboratories to train personnel at the level of international standards. Mutually beneficial cooperation is based on the interaction of science and business, the commercialization of scientific developments, investments in projects that can be brought to market and receive financing.

Universities use the following ways to develop skills and build competencies:

– basic departments that allow you to obtain those competencies that cannot be acquired within the framework of a theoretical educational program (for example, work on nuclear reactors for transport installations, aerospace defense systems, small arms and artillery missile weapons);

– world-class laboratories as a prototype of the sites where graduates will work (for example, in the field of extreme applied optics, research of human brain processes, development of nanostructured materials based on titanium and zirconium for dentistry – practitioners and their patients are waiting for this, that is, almost every one of us);

– a system of clinical practice bases that allow you to prepare and then implement your own micro–project, the main feature of which is to obtain a practically significant result;

– cooperation with institutes of the Russian Academy of Sciences, participation in the work of technoparks, author's schools of scientists, sessions of young scientists at which they make innovative proposals;

– training and production grounds for working out professional competencies directly to meet the requirements of employers;

– upgraded resource centers which accumulate the latest production and educational technologies.

As a result, enterprises do not spend money on "refining" and "tuning" of young personnel: their competencies fully meet the requirements of the labor market. For example, the Russian Union of Builders conducted a certification procedure for the professional qualifications of graduates who undertake to work in production and construction sites, based on world requirements for the World Skills system or personnel certification – Gost R or ISO 9001:2001.

Employer’s expectations from young professionals are:

• be able to replenish their knowledge, strive for additional professional training;

• be oriented in related industries;

• apply non-traditional approaches to solving problems, finding competitive solutions;

• possess modern means of communication, methods of economic analysis and organization of marketing activities;

• promote the results of their professional activities in the market;

• be aware of the basics of Russian legislation, and often international law.

A profession that will always be in demand involves transformation according to the challenges of time – then education will allow you to change with it, "anticipate" tomorrow's demands of the real sector of the economy.

Formation of a multidimensional university model.

Modern higher education acquires features it did not have before. For example, in connection with the formation of the University 3.0 model, an innovative Triple helix model of innovation arises. From this moment, the mission of the educational complex includes education, science and innovation. Such a model involves interaction between universities engaged in basic scientific research, business that creates value added, and the state that coordinates and controls these processes. Hybrid structures such as technoparks, business incubators, etc. can be the results. Fig. 4 demonstrates strategic interactions along the triple helix model (triad) (Itskovits, 2011).

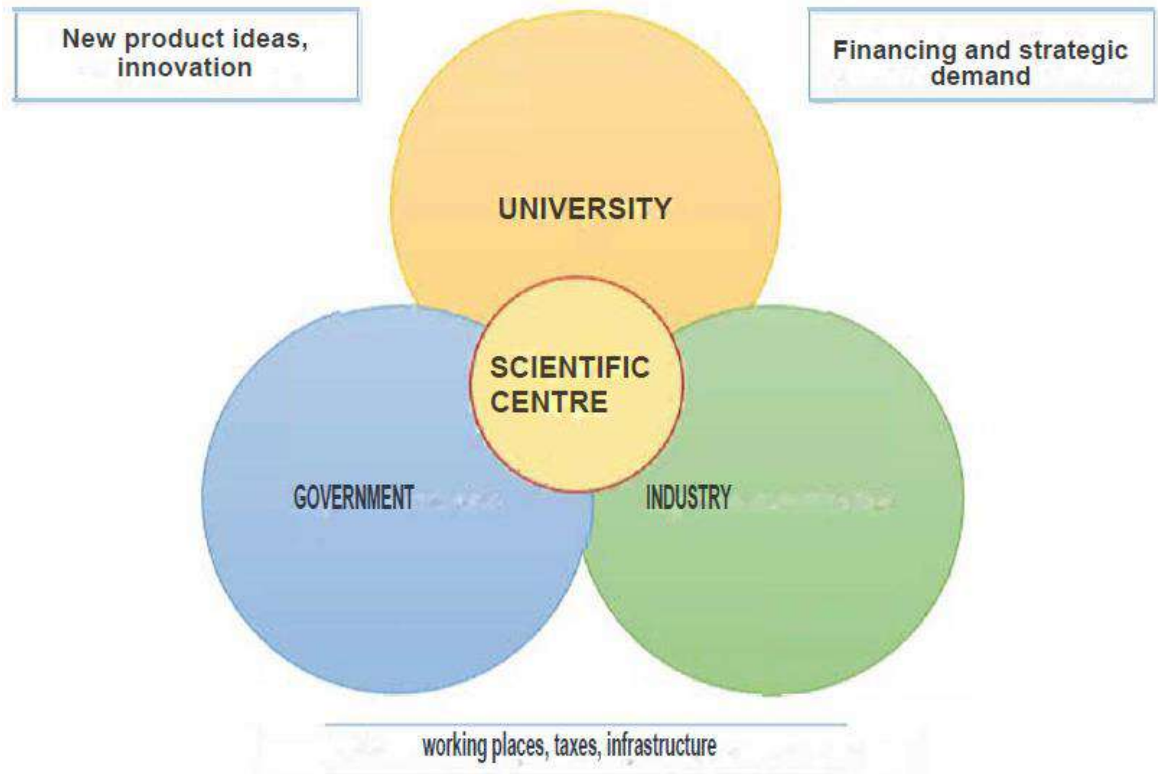


Figure 4: strategic interactions along the triple helix model.

The triple helix model demonstrates the openness of the innovation process and the gradual involvement of new parties in it. In the case of an even greater branching of models, for example, into a four-link one, the interaction of four subsystems is reflected:

– Science and education (universities and research institutes);

– Economic sector (industry, services and financial and credit institutions);

– State and political institutions that set the vector of innovative socio-economic development;

– Society (representatives of the media and culture).

With the further branching of the innovation spiral, issues of social and environmental responsibility of business, society and social institutions are accumulated in the formation of the fifth element – the "natural environment of the society".

5 CONCLUSIONS

Russian science is a strategic area of activity which the state invests in even in the most difficult times, because the viability and prosperity of our country depend on it.

Moreover, science is divided into fundamental, applied and university. At the same time, university science is "two–headed": it can be both fundamental and applied, implementing its developments in industry – many universities use this competitive advantage. And real results generate demand from partners and customers.

Advanced universities are developing experimental, research, testing facilities, and methods for modeling nuclear processes in the energy sector, including by means of supercomputers: improving nuclear installations is impossible without applied developments that are conducted in cooperation with universities.

But development is impossible without talented youth, the point is in their systemic motivation and the creation of conditions for the development of research, entrepreneurial and innovative activity.

The fundamental steps in this regard are legislative initiatives that take into account trends – the need for universities to interact with organizations of the Russian Academy of Sciences and organizations of applied science to conduct research. The Foundation for Advanced Research has been operating in Russia for more than 10 years. It focuses on systematic, purposeful work, because the development of one direction gives an impetus to the development of others. The Russian Scientific Foundation, established for financial and organizational support of fundamental and exploratory scientific research, personnel training, and the development of teams that occupy leading positions in a particular field of science, is successfully functioning.

A number of regions have adopted laws on grants in the field of science, technology and technology, on state support for innovation and investment activities, etc.

6 DISCUSSIONS

The search for a tool that provides advantages in the global hypercompetition of countries for successful future is the goal of our country's development and security. But import substitution is only the first step away from dependence. The following steps are export and import anticipation.

Hence the setting of a super task: to build a balanced, self-improving multi-network of scientific research and cultural support for reforms. The result should be a noospheric society with a predictable future based on multidimensional strategic management systems. The vectors of its development will be such as artificial intelligence and robots, human-machine interaction and bionics, electronics and computing, bio-hybrids, biomedicine, 3D printing and materials, overcoming resource boundaries, energy.

Modern scientific research is the work of many teams of different directions, whose results add up to an unexpected mosaic, and it turns out in something that yesterday seemed impossible. In conditions when there is a competition for the quality of human capital, it is necessary to talk not just about individual innovations, but about the assessment of innovative activity, the formation of an innovative society that imagines new ways, thinks in a new way.

Russia's task is to invest in quality education and support key initiatives aimed at the prosperity of the Russian economy.

REFERENCES

Decree of the President of the Russian Federation dated December 1, 2016 No. 642 "On approval of the Strategy of scientific and technological Development of the Russian Federation". – URL: http://publication.pravo.gov.ru/Document/View/0001201612010007

Apevalova, Z. V., 2013. Organization of the activities of the Consortium of pedagogical universities (questions of methodology). Higher education in Russia. No. 12. – p. 111.

Vaskevich, T. V., 2019. The genesis of national higher education systems: the path to European integration: dissertation, candidate of Pedagogical Sciences. Krasnodar: Kuban State University, 2019. p. 28.

Interaction of universities with industrial partners. Issue 10. – Moscow: Scientific Research Institute for the Development of Education of Plekhanov Russian University of Economics, 2022.

Volkov, A. E., 2019. Presentation at the conference 5-100. - Moscow: Plekhanov Russian University of Economics, 2019.

Vorozhikhin, V. V., 2020. With an eye to a breakthrough. Proposals for the economic recovery plan. *Self-government.* № 2 (119). Pp. 78-82.

Gabrielyan, A.M., 2019. Global trends in the policy of reforming higher education in Russia: abstract of the dissertation, candidate of Political Sciences.Simferopol: V. I. Vernadsky Crimean Federal University.

Indicators of Science: 2022: statistical collection Moscow: HSE, 2022. p. 252.

Itskovits, G., 2011. The Triple Helix model. *Innovations.* № 4 (150). – Pp. 5-10.

International Standard Classification of Education: ISCED-2011. – URL: www.uis.unesco.org/Education/Documents/isced-2011-en.pdf

Methodological guide on the interaction of universities and industrial enterprises. – URL: http://irdclub.ru/wpcontent/uploads/2017/04/UI-collaboration-toolkit.pdf . – p. 31.

Ovchinnikova, N. E., 2018. Interaction of the university with industry 2.0. University management: practice and analysis. Vol. 22. No. 3.

Identification of the main reasons hindering scientific development in the Russian Federation: assessment of scientific infrastructure, sufficiency of motivational measures, ensuring the attractiveness of the work of leading scientists. The report of the Accounting Chamber on the results of the expert-analytical event. 2020. p. 2.

Promising directions for the transformation of higher education in Russia in the context of the exit from the Bologna process: an analytical report. M.: Scientific Research Institute for the Development of Education of Plekhanov Russian University of Economics, 2023.

Trends in the development of higher education in the world and Russia: monitoring results. – M.: Scientific Research Institute for the Development of Education of Plekhanov Russian University of Economics, 2022.

Titova, E. S., Shishkin, S. S., 2023. Actual problems of bioeconomics, the role of postgenomic disciplines. M.: YOUR FORMAT.

Transforming universities. Skolkovo, 2019. – URL: ttps://www.skolkovo.ru/public/media/documents/research/sedec/SKOLKOVO_SEDeC_T-universities_ru.pdf.

Federal state educational standards. SPS "ConsultantPlus".

Shchelkunov, M. D., Nikolaeva, E. M., Fursova, V. V., 2016. On the way to international recognition: Kazan Federal University as a subject of the global higher education space. Kazan: Publishing House of Kazan University.

100 Radical Innovation Breakthroughs for the Future. European Commission. Luxembourg: Publications Office of the European Union, 2019.

Kimatu, J. N., 2016. Evolution of Strategic Interactions from the Triple to Quad Helix Innovation Models for Sustainable Development in the Era of Globalization. *Journal of Innovation and Entrepreneurship*. Vol. 5. – P. 16.

Mertens Donna, M., 2013. Research and Evaluation in Education and Psychology: Integrating Diversity with Quantitative, Qualitative, and Mixed Methods. 3rd ed. SAGE Publications, 2013.

The Gospel of ERC’s New President: Super-disciplinary Science. – URL: https://sciencebusiness.net/news/gospel-ercs-new-president-super-disciplinary-science (дата обращения 04.02.2020).

Transistor Count Trends Continue to Track with Moore’s Law: Research Bulletin. – URL: https://www.icinsights.com/news/bulletins/ transistor-count-trends-continue-to-track-with-moores-law/

Volkov, A., Melnyk, D., 2018. University Autonomy and Accountability in Russian Higher Education. *International Higher Education.* No. 94. P. 31–33.

Zaber Melanie, A., Karoly Lynn, A., Whipkey, K., 2019. Reimagining the Workforce Development and Employment System for the 21st Century and Beyond.

Error Correction in Online Classroom of Foreign Languages: Types of Error Correction and their Benefit

Sokhiba Zokirova[1][a], Ozodakhon Khasanova[2][b], Nargiza Sobirova[3][c]
Department of Primary Education Methods, Fergana State University, Fergana, Uzbekistan
Department of German and French languages, Fergana State University, Fergana, Uzbekistan
Department of Practical Englishs, Fergana State University, Fergana, Uzbekistan
szokirova1987@gmail.com xasanovaozoda51@gmail.com , nanoshsober@gmail.com

Keywords: foreign language teaching, online classroom, error correction, language learner, verbal signs, non-verbal signs.

Abstract: Errors and their correction are the main components of foreign language lessons.Correcting errors in traditional offline lessons can be challenging for teachers, and correcting errors in online foreign language lessons requires even more skill. Foreign language teachers must be able to correct errors effectively in both types of lessons.This article aims to investigate effective techniques for correcting errors made by language learners in online foreign language classes.

1 INTRODUCTION

The intensification of the educational process is changing in harmony with today's rapidly developing society (Yeh, S., Lo, J. J., & Chu, H. M. 2014). Having the ability to speak a foreign language fluently and flawlessly has risen to the level of demand for every professional. The development of a methodology for improving the skills of future German language teachers in dealing with errors is also of urgent importance.

Errors related to analysis, evaluation and correction, and language learning are frequently discussed topics in the didactics of foreign language classes. On the one hand, the spectrum of views on errors shows that errors are harmful to language acquisition. However, it should be remembered that they are evaluated as a necessary component of the language learning process. The belief that "We learn from our mistakes" is often repeated by language learners.

We want to analyze some concepts related to error correction. The most commonly used concept of error correction is task-based error correction, which is different from exam-oriented error correction. In task-based error correction, the error serves as a relearning opportunity for language learners. For this reason, the focus of learning is on the process of learning and progress in learning, not on measuring the level of learning.

German scientist Wulf (2001) stated that correcting errors is very essential for effective communication in a foreign language classroom. However, there are different opinions among scientists regarding the usefulness of error correction in language acquisition. Some scientist agree with the usefulness of error correction, but some scientist do not.

Gerlach, a German teacher at the Goethe Institute in Munich, notes in her article that "...there is no other difficult headache topic for German language teachers than correcting the errors of language learners. There is no recipe for when and how to correct an error because it depends on various factors."

During each lesson, the foreign language teacher hears many sentences that are incorrect. These sentences should be immediately analyzed and corrected. While it may be easy to correct written errors on paper in offline lessons or on the blackboard

[a] https://orcid.org/0000-0002-4026-8509
[b] https://orcid.org/0000-0002-4026-8509
[c] https://orcid.org/0000-0003-4211-5423

in an online classroom, correcting oral errors in language lessons can cause stress not only for the teacher but also for the language learners.

This article discusses ways of error correction in foreign classrooms with online backgrounds.

2 MATERIALS AND METHODS

Gerlach notes that her language learners like encouraging their teachers to correct errors with the help of facial expressions and gestures. It is possible for language learners to organize the correction of each other's errors in the process of checking homework. If the answer recommended by language learner A is still not considered valid by learner B, the teacher can come to help. In addition, the teacher can assign an "ERROR COLLECTOR" for each lesson. During the lesson, the language learner writes down the errors made by other group mates, and at the end of the lesson, s/he corrects and eliminates the errors with her/himself or the teacher. In the plenary, all language learners will have the opportunity to learn about their errors. It is beneficial in online classrooms, too.

Li and Hu stated that online, face-to-face peer and teacher correction influences the accuracy, fluency of speaking, and academic passion of language learners (Li, X., & Hu, W. 2024.). According to them, error correction strategies significantly influence the speaking fluency of EFL learners. Using different correction approaches helps teachers to teach more effectively.

Bannò and Matassoni wrote about the features of using grammatical error correction in their research. According to them, grammatical error correction can help language learners to speak more fluently (Bannò, S., &Matassoni, M. 2024.). Studies on the topic of text-based grammatical error correction have received significant attention, too (Bryant, C., Felice, M., Briscoe, T., 2017; Bryant, C., Yuan, Z., Qorib, M.R., Cao, H., Ng, H.T., Briscoe, T., 2022, Knill, K., Gales, M. J. F., Manakul, P., & Caines, A. 2019).

Our observations showed that foreign language teachers in Uzbekistan often use direct correction to correct language learners' errors.

In direct error correction, correct the teacher learner's inaccuracy as soon as the learner makes it. For example:

Language learner: Mein Vater hat nach Berlin gefahren.

Teacher: Mein Vater ist nach Berlin gefahren.

In indirect error correction, the teacher offers language learners a way to correct errors communicatively. This situation can take the form of a question or an answer. In this case, the language learner will have the opportunity to correct his/her error. For example:

Language learner: Mein Vater hat nach Berlin gefahren.

Teacher:Wohin ist dein Vater gefahren?

In this case, the teacher does not directly say that the verb “fahren”is used with the auxiliary verb sein. If the language learner is attentive, s/he can quickly realize and correct his/her error. For example:

Language learner: Mein Vater hat nach Berlin gefahren.

Teacher:Wohin ist dein Vater gefahren?

Language learner: Ohh, ja. Mein Vater ist nach Berlin gefahren.

In our opinion, when errors are corrected indirectly, language learners are less likely to make the same error again.

In online foreign language classes, language learners can correct such errors using paralinguistic signs without stopping their answers. If the grammatical topic of the lesson is Perfekt/Perfect, and the teacher explained to language learners which verbs are used with the auxiliary verb "haben/to have" and which verbs are used with the auxiliary verb "sein/ to be" in Perfect at the beginning of the lesson, the teacher can correct the language learner’s errors during the exercise by using following actions. However, it is necessary to give language learners an understanding of what these signs mean.

Figure 1. Non-verbal signs to use error correction.

For example, the first sign can be used for the errors with "to have, "and the second one for the errors with "to be." Actually, such non-verbal signs are often used in traditional lessons, too. Next time, these signs can be used to correct other errors. The first sign is often used to remember verb position in sentences because it is like the letter V. When a teacher shows this sign, the language learner knows that s/he has an error in verb position. It is advantageous to use such signs because the language learner's answer does not stop in this case.

Today, the online platform HEMIS is used in almost all educational institutions in Uzbekistan. Through this online platform, teachers can accept students' independent work. In our opinion, correction of errors in independent works of students and to write feedback them is also important.

Here are some examples of how negative feedback can be turned into positive feedback:

Table 1: Turning negative feedback into positive.

Negative feedback	Positive feedback
Your text lacks structure at all.	You were required to focus on essential points, elaborate on given points, and pay attention to the boundaries between them.
...badly written.	You could write better!
You made many errors on this topic...	Next time, pay more attention to this topic!
We have learned this topic; you should have known that...	We have learned this topic with you; maybe you have an error here?
You did not pay attention to the task.	Try to read the task carefully next time.
You only used simple sentences.	Try to use more relaxed complex sentence constructions. This will make your text look better!

In the process of reading the given feedback, the language learner understands the same content, but both feedbacks affect them differently. For this reason, foreign language teachers should try to make the feedback given on written work as positive and constructive as possible.

Our observations also showed that many teachers limit themselves to grading online written works. As a comment, only words such as excellent, good, and average are written. In our opinion, it is appropriate that each error in the independent work submitted by the student should be analyzed in detail, and the feedback written to him/her should consist of at least five or six sentences. Of course, in this feedback, it is necessary to emphasize what the student did well and what his/her achievement was.

The use of blackboards in foreign language classes organized through ZOOM is very effective for error correction. For this, the teacher should provide everyone with the opportunity to use the blackboard. Students write their thoughts on the given assignment on the board. After completing the assignment, the teacher should analyze and correct the errors on the board. In the correction process, it is advisable to encourage students to find their errors and correct themselves.

After correcting the errors in the written work, it is advisable to rewrite the text, too. According to some German language teachers, a language learner should first check his/her own written work with a grammar book and a dictionary and find out which topic s/he makes the most errors in. After that, the subject of the error should be learned repeatedly if necessary. Of course, unclear parts can be asked of the teacher.

We used methods such as interviews, observations, and analysis in our research. Ten German language teachers of Fergana State University were selected for observation, and their attitudes towards errors encountered in the process of teaching the German language were studied. At the same time, their feedback on students' work on the HEMIS platform was analyzed. In addition, methods of correcting errors in additional online classes organized by them were determined.

Here are our research questions:

Which type of error correction do you often use in your online lessons?

How long do you write your feedback on the independent work of students on the HEMIS platform? Or do you give only a mark?

Do your students rewrite their work after your error correction?

3 RESULTS AND ANALYSIS

Which type of error correction do you use in your online lessons?

Almost all teachers participating in the research noted that they use direct and indirect correction methods in their online classes. However, our observations showed that teachers mostly use direct correction of errors. In our opinion, many teachers are used to correcting errors directly. Indirect correction of errors requires more time than direct correction from the teacher. That may be why teachers rarely use this method of correction. While answering this question, some teachers commented that errors are corrected less often in online classes than in traditional classes. According to them, correcting errors in online classes is a little more complicated.

How long do you write your feedback on the independent work of students on the HEMIS platform? Or do you give only marks?

Seven teachers answered this second question, saying that they were limited only to grading, and three teachers graded and wrote feedback. The teachers who recorded both grading and writing feedback were asked about the order of their written feedback. They pointed out that the feedback mainly describes the grade given, for example, a grade of 5 is very well written and a grade of 4 is well written and etc.

Do your students rewrite their work after your error correction?

It was observed that teachers check students' independent work in many cases and evaluate it based on its content and the number of errors. We have come to the conclusion that the fact that the students are not interested in what errors they have received such a grade is the reason why they do not correct the errors in their work and rewrite them. It was observed that only some students expressed their desire to re-submit independent works to the teacher if they were not satisfied with the grades they received.

4 DISCUSSION

Special importance should be attached to the process of correcting the sentences of language learners who do not have confidence in themselves. Correcting them in a negative tone or in a loud voice can cause them to not respond at all in the future. For example, if a language learner is speaking on the topic of his/her interests (for example, My Hobby), it is often observed that if his/her speech is interrupted or corrected, s/he prefers not to continue his/her speech but to limit him/herself to expressing his/her one interest. Speech splitting can be considered the most unpleasant type of error correction.

Language learners also like to be corrected after they finish their speech.

In our opinion, 5 to 10 minutes at the end of each lesson should be spent analyzing, discussing, and correcting errors made by language learners. Then, language learners will get used to it. In addition, language learners try to make fewer errors because they know that their errors will be noticed. The teacher should analyze and correct the errors of all language learners. In many cases, the error is related to the new topic and acquires the same character. In this case, the teacher should repeat the names of the language learners who have made the same error and tell them that they all have the same error so they can give them another explanation.

5 CONCLUSIONS

Constantly using feedback in the form of "good, but..." does not work well. It is advisable for the teacher to come up with various cards and small prizes so that the motivation of language learners does not fall.

Working with errors made by language learners should not be seen as a rebuke given by the teacher, but as a tool that serves to advance the learning process. It should be detailed and creative, and not only the teacher, the language learner should also participate in checking and correcting errors. If working with errors organized as an exchange of ideas among language learners, the result will be even better. In addition, students begin to acquire the skills of working with errors, which are necessary for future activities.

REFERENCES

Bannò, S., Matassoni, M., 2024. Back to grammar: Using grammatical error correction to automatically assess L2 speaking proficiency. *Speech Communication*, *157*, 103025.

Li, X., Hu, W., 2024. Peer versus teacher corrections through electronic learning communities and face-to-face classroom interactions and EFL learners’ passion for learning, speaking fluency, and accuracy. *Heliyon*, *10*(4), e25849.

Liu, X., 2024. Understanding the development and implementation of teachers’ beliefs of written corrective feedback: A study of two novice transborder teachers in mainland China. *Teaching and Teacher Education*, *142*, 104519.

Yeh, S., Lo, J. J., Chu, H. M., 2014. Application of online annotations to develop a web-based Error Correction Practice System for English writing instruction. *System (Linköping)*, *47*, 39–52.

Bryant, C., Felice, M., Briscoe, T., 2017. Automatic annotation and evaluation of error types for grammatical error correction. In *Proceedings of the 55th Annual Meeting of the Association for Computational Linguistics*.

Bryant, C., Zheng, Y., Qorib, M. R., Cao, H., Ng, H. T., Briscoe, T., 2023. Grammatical Error Correction: A survey of the state of the art. *Computational Linguistics - Association for Computational Linguistics (Print)*, 1–59.

Gerlach, F., 2024. *Korrekturmodus im DAF Unterricht*. Goethe Institut.

Knill, K., Gales, M. J. F., Manakul, P., Caines, A., 2019. *Automatic Grammatical error detection of non-native spoken learner English*.

Lu, Y., Bannò, S., Gales, M. J. F., 2022. *On assessing and developing spoken 'Grammatical Error Correction' systems*.

Wulf, H., 2001. Communicative Teacher Talk: VorschlägezueinereffektivenUnterrichtssprache. *Hueber*.

Havranek, G., 2002. When is corrective feedback most likely to succeed? *International Journal of Educational Research*, *37*(3–4), 255–270.

Electric Pylon Detection in Various Environmental Conditions Through High-Resolution Satellite Images

Natalia Denisenko[1] [1], Dmitrii Shadrin[2] [2] and Svetlana Illarionova[2] [3]
[1]*Northwestern university, 633 Clark St, Evanston, Illinois, USA*
[2]*Skolkovo Institute of Science and Technology, 143026, Bolshoy Bulvar 42, bldg. 1, Skolkovo, Moscow, Russia*
d.shadrin@skoltech.ru, s.illarionova@skoltech.ru

Keywords: Object detection; satellite imagery; augmentation; computer vision.

Abstract: Earth remote sensing data can be applied to detect and assess the condition of infrastructure objects on vast territories. One such object is electric pylons, which ensure the sustainability of the energy supply in rural and urban areas. In some remote regions, power lines can be damaged by natural hazards such as earthquakes, strong winds, or floods. Currently, the main limitation in developing highly effective algorithms for electric utilities assessment is associated with data availability and diverse environmental conditions. Therefore, in this study, we aim to explore solutions for new study territories with various backgrounds and forms of electric pylons. We examined several detection algorithms from the YOLO-family. The study includes experiments with datasets for Chinese territories and additionally collected data for regions in Russia. We managed to improve the initial score for polygon detection, achieving an mAP of 79.8%. The obtained results demonstrate high potential for power lines assessment and damage detection through satellite data and deep learning algorithms.

1 INTRODUCTION

Object detection is a fundamental task involving the localization and classification of objects within an image. This diverse field can be categorized into two distinct subtypes: object-centric and non-object-centric. The former involves data in which each image contains a single object, whereas the latter deals with instances in which multiple objects may be included in a single image. There are a broad number of datasets within the first category such as MNIST (MNIST, 2019) and ImageNet (ImageNet 2017). Contrariwise, non-object-centric datasets, typified by the widely recognized COCO (COCO, 2021), often feature backgrounds alongside multiple objects belonging to predefined classes. It could be noted that all these datasets commonly exhibit a balanced ratio of background to object, with objects captured at the average height of a person. Datasets that differ in these aspects, for example, those that consist of fine-grained objects, are less common. These datasets consist of data taken from satellites or airplanes and in addition, stand out due to the presence of both types of data: with a single object or even none and with an abundance of objects on a single image. Furthermore, these objects typically occupy a small fraction of the total image space in comparison to the background (Illarionova S. et al., 2021 a).

Remote sensing datasets hold a significant role in the detection of damage resulting from natural and anthropogenic disasters (Shadrin D. et al., 2024). Electric pylons are an important part of infrastructure that ensures the sustainability of the economy in regions. However, they can be damaged by earthquakes or strong winds. The rapid and accurate assessment of the electric utilities and its possible damages can be performed using remote sensing data and machine learning techniques (Illarionova S., 2022). A number of papers have been dedicated to the topic of pylon detection in satellite-collected data, such as (Xiaoling L., 2021), (Ou W., 2019), and (Tian G,, 2020). However, the task of electric pylon detection presents challenges, primarily stemming from the limitations of available open-source datasets. This absence not only poses challenges related to dataset diversity but also exacerbates the

[1] https://orcid.org/0000-0002-9719-2461
[2] https://orcid.org/0000-0003-3486-8214
[3] https://orcid.org/0000-0003-2448-9907

complexities associated with the varied nature of different regions within the Russian Federation.

This study focuses on augmentations and models designed to improve performance on datasets with fine-grained attributes, with a particular focus on the Electric Pylon Detection (EPD) dataset introduced in (Sijia Q., 2020).

In this study, we accomplished the objective of detecting pylons within the Russian territory utilizing data from sensors with varying resolutions. Through training on the initial dataset, our approach demonstrated robust pylon detection capabilities which we then further improved with the implementation of the augmentation method contributing to enhanced accuracy and effectiveness in the pylon detection task.

2 RELATED WORKS

2.1 Field Overview

In this study, we focus on remote sensing data. The basic example of such a dataset was presented in (David N., 2021). It is the dataset from the MNIST family distinguishing feature of which is lack of background. The lack of diversity in classes is another of its drawbacks. Later the same year another aerial dataset was introduced in the paper (Xian S., 2021). The authors of FAIR1M have done an outstanding job of gathering data from multiple sources including Google Earth and one of the Chinese satellites. All data was marked up into 37 classes of different types of vehicles and geographical structures and compiled into one uniform format. The main advantage compared to other datasets is the number of instances and diversity of classes. The detriment of this dataset is the strong dispersion of data. Previous to that, another work on this field was presented in the paper (Gui-Song X., 2017). The authors introduced a dataset for aerial detection, data was collected from different sources and was marked up into 15 categories. But in order to narrow the research field, we decided to work with the EPD dataset (Sijia Q. 2020), - a dataset that consists of aerial imagery containing pylons.

2.2 Initial Dataset

The EPD dataset was presented in the (Sijia Q., 2020) article alongside the result of comparison of multiple computer vision models. The dataset contains 1450 images for training purposes and an additional 50 for validation. Images were collected from two main sources - Google Earth and the Pleiades satellite. Images from the latter source are orthoimages, while images from the former are multispectral products acquired by various sensors. The ability of deep learning detectors to generalize will be tested using such multi-source data. Another difficulty occurs due to the great variety in sizes and shapes of pylons as well as other factors like differences in colors and the variety in the angle of observation.

2.3 Models

Models used for the task of object detection usually belong to the supervised learning category, where labeled data is used. As a result, algorithms should return the classes of all objects and the coordinates of their bounding boxes. The problem occurs in the length of an output layer as it is not constant therefore we can not preset the number of objects we expect to find. The possible solution is to choose multiple regions in which we expect to discover an object, however, the number of them could be exceedingly large. Multiple models were developed to overcome this.

The authors of (Ross G., 2014) proposed a method that firstly searches for 2000 regions of an image that presumably contains an object; later those areas are sent to the CNN model to extract features and build a prediction on the presence of an object in it. Although this algorithm reduces the number of regions of interest, it still suggests 2000 of them, therefore it takes a long time to make a prediction. Based on the drawbacks of previous work, one of the authors introduced an improved method in (Ross G., 2015). The main advantage of that work is in the processing of proposed regions, it allows convolution operation once per image rather than for every area separately. In the next work (Shaoqing R., 2016), the authors managed to improve another part of the algorithm. The use of selective search used to go through possible regions was time-consuming, so the authors managed to eliminate it, instead, they used a separate network to predict regions of interest.

All previous works had two parts: searching for the regions and then predicting using them. The paper (Joseph R., 2016) contains a method that uses a single CNN to find bounding boxes and category probabilities. This algorithm works significantly faster than other methods but it is known for having problems with detecting small objects within an image. Other attempts to improve existing algorithms were made.

RetinaNet introduced in (RetinaNet, 2018) improves results on small-scaled objects. It features two novelties introduced in (Tsung-Yi L. Piotr D., 2017) and (Tsung-Yi L., Priya G., 2017). The algorithm from the former article is used in the feature extraction and the focal-loss that was presented in the latter one is used as a solution for the class imbalance in the target prediction. Focal loss resolves the problem that appears due to an imbalance in the background and the foreground. It prevents the detector from being overwhelmed by an exceedingly large number of easy negatives. As a feature extractor, RetinaNet uses ResNet (Kaiming H., 2015) with 101 layers as it is a quite new network with great results in various object detection tasks. Overall this model performs well and belongs to the class of one-stage detectors as it requires just one pass through the network to extract features and make a classification. The difference between one-staged and two-staged detectors can also be seen in Figure 1.

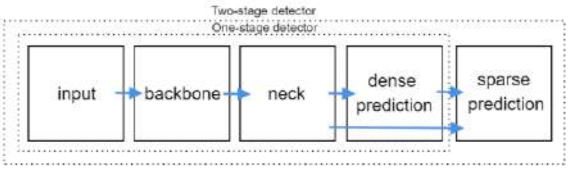


Figure 1: Object detector.

Trained on COCO, RetinaNet has advantages in the metrics compared to the third version of YOLO, however, it can not make multiple predictions simultaneously. The latter model is also a one-stage detector but it uses Darknet-53 (Joseph R., 2013-2016) for feature extraction. Darknet-53 is composed of multiple blocks that contain two convolution modules 1x1 and 3x3 after which comes one residual module, overall, it has 53 convolutional layers. Also, its convolution module consists of Conv2d, BatchNormalization, and leaky ReLU layers. Input images are passed five times through downsampling. Furthermore, it uses the idea of multi-scale features presented in (Tsung-Yi L., Piotr D., 2017). YOLOv3 (Joseph R., 2018) uses the bag of freebies and the bag of specials to improve the algorithm's performance.

The bag of freebies includes

- Complete IoU loss (CIOU)
- Drop block regularization
- Several augmentation approaches

The bag of specials

- Mish activation
- Diou-NMS
- Modified path aggregation networks

As for the performance of the YOLOv3, it could be noticed that the detection of small objects improved compared to the previous versions of YOLO. At the same time, it has comparatively worse results on medium and large object detection.

Another YOLO version was proposed in YOLOv4 (Alexey B., 2020) by a different author. Improvements were made in the architecture of the model itself and in the feature extraction module. The fourth version's backbone consists of CSPDarknet53 (Chien-Yao W., 2019) over the Darknet-53 in its predecessor. The former addresses the repeating gradient information in big backbones and integrates gradient change into a feature map, which improves inference speed, and accuracy, and reduces the model size by decreasing the number of parameters. SPP (Kaiming He, 2014) and PANet (Shu L, 2018), which adopt FPN, were used afterward in order to increase the receptive field of the feature extractor module and simultaneously shorten its important features. Similar to the third version, the fourth uses the bag of freebies and the bag of specials. Also, a new method was utilized - Mosaic augmentation which expands data by combining 4 images in a 2x2 grid. Furthermore, several methods were improved in order to adapt training to the usage of a single GPU.

Compared to the YOLOv4 the YOLOv5 (YOLOv5, 2020) abandons the previously utilized SSP. At the same time, it introduces back the Focus layer from YOLOv3 and improves it by replacing the first three layers with just a single one. Similar to the third and the fourth versions it also generates three output of feature maps that helps to achieve multi-scale predictions.

2.4 Augmentations

Nevertheless, all of the presented algorithms use a lot of data during training which is a major drawback in the areas that are resource-consuming when it comes to data collection.

Due to demand in the size of data used for training, overfitting or inability to generalize is a possible outcome. At the same time, data acquisition is a costly process, therefore, improving quality using smaller datasets is a desirable goal. Traditional methods of data augmentation are used to diversify data (Nesteruk S., 2024). Due to the properties of the researched dataset such as a few objects on an image, methods of augmentation that replenish a number of them could be used. There are several possible approaches. The simplest one concludes by taking a copy of the area within the bounding box and placing it in the other place of an image without any processing (Ghiasi, G., 2021). That could be not applicable if the background of the new place significantly differs from the original location. In this case, other algorithms could be used in order to seamlessly blend objects into the new position. There are different methods to achieve these results. Library REMBG introduced in (Daniel G., 2020) is one of them. It works well in the case of medium and large objects. It also demonstrates a great performance when the background and the foreground are clearly distinct. When the object of detection is small, REMBG performance deteriorates significantly. All the examples described can be seen in Figure 2.

(a) the result of rembg on an image of a pylon

(b) the result of rembg on images of oranges on the floor

Figure 2: The results on the oranges imitate the expected results on the images of the pylon.

Another method of augmentation based on background blending was introduced in (Hilmi K., 2020). It proposes a two-staged method consisting of training and augmentation.

The first stage entails separate training of a generative network and a detector network. Patches of images are being fed to both models since the main goal of this method is to generate a new instance on a small patch of an original image. Similarly, the detector network is trained to be able to separate the generated samples from the original ones.

The second stage involves augmentation based on the previously trained generative network. Afterward, the results are sent to the detector to determine whether or not they are feasible. Eventually, samples that pass the detector are collected in the augmented set.

The remote sensing domain poses additional challenges in data processing. Therefore, the advanced augmentation algorithms are proposed to address these challenges by combining multispectral information (Illarionova S., 2021 b) or integrate the spatial properties of the studied environment (Dolgaia L., 2023).

3 METHODOLOGY

3.1 The Collected Dataset

Based on our research, there is a lack of openly available datasets containing satellite images and information on electrical pylons in Russia that can be directly used for machine learning model development. Therefore, we collected a special dataset and created annotations. For this reason, we chose to use the software QGIS (QGIS, 2022), which allows users to upload multiple different maps and obtain aerial photographs from them. For the maps, we settled on the Google Earth map since it appears to be the most accurate and also offers multiple resolutions. We chose to collect data from several districts because Russia's size results in radically varying conditions of biomes. Nonetheless, to simplify the task we have limited seasons to spring, summer, and the beginning of autumn.

We utilized Roboflow (RoboFlow, 2020) to annotate the photographs after they were collected. Most of the models we were working with use the Yolo format and this website allows users to easily process large quantities of data and save them in this format. Another great feature is that it also allows you to preprocess and augment images beforehand. As a result, using the data obtained from that website becomes rather simple and straightforward.

It is known that there is a large spectrum of different types of pylons and we decided not to handle some of them. Examples of used and unused pylons can be found in Figure 3.

3.2 Models Overview

We conducted experiments with the following models: YOLOv3 (Joseph R., 2018), YOLOv4 (Alexey B., 2020), and YOLOv5 (YOLOv5, 2020). The EPD dataset (Sijia Q., 2020) was used for the training. For the inference, we collected samples containing pylons on the territory of Russia using QGIS tools.

(a) Annotated pylons

(b) Poles skipped during annotation

Figure 3: Examples of different types of pylons.

3.2.1 YOLOv4

The implementation YOLOv4 is from the official GitHub repository (Alexey B., 2020). The configuration file was changed according to the information from the research (Sijia Q., 2020). There are some differences in the used terms between the model and the article, as the latter states that the batch size should be 4, and the whole number of epochs should be 25. At the same time, the model takes a number of iterations therefore, there should be (1450 /4) * 25 ~ 9063 iterations. According to the information in the article, other changes in the original configuration file include:

- the sizes of anchors should be changed to (26, 22, 30, 41, 35, 60, 45, 29, 47, 48, 61, 86, 63, 35, 88, 55, 168, 140)
- parameter “random” should be set to 0
- there should be 500 iterations of warm-up
- parameters “momentum” should be set to 0.9
- learning rate should be set as 0.0125
- on epochs 20 and 23 (7250 and 8338 iterations respectively) learning rate should be decreased by 10

However, these parameters lead to an almost immediate explosion of loss in the first few iterations. Multiple experiments were conducted to determine the cause. In the end, it was identified that the learning rate from the article - 0.0125, is not optimal for the current model. Multiple possible changes were tested, and the learning rate with the number of warm-up iterations was the main focus. It was decided to use lr = 0.0015625 and warm-up = 500 since this initialization leads to better results in the metric on the validation.

3.2.2 YOLOv3

YOLOv3 has some similarities in configuration to the fourth version. For example, the same sizes for anchors were used (26, 22, 30, 41, 35, 60, 45, 29, 47, 48, 61, 86, 63, 35, 88, 55, 168, 140). At the same time, some new parameters are also presented, such as =0.8 and =1.0 used in the focal loss. Other changes include:

- batch size set to 16
- the total number of epochs to 20 (1813 iterations)
- the learning of 0.01
- momentum should be set to 0.9
- on epochs 16 and 18 (1450 and 1632 iterations respectively) learning rate should be decreased by 10
- warm-up should be removed (set to 0 iterations)

Similar to the previous model, these parameters also lead to the explosion of the loss, therefore, it was decided to use the learning rate from the official EPD repository (Sijia Q., 2022). We conducted additional experiments on that parameter. The final configuration includes lr = 0.000625, the model trained with this parameter leads to the best results we could achieve on YOLOv3 architecture.

3.2.3 YOLOv5

YOLOv5’s implementation differs from the previous versions as it was written on PyTorch. Initially, the only change made to the original configuration file was to decrease the learning rate to 0.001 from 0.01 as it was the main improvement made in the fourth and third versions of YOLO.

3.2.4 YOLOv5 evolution

One of the advantages of the fifth version over the previous is that it has an implemented hyperparameter evolution. This method optimizes parameters using genetic algorithms. About 25 parameters are employed in YOLOv5 for various training settings. Even when using the evolution method for parameter optimization it is quite important to initialize them with viable values. After evolution, the best results were achieved using these parameters:

- lr0 should be set to 0.01 and lrf to 0.02

- momentum and weight decay used in an optimizer should be 0.937 and 0.0005 respectively
- there should be 5 epochs for warmup
- HSV saturation augmentation should be set to 0.7, value augmentation to 0.3, and HSV augmentation in hue to 0.015
- set focal loss gamma as 0
- set probability of scale, shear, rotation, and translation augmentations as 0
- set IoU training threshold to 0.2
- set probability of mosaic and mixup augmentations to 1 and 0 respectively
- set probability of flipping image up-down to 0.3, and for left-right to 0.5
- scale augmentation should be set to 0.7

(a) EPD pylons (collected from the territory of China)

(b) Our pylons (collected from the territory of Russia)

Figure 4: Comparison of pylons from China and Russia.

3.3 Augmentation

We can compare the types of pylons from China and Russia, as shown in Figure 4. It is evident that they exhibit significant differences, with some shapes being notably distinct from those found in the other country. Unfortunately, there is insufficient accurate data available to train a model for pylon detection using Russian data. However, we were able to obtain a sufficient amount of similar data from China, with a larger number of collected and annotated objects.

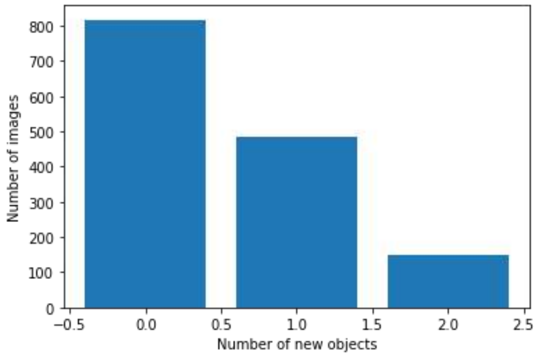


Figure 5: Distribution of the number of new objects.

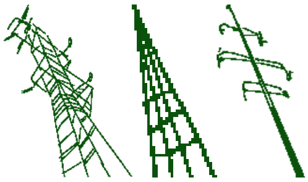
Therefore, we propose an augmentation strategy that would integrate some of our data into the already collected dataset. Firstly, we separated 5 images from our dataset, since some parts of these images are going to be used in augmentation we removed them from validation as, otherwise, it could compromise the results. Using these 5 images, we collected 12 shadows from those images and outlined them by hand (you can see an example in Figure 7). For augmentation, we used all objects from the EPD train dataset (EPD dataset-S), number of new objects that are going to be added to an image is a random number from 0 to 2, where the probability for 0 is ~55%, for 1 - ~33%, and for 2 - ~11%. The distribution of the number of new objects can be found in Figure 5.

Augmentation algorithm

```
for image in train dataset do:
    number of new images ← random(0, 0, 0, 0, 0, 1, 1, 1, 2)
    new labels ← image_labels
    while number of new images ≠ 0 do
        number of new images ← number of new images − 1

        new object ← random(image_bounding boxes)
        new shadow ← resize shadow(random(collected shadows),
            new object)

        new object location ← get vacant location(new object, image)
        new labels ← {new labels} ∪ {new object location}

        shadow direction ← random(north, east, south, west)
        new shadow location ← get shadow location(new shadow,
            shadow direction, new object, new object location, image)

        image ← paste region(image, new object, new object location,
            blend_mode=normal)
        image ← paste region(image, new shadow, new shadow location,
            blend_mode=multiply)
    end while
    save image to the new location
    save new labels to the new location
end for
```

Figure 6: Augmentation algorithm.

For every new object, one of the ground truth boxes in an image is chosen, copied, and pasted into the new place. A shadow is chosen randomly and resized to match the size of the object. The direction of the shadow is chosen randomly from north, east, south, and west. The shadow is pasted on top of an image as on a layer with multiply types. The pseudocode for that segment can be found in Figure 6. The examples of shadows and results of augmentation can be found in Figure 7.



(a) Examples of masks used for augmentation

(b) Original and Augmented images

Figure 7: Augmentation examples.

The numbers of images and objects in datasets can be found in Table 1.

Table 1: Dataset statistics.

	EPD **Train**	**EPD** **Augmented**	**EPD** **Validation**	**Our** **Validation**
Number of Objects	3072	3854	159	72
Number of Images	1450	1450	50	26

YOLOv5 was trained using augmented data. Hyperparameters were left the same as stated in the previous section.

3.4 Training on Half of the Data

Experiments on the number of images used during the training were conducted. We chose 725 images from the initial EPD dataset and used them to train the model with parameters from our initial run of YOLOv5. At the same time, augmented counterparts of the chosen images were used to train another YOLOv5 model with the same parameters.

3.5 Evaluation Metrics

As a criterion of comparison between different models and training setups, we used mAP which is calculated as the area under the Precision-Recall curve. By definition:

$$Precision = \frac{TruePositive}{TruePositive + TrueNegative}$$

$$Recall = \frac{TruePositive}{TruePositive + FalseNegative}$$

Since the predictions of object detection cannot be easily separated into groups of TruePositives, TrueNegatives, FalsePositives, and FalseNegatives, we used Intersection over union (IoU) threshold to distribute them. It is calculated as follows:

$$IoU = \frac{AreaOfOverlap}{AreaOfUnion}$$

Here areas of overlap and areas of the union are calculated based on pair of ground truth and predicted bounding boxes. The closer IoU to 1 the closest prediction to the ground truth, therefore, based on the threshold we can classify whether a prediction is a TruePositive or a FalsePositive. In this case, we also can simplify precision for the task of object detection as follows:

$$Precision = \frac{TruePositive}{NumberOfPredictions}$$

To calculate mAP, we should separate classes under consideration, for each of the predictions should be sorted based on probabilities, we need to calculate the precision and recall of each prediction, we can calculate average precision (AP) for a class as follows:

$$AP = \sum_{i=0}^{n-1} \Big(Recall_i - Recall_{i+1} \Big) * Precision_i$$

Here n is a number of predictions. The mAP metric is defined:

$$mAP = \frac{1}{c} \sum_{i=1}^{c} AP_i$$

Here c is a number of classes and APi is an average precision of class i. The best parameters for the models are chosen based on the introduced metrics.

(a) Ground Truth (b) Yolov4 Predictions

(c) Yolov3 Predictions (d) Yolov5 Predictions

Figure 8: Examples of prediction with different models.

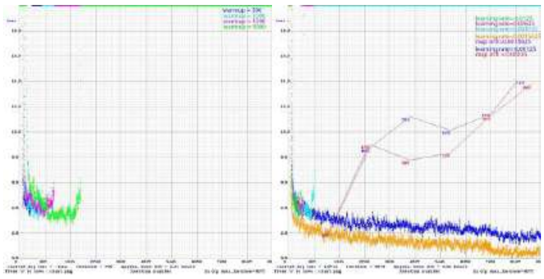
4 RESULTS AND DISCUSSION

To evaluate the quality of detection, we used the mAP metric which stands for mean average precision for the class of pylons. The results were compared to methods introduced in the initial article on the EPD Dataset, to ensure that our results could compete with existing works. Multiple experiments were conducted for each model.

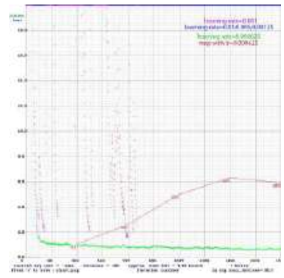
We were able to determine the cause of the loss explosion during the training of YOLOv4. Multiple approaches have been tested, and the results of them can be found in Figure 9a and Figure 9b. The usage of our configuration leads to better results than those presented in the original article. We managed to get to 70.72 percent by comparison to 65. An example of the prediction using our additional collected data is shown in Figure 8b.

Our results on YOLOv3 were not as good. The loss value on the training dataset and the final result on the validation dataset of this model are shown in Figure 9c. More experiments should be conducted to improve the results. At the current stage, the accuracy of the original validation and on our data that this model produces is the lowest among all the results we achieved. An example of the prediction on our data can be found in Figure 8c.

YOLOv5 was tested most thoroughly. Without any major configuration changes, the model was able to achieve the best results on validation - 79,8% mAP. The training chart is shown in Figure 10a and the prediction on our data is shown in Figure 8d.



(a) Loss charts with different warm-up iterations YOLOv4 (b) Loss charts with different learning rate values YOLOv4



(c) Loss charts with different learning rate values YOLOv3

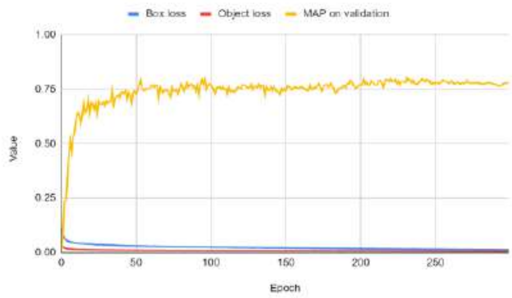
Figure 9: Training with different hyperparameters.

Evolution was used in order to optimize hyperparameters. It leads to slightly worse results on validation and significantly worse results on our data training chart of training can be found in Figure 10b.

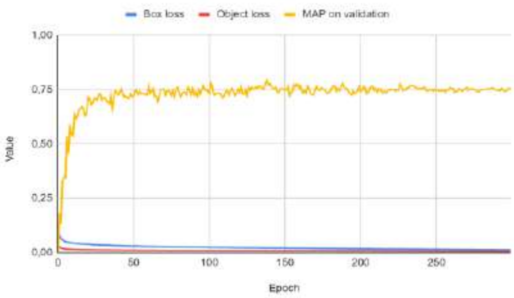
Table 2: mAP results with IoU threshold 0.5.

	EPD Train	**EPD** Validation	**Our** data
YOLOv4	92.30%	70.72%	44.88%
YOLOv3	47.20%	30.20%	15.30%
YOLOv5	99.50%	79.80%	45.20%
YOLOv5 after evolution	99.50%	76%	39.60%

All mAP results and comparisons between initial models are shown in Table 2. It should be noted that the results of YOLOv5 model on train data could be interpreted as overfitting. Therefore, for further improvement, we have implemented data augmentation to diversify existing training data.



(a) YOLOv5 training results without evolution



(b) YOLOv5 training results after evolution on initial hyperparameters

Figure 10: Training results.

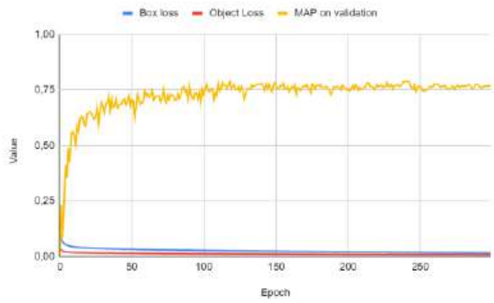
YOLOv5 was trained using augmented data. In comparison to previous results of evolution, this model achieves slightly worse results on validation - 75,4% but better results on our additional collected data - 41.5%. Also, in Figure 11a, a higher train loss is achieved but mAP on the training dataset stays almost the same - 99.4%.

Experiments on the amount of data used in training show a positive contribution of the augmentation in the results on our additional data. Training charts of models trained on original and augmented data are shown in Figure 11b and Figure 11c.

Table 3: Results of training on the half of the dataset.

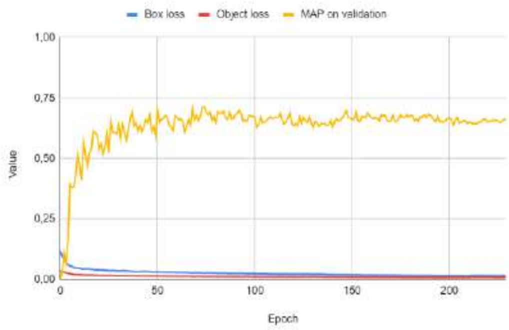
	EPD Train	**EPD** Validation	**Our** data
YOLOv5 trained on original dataset	99.5%	75.4%	37.2%
YOLOv5 trained on augmented dataset	97.3%	71.2%	39.9%

The training results are presented in Table 3. It is shown that our model trained on the augmented data produces better results on our data. However, it should be noted that at the same time, it loses some precision on the original validation dataset.



(a) YOLOv5 trained on augmented data

(b) YOLOv5 training on half of the original data



(c) YOLOv5 training on half of the augmented data

Figure 11: Additional training results.

We managed to surpass the original results. The best results were achieved using the YOLOv5 model and trained on the EPD dataset with the result of 79,8% and 45,2% on the original and our datasets respectively. Evolution was used to further improve results on YOLOv5.

In order to mitigate overfitting and improve results on our data, we implemented augmentation that was used to diversify training data. Model, trained on the augmented dataset, was able to outperform YOLOv5 after evolution.

Experiments with the quantity of information utilized in training show that our augmentation leads to improvement in the results on our dataset.

We were able to achieve our goal of being able to detect pylons on the territory of Russia, collected using sensors of different resolutions, after training on the initial dataset. And also we were able to implement augmentation that aids tested models to produce better results on the collected dataset.

5 CONCLUSION

In this paper, we integrated existing methods to detect objects collected within the territory of Russia. Most studies on object detection assume that the objects in images occupy significant space and that all data has the same resolution. Building upon these observations, we aimed to enhance the accuracy of object detection on the EPD dataset, which contains images from various sources and often has an excessive amount of background compared to the area occupied by objects. This task could be instrumental for future advancements in object detection. Furthermore, this research could facilitate monitoring the number of pylons in extremely windy areas to identify any that may have fallen due to weather conditions and require maintenance.

ACKNOWLEDGEMENTS

The work was supported by the Russian Science Foundation (Project No. 23-71-01122).

REFERENCES

Xian, S., Peijin, W., Zhiyuan, Y., Feng, X., Ruiping, W., Wenhui, D., Jin, C., Jihao, L., Yingchao, F., Tao, X., Martin, W., Stefan, H., Cheng, W., Kun, F., 2021. FAIR1M: A Benchmark Dataset for Fine-grained Object Recognition in High-Resolution Remote Sensing Imagery. In *arxiv: 2103.05569.*

David, N., Samantha, E. Miller, N., 2021. MNIST: A Benchmark Satellite Dataset. In *arxiv: 2102.04266.*

Gui-Song, X., Xiang, B., Jian, D., Zhen, Z., Serge, B., Jiebo, L., Mihai, D., Marcello, P., Liangpei, Z., 2018. DOTA: A Large-scale Dataset for Object Detection in Aerial Images. In CVPR 2018.

YOLOv5 Accessed on: Jan. 23, 2022. [Online]. Available: https://github.com/ultralytics/yolov5

Zheng G., Songtao L., Feng W., Zeming L., Jian S., 2021. YOLOX: Exceeding YOLO Series in 2021. In arxiv: 2107.08430.

RetinaNetAccessed on: Jan. 3, 2022. [Online]. Available: https://github.com/yhenon/pytorch-retinanet

Shaoqing, R., Kaiming, H., Ross, G., Jian, S., 2016. Faster R-CNN: Towards Real Time Object Detection with Region Proposal Networks. In IEEE Trans. Pattern Anal. Mach. Intell. 39(6).

Zhaowei, C., Nuno, V., 2018. Cascade R-CNN: Delving into High Quality Object Detection. In CVPR 2018.

Wouter Van, G., Simon, V., Stamatios, G., Luc Van, G, 2021. Unsupervised Semantic Segmentation by Contrasting Object Mask Proposals. In ICCV 2021.

Daniel G, 2020. Rembg. Accessed on: Feb. 10, 2022. Available online: https://github.com/danielgatis/rembg

Hilmi, K., Cihan, ˙O., Alptekin, T, 2020. Data Augmentation for Vehicle Detection in Aerial Images. In ICPR Workshops (8)

2019 MNIST. Accessed on: Feb. 20, 2022. Available online: https://deepai.org/dataset/mnist

2017 ImageNet. Accessed on: Feb. 20, 2022. Available online: image-net.org/download.php

2021 COCO. Accessed on: Feb. 20, 2022.a Available online: https://cocodataset.org/home

Joseph, R., Santosh, D., Ross, G., Ali, F, 2016. You Only Look Once: Unified, Real-Time Object Detection. In CVPR 2016

Ross, G., Jeff, D., Trevor, D., Jitendra, M, 2014. Rich feature hierarchies for accurate object detection and semantic segmentation. In CVPR 2014:

Ross, G, 2015 Fast R-CNN. In ICCV 2015.

Tsung-Yi, L., Piotr, D., Ross, G., Kaiming, H., Bharath, H., Serge, B, 2017. Feature Pyramid Networks for Object Detection. In CVPR 2017

Tsung-Yi, L., Priya, G., Ross, G., Kaiming, H., Piotr, D, 2017. Focal Loss for Dense Object Detection. In ICCV 2017

"torchvision.transform" Accessed on: Feb. 12, 2022. Available-online: https://pytorch.org/vision/stable/transforms.http

Irvin, J., Sheng, H., Ramachandran, N., Johnson-Yu, S., Zhou, Sh., Story, K., Rustowicz, R, Elsworth, C., Austin, K., Ng, Y., 2020. ForestNet: Classifying Drivers of Deforestation in Indonesia using Deep Learning on Satellite Imagery. In arxiv: 2011.05479. 2020

Liang, D., Geng, Q., Wei, Z., Vorontsov, D. A., Kim, E.L., Wei, M., Zhou, H., 2021. Anchor Retouching via

Model Interaction for Robust Object Detection in Aerial Images, In arxiv:2112.06701 2021

Qiao, S., Sun, Y., Zhang, H., 2020. Deep Learning Based Electric Pylon Detection in Remote Sensing Images. In Remote. Sens.

He, K., Zhang, X., Ren, Sh., Sun, J., 2016. Deep Residual Learning for Image Recognition. In CVPR 2016.

Darknet. J.R., 2022. Accessed on: Feb 11 2022. Available online: http://pjreddie.com/darknet/

Misra, D., 2019. Mish: A self regularized nonmonotonic neural activation function. In arXiv: 1908.08681

Zheng, Zh., Wang, P., Liu, W., Li, J., Ye, R., Ren, D., 2020. Distance-IoU Loss: Faster and better learning for bounding box regression. In AAAI 2020

Bochkovskiy, A., Wang, Ch.-Y., Liao, H.-Y. M., 2020. YOLOv4: Optimal Speed and Accuracy of Object Detection. In arXiv: 2004.10934

Wang, Ch.-Y., Liao, H.-Y. M., Wu, Y.-H., Chen, P.-Ya., Hsieh, J.-W., Yeh, I-H., 2019. CSPNet: A new backbone that can enhance learning capability of cnn. In arXiv: 1911.11929

He, K., Zhang, X., Ren, Sh., Sun, J., 2014. Spatial pyramid pooling in deep convolutional networks for visual recognition. In ECCV (3) 2014

Liu, Sh., Qi, L., Qin, H., Shi, J., Jia, J., 2018. Path Aggregation Network for Instance Segmentation. In CVPR 2018

Redmon, J., 2022. YOLOv5. Accessed on: Apr 24. Available online: github.com/ultralytics/yolov5

Redmon, J., Farhadi., A., 2018. YOLOv3: An Incremental Improvement. In arXiv: 1804.02767

Bochkovskiy, A., Darknet repository, Accessed on: Apr 24, 2022. Available online: github.com/AlexeyAB/darknet

Qiao, S., Sun, Y., Zhang, H., 2022. Electric Pylon Detection in RSI. Accessed on: Apr 24, 2022. Available-online: //github.com/qsjxyz/Electric-Pylon-Detection-in-RSI

QGIS: A Free and Open Source Geographic Information System, Accessed on: Apr 24, 2022. Available online: https://qgis.org/en/site/

Roboflow. Accessed on: Apr 24, 2022. Available online:https://roboflow.com

Xiaoling, L., Chen, J., Qiu, X., 2021. A Pylon Detection Method Based on Faster R-CNN in High-Resolution SAR Images. In APSAR.

Ou, W., Yang, Z., Zhao, B., Fei, X., Ma, X., Yang, G., 2019. Research on Automatic Extraction Technology of Power Transmission Tower Based on SAR Image and Deep Learning Technology. In ICISCE.

Guishen, T., Song, M., Xuejiao, B., Lijuan, L., Yang, Zh., Wenhao, O., Xiangze F., Yuanpeng, T., 2020. Electric Tower Target Identification Based on High-resolution SAR Image and Deep Learning, In Journal of Physics: Conference Series

Illarionova, S., Nesteruk, S., Shadrin, D., Ignatiev, V., Pukalchik, M., Oseledets, I., 2021. Object-based augmentation for building semantic segmentation: Ventura and santa rosa case study. In Proceedings of the IEEE/CVF International Conference on Computer Vision (pp. 1659-1668).

Illarionova, S., Nesteruk, S., Shadrin, D., Ignatiev, V., Pukalchik, M., Oseledets, I., 2021. MixChannel: Advanced augmentation for multispectral satellite images. Remote Sensing, 13(11), 2181.

Shadrin, D., Illarionova, S., Gubanov, F., Evteeva, K., Mironenko, M., Levchunets, I., Burnaev, E., 2024. Wildfire spreading prediction using multimodal data and deep neural network approach. Scientific Reports, 14(1), 1-17.

Ghiasi, G., Cui, Y., Srinivas, A., Qian, R., Lin, T. Y., Cubuk, E. D., Zoph, B., 2021. Simple copy-paste is a strong data augmentation method for instance segmentation. In Proceedings of the IEEE/CVF conference on computer vision and pattern recognition (pp. 2918-2928).

Nesteruk, S., Illarionova, S., Somov, A., 2016. Image Dataset Augmentation A Survey and Taxonomy. Measurements and Instrumentation for Machine Vision, 110-136.

Dolgaia, L., Illarionova, S., Nesteruk, S., Krivolapov, I., Baldycheva, A., Somov, A., Shadrin, D., 2023. Apple Tree Health Recognition Through the Application of Transfer Learning for UAV Imagery. In 2023 IEEE 28th International Conference on Emerging Technologies and Factory Automation (ETFA) (pp. 1-8). IEEE.

Illarionova, S., Shadrin, D., Ignatiev, V., Shayakhmetov, S., Trekin, A., Oseledets, I., 2022. Estimation of the canopy height model from multispectral satellite imagery with convolutional neural networks. IEEE Access, 10, 34116-34132.

On the Issue of Professional Growth of Teachers in Digital Education

Imanberdiev D.Ch.[a], Zhang Weiqi[b], Arystangalieva G.G.[c], Kokombaev K.S.[d].
Kyrgyz National University named after J. Balasagyn, 547 Frunze Street, Bishkek, Kyrgyzstan
imandos01@gmail.com,2634783486@qq.com , arystangalieva_gulzhanat@mail.ru, skubat50@mail.ru

Keywords: digitalization of education; means of electronic communication; advanced training; hard skills; soft skills; digital skills.

Abstract: The study analyzes transformational processes in education in the context of digitalization. It is noted that traditional distance learning tools, such as Moodle, Zoom, Google Meet and other platforms, continue to operate successfully. The authors of the article emphasize that in modern conditions the Internet is becoming a means of encouraging the formation of information culture among the subjects of the educational process, in particular, the skills of mastering digital technologies in professional activities. For example, using Zoom conference, BigBlueButton (Virtual Classroom Software), Google Meet, etc. for organizing the educational process and transmitting educational content in real time. It is noted that within the framework of e-learning it is necessary to develop such digital methods and skills as "scaffolding (long read)", etc. In addition, it is emphasized that questioning of students through Internet constructors is becoming a leading skill. The article also notes that the most relevant aspect of the system of advanced training for specialists is the development of flexibility of professional abilities ("Soft skills"), which form a set of non-professional skills and ensure high productivity and effectiveness of professional activity. The issues of motivating and ensuring the success of students, as well as the optimal choice of technologies, methods and forms of teaching by means of electronic communications are studied. It is claimed that the digital competence of a teacher is based on their cognitive, social, and emotional components and takes into account their life in the digital environment. It has been found that professional growth of specialists occurs through advanced training, in particular, in the conditions of postgraduate education.

1 INTRODUCTION

At the beginning of the new century, the COVID-19 pandemic, which caused the rapid onset of the information age of society development, contributed to the intensive global digitalization of education. This emphasizes that despite the need to provide educational services online, teachers need to ensure their quality and free access to educational content.

Analysis of the latest research and publications. Theoretical and practical aspects of the provision of educational services by educational institutions for the professional growth of specialists as a priority area for the formation of the educational potential of the state have received significant development in the works of Kyrgyz scientists such as U.U.Beishenalieva, A.S.Rayymkulova, T.R.Oruskulov and G.D.Pankov, where the effects of information technology on the quality of education are studied. The issues of using gadgets, computers, mobile devices as an object of education and a means of learning are considered in the works of D.Azhybaev, S.K.Kaldybaev, U.Kasymaliev, A.M.Kenenbaev, U.E.Mambetakunov and others.

Scientific research by foreign scientists has become relevant for our research in today's conditions. Thus, José María Fernández-Batanero, Marta Montenegro-Rueda, José Fernández-Cerero and Inmaculada Garcio-Martínez analyzed Scopus and WoS data to identify a number of problems that teachers face. According to the authors, it can be concluded that teachers lack or do not have sufficient

[a] https://orcid.org/0000-0002-7009-8782
[b] https://orcid.org/0009-0002-4339-839X
[c] https://orcid.org/0009-0006-3587-4893
[d] https://orcid.org/0009-0000-9475-2788

digital competencies. The authors give advice on the development of Digital skills of modern teachers in the postgraduate education system (Fernández-Batanero, Montenegro-Rueda, Fernández-Cerero, García-Martínez, 2022). In addition, to determine the possibilities of using mobile devices for e-learning, it is useful to study the works of scientists such as Carl Royle, Sarah Stager and John Trexler, who note that today gadgets (mobile devices) are becoming digital learning tools and are turning from a system of "delivering" educational content into a system of mastering educational materials and receiving feedback (Royle, Stager, Traxler, 2014). Research conducted by Miriam Schmid, Eliana Brianza and Dominique Petko showed that the use of information technology by teachers during the planning of the educational process is necessary (Schmid, Brianza, Petko, 2021). A significant number of lesson plans were analyzed and it was found that only those teachers who used STEM technologies demonstrated a close connection between ICT and the educational process.

Thus, digitalization of education and the use of information technologies in the educational process are relevant today.

An analysis of the state of the specified issue in scientific sources contributed to the fact that we conducted a survey of teachers (mobile messengers, mobile groups, oral surveys of listeners, students, questions in chats during real-time conferences, etc.) to identify the urgent needs for the development of professional competence in the context of digitalization.

It was found that the primary demand is for:

- the development of conceptual foundations of digital learning content;
- the definition of educational content, essential characteristics of integral competence, as well as general and special skills of teachers (why exactly it is necessary to teach);
- finding ways to optimally interact with participants in the educational process with innovative digital technologies (which platforms and means of electronic communication are best to choose, etc.), mechanisms;
- the definition of effective technologies for managing the processes of formation and provision of digital educational services and ensuring their quality;
- substantiation of the mechanism for using the Internet as a communication platform to increase the motivation of learning and interactive communication of participants in the educational process, ensuring the effectiveness and productivity of mastering the content of education.

An urgent and relevant requirement of today, which is caused by the need for free access to educational content, is the information environment of the educational institution and the use of messengers by scientific and pedagogical staff as mobile educational technologies.

This is also enshrined in legislative documents. In the Law of the Kyrgyz Republic "On Education", in Article 39, paragraph 9, it is stated that "each student has the right to free access to information resources in educational institutions (this means access to public educational, scientific and information resources, including the Internet, electronic textbooks, and other multimedia educational resources)."

In addition, the concept of the "Internet" as a worldwide unified system of computer networks is more often interpreted as the web and the information available through it, rather than the physical network itself. The domain statistics are interesting, as they show a constant positive growth trend in the number of domains in the Kyrgyz Republic. Regular updating of domains indicates a constant change in digital content, and with it the prolonged development of on(off)line Internet communication channels.

This resource, which is dedicated to domain events, notes that all the restrictions caused by the Covid-19 pandemic have stimulated small and medium businesses to more actively transfer their activities to the Internet. All meetings, sales, and services are now provided mainly by electronic means. As of today, the number of Internet subscribers in Kyrgyzstan by the end of 2024 amounted to 5.41 million registrations. Consequently, there is an intensive transformation of people's activities (including professional ones) into an electronic format. This growth is also enhanced by the fact that educational services are undergoing digital transformation and teaching activities are also moving into an electronic format.

In the context of our research, by Internet communication channels and digital transformation of education we will understand the use of web platforms of the worldwide system of computer networks, the main purpose of which is the information interaction of participants in the educational process in the formation and provision of educational services by an educational institution.

The purpose of the study is to systematize and scientifically generalize the components of professional competence of teachers relevant in modern conditions, including Digital skills, and to reveal the directions of using electronic communication tools in the organization of the educational process. In addition, the following tasks are expected to be solved: disclosure of directions for using Internet resources to obtain information in order to promote educational services of an educational institution and a description of traditional and new electronic pedagogical means of activity.

2 METHODS

During the research and in order to solve the set tasks, we analyzed scientific sources and Internet services, conducted a survey of students and analyzed its results. In this work, a certain set of general methods of scientific cognition is used, which are used both at the empirical and theoretical levels of research.

The study presents a generalized description of the use of electronic communication tools to provide educational services both during distance learning of future specialists in higher education institutions and during the professional growth of working teachers in the advanced training (AT) system.

The hypothesis of the study is that in the context of digital education, the professional growth of teachers depends on their competence in the field of digital technologies, the availability of equipment and software, as well as support from the administration of educational institutions. Higher levels of digital competence, improved access to resources, and positive attitudes on the part of the administration are associated with more effective professional growth of teachers

3 RESULTS AND DISCUSSION

The challenges that today encourage the rapid development of digitalization of the education system can be conditionally divided into external and internal. The external ones include: firstly, the global transition of education to an online format and, in this regard, the rapid updating of strategic goals of education in the context of digitalization. Secondly, the development of the education quality system, both internal and external, and the need for its digital support.

The internal system includes the digital modernization of the educational content and the mastery of the forms and methods of online learning interaction by the subjects of the educational process. This implies the development, testing and mastering of new digital technologies for the organization of the educational process and determines the essence of the continuous professional growth of specialists.

It should be noted that the global digitalization of education has contributed to ensuring the effectiveness and efficiency of professional growth of specialists in general, and teachers in particular, on the basis of Internet marketing of educational services. The main purpose of using any Internet technologies is to increase the efficiency of interaction between participants in the educational process and ensure the effectiveness of learning.

The advantages of using the above technologies include: relevant targeted messages to the target audience, tracking the content of potential consumers of educational services, constant communication with consumers and prompt response to demand.

Analyzing the positions mentioned, it can be emphasized that educational institutions should use Internet resources to publish their primary information and obtain primary and secondary information about other institutions. Initial information is received on the websites (portals) of the educational institution, where information about products and educational services is posted and there is feedback from applicants, students and other stakeholders. For example, during the accreditation process, educational institutions post questionnaires, tests, and surveys for stakeholders, students, teachers, etc. on their websites to receive feedback.

In addition, the websites contain a variety of educational information, information and methodological materials for conducting classes. The electronic library also helps to obtain primary information about the educational institution. For current monitoring and adjustment of the state of the educational process, information is also obtained through Internet communication channels.

Secondary information obtained from other sources is necessary to clarify the place of the institution in the educational services market and its reputation in society. For example, a way to obtain secondary information using Internet communication channels is to monitor consumer content. This is tracking information left by consumers in reviews on portals (websites), etc. The emotional content of visitors' messages is analyzed regarding their positive or negative attitude towards the quality of educational services.

The advantage of monitoring consumer content is prompt response to feedback and the ability of educational institutions: - to "hear" consumers of educational services;

- ✓ to find out their advantages and disadvantages;
- ✓ to understand the demands and needs of both existing and potential consumers;
- ✓ to find out what level of quality of educational services and what image of the institution has been formed in the minds of consumers.

Usually, this type of monitoring is carried out on social networks. We would like to emphasize that traditionally, online positioning of an educational institution is carried out through the institution's own website, a distance learning website, forums, blogs, and banners on partner websites. Although, undoubtedly, the most powerful tool for building a positive reputation of an institution and obtaining secondary information is social networks.

At the same time, operational information is obtained through mobile messengers such as Viber, WhatsApp, Telegram and others, which is clearly visible in Kyrgyzstan today. We emphasize that these messengers are now actively developing and adding new functions: from simply providing information to holding a group conference.

As an example, we can take the creation and operation of ilimbox.kg - the first educational online platform for schools in Kyrgyzstan, focused on promoting free website services. The main purpose of the created educational service is to develop digital literacy of every student in the country. The site has created a number of educational series that form and develop basic digital skills, digital literacy of both teachers (online services for learning) and parents (for example, "Children's Safety on the Internet"). Thus, using mobile messengers, an educational institution can both monitor educational offers, focusing on the current demand for the content of educational services, and facilitate their promotion.

In addition, during the forced online training, curators of groups of various courses in all universities of Kyrgyzstan, as well as teachers in all schools, created mobile groups (Viber groups, WhatsApp groups, etc.) to communicate operational information about the progress of training and conduct group consultations with students. Upon completion of training, these groups are used for the purpose of providing and receiving marketing information, both to inform about the emergence of new products and services of the educational institution, and to determine the demand for new services.

Taking into account the above, we emphasize that today, for the professional growth of specialists, the formation of digital skills and the development of their use in professional activities is important. At the same time, analyzing various Internet resources, it can be noted that the leading demand in the system of advanced training of specialists is the development of flexible specialist skills ("Soft skills"), which in essence are a set of non-specialist skills that ensure high productivity and effectiveness of professional activities. Based on the results of scientific research, we will highlight those needs for knowledge and skills that scientists consider necessary in the 21st century for successful professional activity, including teaching.

There are four blocks of skills for successful professional activity of a person, namely:

– methods of thinking (creativity; critical thinking; project-based thinking; problem solving; independent decision-making; lifelong learning);

– means of labor (information culture and free use of digital technologies);

– working methods (creativity and interaction);

– skills necessary for successful life (civic position; life and professional activity; personal and social responsibility).

We emphasize that the means of labor in modern conditions highlight the information culture and knowledge of a specialist in the field of digital technologies. Based on the above, the following positions can be added to the classical structure of professional competence of a teacher in the context of digitalization:

- ✓ the ability of a person to carry out effective teaching activities both in full-time education and remotely using digital services;
- ✓ developed skills: Hard skills – professional; Soft skills – universal; Digital skills – digital;
- ✓ academic performance skills: professional activity based on project-based thinking in both real and digital space (including educational).

The analysis of the survey of consumers of services provided by the educational institution of postgraduate education (KSU named after I. Arabaev) and the analysis of Internet content allows us to assert that the professional growth of specialists in the context of digital education will be successful provided that there is a rethinking and updating of:

- ✓ the content of training for students in higher education and working teachers in the system of advanced training, that is, determining the current content of the education in demand,

- ✓ the goals and results of training (advanced training) taking into account global digitalization (which should be the integral competence of a specialist, general, special, "soft" skills, etc.);
- ✓ the directions of digitalization of the educational process and work in digital mode (provision of educational services by means of electronic communication), answering the questions: how to ensure the quality of provision of educational services, what services and platforms exist for training, which platform to choose (which Internet resource to choose for the provision of educational services, by what criteria to do this);
- ✓ the digital models of educational interaction, figuring out how to motivate and ensure the success of learning, which technologies, methods and forms should be used during digital learning and how to ensure interactive communication of participants in the educational process;
- ✓ the methods and technologies for evaluating educational results of applicants for education, how to reflect on this process?

We would like to emphasize that the above positions will contribute to the development of teachers' competence in the field of digital technologies, which, first of all, is based not only on knowledge of the essence of digital technologies, but also on knowledge of their use in the educational process. Digital skills of teachers are based on the cognitive, social and emotional components of their professional activities and their life in a digital team and society.

It should be noted that the quality of services provided by educational institutions is determined on the basis of such criteria as: compliance of educational services with state orders, regional requests, consumer needs; consistency of educational services (to what extent the complex of educational services provided by an educational institution is unchanged and meets modern challenges); the level of organization of the educational process and their compliance with the requirements; the result obtained (to what extent it meets expectations). Monitoring the quality of the provision of educational services based on these criteria ensures the study of the state of meeting the needs of stakeholders and promotes the introduction of ICT into the activities of an educational institution.

In our opinion, it is possible to ensure the formation of digital skills by building the content of educational programs of an educational institution on a digital project-oriented basis, which will contribute to the formation of soft skills among specialists based on the project type of thinking. It is this approach that will provide specialists who have completed the appropriate advanced training course with the ability to acquire new competencies, while simultaneously acquiring the necessary competencies (primarily digital) to effectively perform their job responsibilities.

A survey of teachers at KSU named after I. Arabaev showed that the platform for conducting video meetings – Google Meet - is mainly used for conducting classes online. This service was first introduced in March 2017. In March 2020, due to the COVID-19 pandemic, the developers announced free access to the program. This increased the number of users by 30 times, and in April 2020 it reached 100 million users per day.

This application allows to communicate in video or audio format, has a chat and presentation demonstrations. That is, it creates all the opportunities for teamwork and discussion on issues that require discussion. If it is impossible to establish an audio connection, applicants for education can use the chat. As practice shows, Google Meet can be used not only for conducting lectures, but also for practical classes, introducing elements of independent work with simultaneous collective verification of the correctness of execution. So, within the framework of the Web conference, the entire group discusses the issues raised by the teacher for discussion. This saves time and provides more opportunities for mastering educational information.

So, the transition to distance learning due to the COVID-19 pandemic has accelerated and created conditions for the inevitable intensive digital development of both teachers and students. This contributed to the mastery of computer-oriented methodological systems and telecommunication technologies. This, in turn, ensured the activation of communication between scientific and pedagogical workers and students by means of electronic communication.

In general, the use of modern means of electronic communication and other Internet resources in the process of developing the professional competence of future specialists, specialists in general and teachers in particular ensures the integrated formation of professional, universal and digital skills. This contributes to the successful life of a person, the well-being of society and, as a result, the competitiveness of the state.

In particular, it may be a response to the challenges facing humanity, as noted in the Human Development Report. The use of mobile learning provides commonality in working with university students, provides new opportunities for prolonged continuous learning both within and outside the institution, contributing to a more thorough understanding of certain categories and the formation of sustainable knowledge by discussing them online. The continuity of learning is ensured through the motivation of the learning process. In addition, the role of teachers changes: they move from being a transmitter of information to a supporting facilitator of students, facilitate collective solutions to educational problems, provide consultations on writing final theses, etc. At the same time, a variety of interactive task constructors ensure increased motivation for learning activities.

4 CONCLUSIONS

In the course of the empirical study, the systematization and scientific generalization of the relevant components of teachers' professional competence in the context of digitalization was carried out. In particular, it is noted that Internet communication channels are used both to obtain marketing information and to organize the educational process. During the study, the authors, based on an analysis of scientific sources and a survey of students of PC courses, clarified the content of professional competence of teaching staff in the context of digitalization. Three blocks (three directions) of its development were identified: the formation of a person's ability to effectively teach, including in digital format; the formation and development of skills: professional (Hard Skills); universal (Soft skills) and digital skills; the formation of academic performance skills: professional activity based on the project type of thinking both in real and in educational digital format. In addition, justifying the directions of transformation of professional growth of teachers in the context of provision of educational services by means of electronic communication, the main condition was identified - prolonged training in the form of advanced training. It was found that in order to ensure a constructive dialogue between participants in the educational process, it is necessary to combine both traditional forms of online learning (Internet platforms) and the latest ones (mobile messengers), in particular platforms for real-time conferences and mobile messengers for the rapid exchange of information. This also highlights the innovative nature of the scientific research presented in the article. The relevance of using e-technologies to assess the level of formation of effective professional competence of teachers, as well as the level of mastery of educational content by applicants for education is emphasized.

The article summarizes the use of digital technologies in the process of training specialists in higher education institutions and in the process of professional development of working teachers in the postgraduate education system. Further research will be devoted to the development of technology for using Internet marketing to promote educational services by means of electronic communication and technologies for using electronic resources to evaluate the learning outcomes of students.

REFERENCES

Fernández-Batanero, J.M., Montenegro-Rueda, M., Fernández-Cerero, J., García-Martínez, I., 2022. Digital competences for teacher professional development. Systematic review, European Journal of Teacher Education, 45:4, 513-531.

Royle, K., Stager, S. Traxler, J., 2014. Teacher development with mobiles: Comparative critical factors. Prospects 44, 29–42.

Schmid, M., Brianza, E., Petko, D., 2021. Self-reported technological pedagogical content knowledge (TPACK) of pre-service teachers in relation to digital technology use in lesson plans, Computers in Human Behavior, Volume 115.

Zakon KR «Ob obrazovanii» //https://cbd.minjust.gov.kg/112665/edition/1273902/ru

Stalo izvestno, skol'ko v Kyrgyzstane pol'zovatelej socsetej (25.02.2024), https://ru.sputnik.kg/20240225/kyrgyzstan

https://isoc.kg/ru/news/open-educational-platform-ilimbox

Linda Darling-Hammond (Transforming Teacher Education ,2023), John Hattie (Visible Learning and the Science of How We Learn, 2013), Andy Hargreaves (Professional Capital: Transforming Teaching in Every School, 2012) etc.

Institut povysheniya kvalifikacii KGU im.I.Arabaeva// https://arabaevksu.edu.kg/ru

Google Meet// https://meet.google.com/?hs=197&authuser=0

Vyhod iz tupika: pereosmyslenie sotrudnichestva v polyarizovannom mire. Programmoj razvitiya OON (PROON) https://www.undp.org/ru/kyrgyzstan/.

Fatty acid profile of milk fat of different breeds of cows of the Voronezh region

Saranov Igor Aleksandrovich[1][a], Rudakov Oleg Borisovich[2][b] and Polyansky Konstantin Konstantinovich[3][c]

[1]*Department of Information Security, Voronezh State University of Engineering Technologies, Revolutsii Avenue, 19, Voronezh, Russian Federation*

[2]*Department of Chemistry and Chemical Technology of Materials, Voronezh State Technical University, 84 20th Anniversary of October Street, Voronezh, Russian Federation*

[3]*Department of Information Technology in Economics, Voronezh Branch of Plekhanov Russian University of Economics, Karla Marksa Street, 67a, Voronezh, Russian Federation*

mr.saranov@mail.ru

Keywords: gas-liquid chromatography, fatty acid profile, milk fat, cow breed.

Abstract: The article examines the results of gas chromatographic analysis of the profile of fatty acids in milk fat from cows of different breeds. The changes in the fatty acid profile of milk fat of individual cows of red-and-white, black-and-white, Holstein and Jersey breeds bred in the Voronezh region are analyzed. Correlations of the fatty acid profile of milk fat of Jersey and Holstein cow breeds with a median profile, as well as a correlation between the content of fatty acids C10:0 and C12:0; C12:0 and C14:0 were found. The variability of the fatty acid profile in the milk of cows of different breeds and the presence of natural correlations in the ratios of fatty acids depending on the sum of genotypic and phenotypic factors were confirmed. Algorithms for identifying these factors using gas chromatographic data were proposed.

1 INTRODUCTION

As is known, the red-and-white breed of cows was bred in Russia by crossing Simmental cows with Holstein bulls of red-and-white color (genetically valuable servicing bulls from the USA and Canada were used for crossing). The breed was approved in the late 90s. Red-and-white cows have a pronounced dairy type, similar to the type of Holstein cattle. The milk of these cows is used for the production of butter and hard cheeses.

The black-and-white breed is a breed of cattle, primarily in the dairy sector of productivity. The black-and-white breed is related to the Dutch breed. It was bred in the USSR in the 1930s–1940s as a result of crossing local cattle, bred in various areas of the country, with black-and-white cattle of the East Friesian, black-and-white Swedish and other breeds, descended from the Dutch breed. The breed was approved in 1959, when animals with red colors were separated from it.

The Holstein breed is the most widespread breed of dairy cattle in the world, this breed of cows is considered one of the best in the world in terms of milk yield. The Holstein breed was created in the USA and Canada as a result of breeding the Dutch black-and-white breed of cows for productivity.

The Jersey breed belongs to small breeds of dairy cows. One of the oldest and most milk-rich cultivated breeds. Until recently unknown in Russia, the Jersey breed now ranks second in the world in terms of numbers after the Holstein breed, and its population is growing rapidly due to the fact that with smaller needs for living space, lower feed consumption (lower feeding costs, which make up 60% of the cost of milk), the Jersey breed shows a feed conversion rate that is 30% higher than the Holstein breed, and its milk is valued at least 20% higher than the milk of other breeds. The Jersey breed was bred in England

[a] https://orcid.org/0000-0002-9510-5168
[b] https://orcid.org/0000-0003-2527-2857
[c] https://orcid.org/0000-0002-8817-1466

on the island of Jersey by improving local Norman and British cattle and selecting them according to their fat content.

The article [Rudakov, 2017] shows that the fatty acid profile of cow's milk, as well as natural vegetable oils, varies in characteristic ranges not in a statistically random manner, but in compliance with biochemical correlations [Rudakov, 2005, 2018]. If the content of a particular fatty acid (FA) in the triglycerides of natural fat or oil that have not been fractionated, chemically and thermally affected, decreases or increases depending on the breed, nutrition, season and other climatic factors (for animal fats), varieties (for vegetable raw materials), etc., the content of another FA can increase or decrease symbatically (Soyeurt, 2006). Compliance with ranges within which the content of FA can vary, while maintaining natural correlations due to genotypic and phenotypic factors, is a sign of the naturality of this fat (Paszczyk, 2020).

The purpose of this work was to identify differences in the fatty acid profile of cow's milk fat in different breeds bred in the Central Black Earth Region based on chromatographic data, to confirm the presence of natural correlations, namely, to establish the most characteristic ratios for fatty acids typical in milk fat, which can serve to identify the naturality of milk fat (Hanuš, 2018).

2 EXPERIMENTAL PART

Milk was separated on a household separator "Rotor" at a temperature of 40-45 ° C, with the production of cream and skimmed milk. The ratio of the volume of cream and the volume of skimmed milk is 1:7.5. Milk fat was obtained by churning from cream cooled in a household refrigerator to 3 °C and then separating the fat phase from buttermilk by rinsing with ice water. The separation of butter into fat and serum was carried out according to GOST R 70238-2022 "Milk and dairy products. Method for identifying the profile of the fat phase and determining the mass fraction of milk fat." 50–70 g of product were placed in a glass with a capacity of 150 cm^3. A glass with a product sample was placed in a thermostat and kept at a temperature of (55±5) °C until the product was separated into fat and milk serum. The upper fat fraction was separated by carefully pouring it into another glass and filtered through a dry foldfilter at the same temperature (Wang, 2022).

The fatty acid profile of milk fat was obtained by the method described in GOST 32915-2014. "Milk and dairy products. Determination of the fatty acid profile of the fat phase by gas chromatography." Gas chromatograph Crystal 2000 M, capillary column SP-2560 (100 m; 0.25 mm), flame ionization detector.

3 RESULTS AND DISCUSSION

Tables 1 and 2 show the results of gas chromatographic determination of the fatty acid profile of milk fat from 9 cows of 4 breeds from farms in 3 locations in the Voronezh region during the transition from pasture to stall barn housing. To analyze the data in Table 1, we will use control charts (CC) [Rudakov, 2005, 2016, 2021]. We normalize the values of the selected controlled parameters and convert them into dimensionless values from 0 to 100% using the formula (1):

$$P_N=100(P_i–P_{min})/(P_{max}–P_{min}) \quad (1)$$

where P_i is an unnormalized parameter; P_{min} is the minimum permissible value of this parameter; P_{max} is the maximum permissible value of the parameter according to GOST 32261-2013 (percentage of the *i*-th fatty acid). The results of the analysis are visualized in MS Excel in the form of diagrams, where the normalized value of the FA content is plotted on the y-axis, and the x-axis, the category axis, indicates a number of 11 FAs, according to which fat is checked for compliance with GOST 32261-2013 (Fig.1). Jersey cow milk fat passed this test perfectly. All FAs were in the range from 0 to 100% according to normalized criteria.

Table 1: Fatty acid profile of cow's milk fat.

Fatty acid	Standard according to GOST 32261-2013	**1**		**2**		**3**		**4**		**5**
Butyric acid, C4:0	2.4-4.2	2.5	2.9	3.2	2.4	2.6	2.1	3.3	3.5	4.0
Caproic acid, C6:0	1.5-3.0	1.5	1.3	2.3	1.5	2.0	1.8	1.5	1.3	2.8
Caprylic acid, C8:0	1.0-2.0	0.8	0.9	1.4	1.1	1.3	1.4	0.7	1.0	1.5
Capric acid, C10:0	2.0-3.8	1.8	1.9	3.2	2.8	3.2	3.5	1.4	2.2	2.7
Decenic acid, C10:1	0.2-0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.2	0.2	0.4

Lauric acid, C12:0	2.0-4.4	2.3	2.6	3.7	3.6	4.2	4.7	1.7	1.9	3.1
Myristic acid, C14:0	8.0-13.0	9.5	9.8	11.5	12.0	13.0	13.1	6.8	8.0	11.0
Myristoleic acid, C14:1	0.6-1.5	1.3	2.0	1.3	1.7	1.3	1.9	0.7	1.1	1.4
Palmitic acid, C16:0	21.0-33.0	26.4	23.8	33.1	31.7	38.2	33.3	24.8	22.4	22.8
Palmitoleic acid, 16:1	1.5-2.4	2.2	1.9	1.9	1.9	2.5	2.1	2.2	2.0	1.7
Stearic acid, C18:0	8-13.5	10.8	11.8	9.0	10.2	5.8	6.9	11.7	13.2	13.4
Oleic acid, C18:1*	20-32	31.6	25.5	22.4	20.5	16.8	15.5	36.6	29.9	21.3
Linoleic acid, C18:2*	2.2-5.5	3.5	2.0	3.3	2.1	3.3	2.6	4.0	2.7	3.4
Linolenic acid, C18:3*	up to 1.5	1.0	0.8	0.4	0.3	1.0	0.9	0.9	0.8	0.6
Behenic acid, C22:0	up to 0.1	0.1	0.2	0.1	0.0	0.1	0.1	0.1	0.1	0.2
Arachidic acid, C20:0	up to 0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.4

Note: 1 – red-and-white breed (Yamnoye village); 2 – Holstein (Yamnoye village); 3 – Holstein (Novaya Usman settlement); 4 – black-and-white (Yamnoye village); 5 – Jersey breed (Liskinsky district)

Table 2: The ratio of the mass fractions of methyl esters of fatty acids.

The ratio of the mass fractions of methyl esters of fatty acids	GOST 32261-2013	1		2		3		4		5
Linoleic to myristic (C18:2/C14:0)	0.1-0.5	0.4	0.2	0.3	0.2	0.3	0.3	0.2	0.3	0.3
Oleic to myristic (C18:1/C14:0)	1.6-3.0	3.3	2.6	1.9	1.7	1.3	1.3	2.7	3.7	1.9
Palmitic (C16:0) to lauric (C16:0/C12:0)	5.8-14.5	11.5	9.1	8.9	8.8	9.1	9.1	9.6	11.8	7.4
Stearic acid to lauric acid (C18:0/C12:0)	1.9-5.9	4.7	4.5	2.4	2.8	1.4	1.4	5.8	6.9	4.3
Oleic and linolenic acid to lauric, myristic, palmitic and stearic ones (C18:1+C18:3)/(C12:0+C14:0+C16:0+C18:0)	0.4-0.7	0.7	0.5	0.4	0.4	0.3	0.3	0.5	0.7	0.4

In other cases, certain deviations from the norm are observed. Adulteration of milk fat is excluded, since the milk was collected from individual animals by the experimenters themselves. The fat phase was obtained from this milk under laboratory conditions. Thus, it can be concluded that GOST 32261-2013 provides a somewhat narrowed range of variation of FAs, which does not fully take into account the individual characteristics of the fatty acid profile of individual animals of different breeds, the season, climatic conditions and the diet of cows.

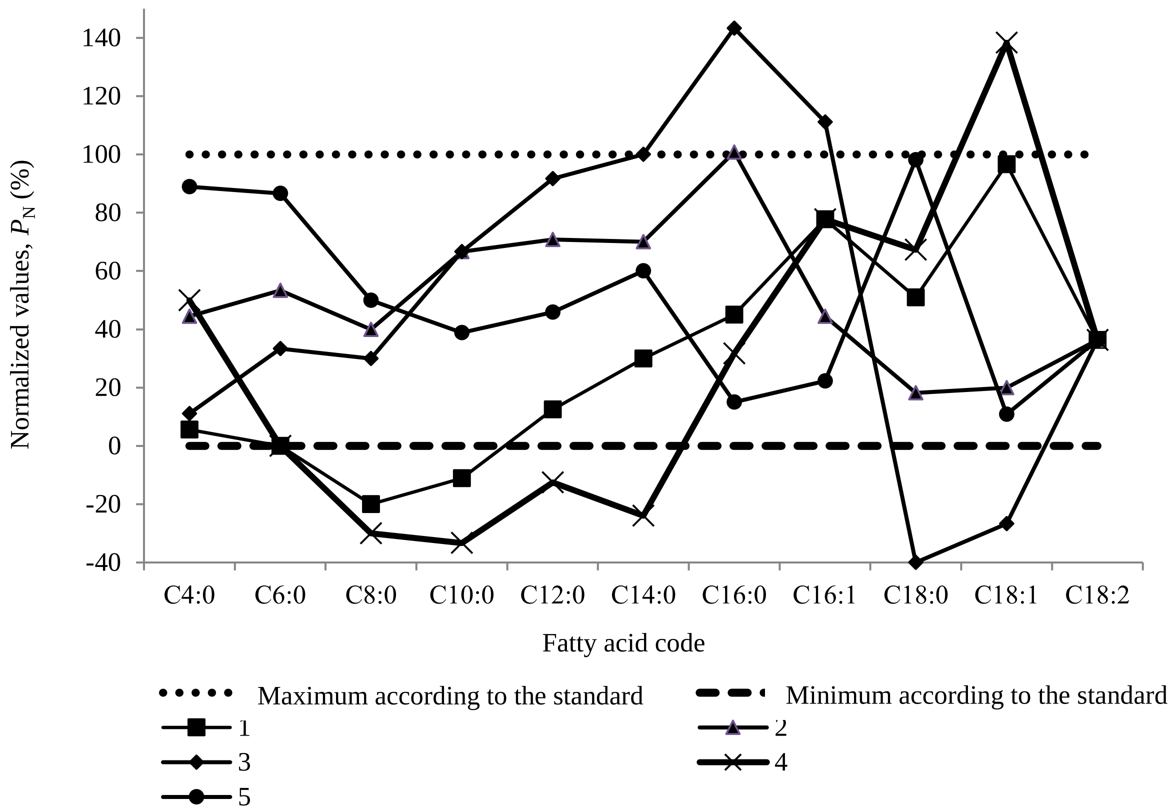


Figure 1: Fatty acid profile of milk fat of:
1 - red-and-white (Yamnoye village), 2 - Holstein (Yamnoye village), 3 - Holstein (Novaya Usman settlement), 4 - black-and-white (Yamnoye village) breeds of cows.

In GOST 32261-2013, the permissible range of fatty acid content was expanded for individual acids compared to GOST P52253-2004. Perhaps the standard should be revised again. If you look at the figures in Table 1, you can see that they are within the permissible limits of determination errors (for content less than 5% $\Delta=\pm0.4$, and for more than 5% $\Delta=\pm2.2$. That is, for the content, for example, 1.0%, values of 1.0 ± 0.4 are acceptable (i.e. ±40 rel. %); and for 10.0 we have 10.0 ± 2.2 (i.e. ±22 rel.%). It follows that, taking into account the errors, most of the indicators comply with the standards, but are close to the lower or upper limits of the CC. Absolute errors are most sensitive in normalized coordinates for minor fatty acids.

Apparently, a preliminary conclusion can be drawn from the diagrams in Fig. 1. Their profile depends on the genotypic factor, that is, on the breed of cows. Of course, phenotypic factors are superimposed on this factor – some differences in feed and livestock management [Rudakov, 2005], but if we assume that milk fat was produced with a similar diet, in the same region, in the autumn season, then the hypothesis about the influence of breed on the fatty acid profile of milk is viable. It is also possible to find similarities and differences in the fatty acid profile of milk of different breeds by comparing it with the "median" profile (average values in acceptable ranges - in the CC correspond to values of $P_N = 50$).

Let us check on our sample the observance of natural correlations identified in [Rudakov, 2002] based on statistical data for 50 samples of cow's milk fat.

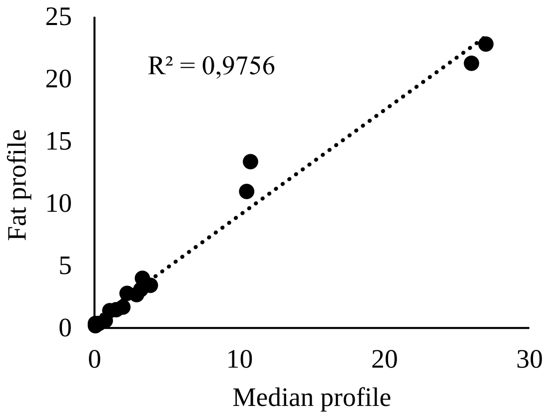


Figure 2: Correlation of the fatty acid profile of Jersey cow milk fat with the median profile.

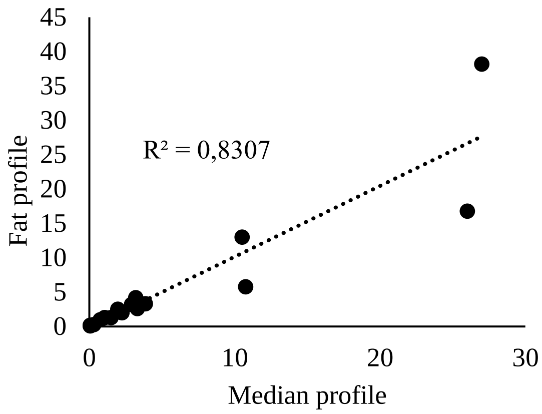


Figure 2: Correlation of the fatty acid profile of Holstein cow milk fat with the median profile.

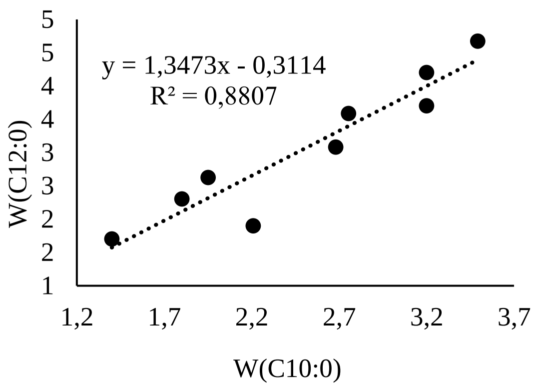


Figure 4: Correlation between C10:0 and C12:0 FA content, n=9.

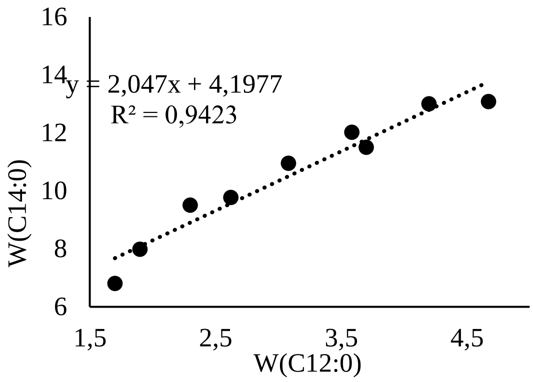


Figure 5: Correlation between C12:0 and C14:0 FA content, n=9.

As shown in [Rudakov, 2002], three acids are most sensitive to changes in the total FA profile: capric, lauric and myristic; the closest linear correlations are also observed between their content in milk fat. The content of palmitic, oleic and polyunsaturated acids slightly depends on the amount of other acids. Indeed, the ratios of the FAs C10:0 and C12:0, C12:0 and C14:0 closely correlate with each other (Fig. 8 and 9) even in such a seemingly not very representative sample (n=9). The data for other ratios (Table 2), provided by GOST 32261-2013, correspond to the permitted ranges, except for two indicators of one black-and-white cow, which, taking into account the maximum errors of chromatographic analysis, can be neglected, or one can think about standards that are acceptable for the average profile of fatty acids from large batches of milk. At the level of individual cows, deviations from the statistical data found with a confidence coefficient of P=0.95 are quite expected.

4 CONCLUSIONS

Thus, the study confirms the variability of the fatty acid profile in the milk of cows of different breeds and the presence of natural correlations in the ratios of fatty acids depending on the sum of genotypic and phenotypic factors. Algorithms for identifying these factors using gas chromatographic data were proposed.

ACKNOWLEDGEMENTS

The study was supported by the Russian Science Foundation grant No. 23-73-01166, https://rscf.ru/project/23-73-01166/.

REFERENCES

Wang, X., Zhu, H., Zhang, W., Zhang, Y., Zhao, P., Zhang, S., Lv, J., 2022. Triglyceride and fatty acid composition of ruminants milk, human milk, and infant formulae. *Journal of Food Composition and Analysis,* 106, 104327.

Rudakov, O. B., Rudakova, L. V., 2017. CHem grudnoe moloko otlichaetsya ot korov'ego?. *Pererabotka moloka,* (1), 40.

Paszczyk, B., Łuczyńska, J., 2020. Fatty acids profile, conjugated linoleic acid contents and fat quality in selected dairy products available on the Polish market. *Czech Journal of Food Sciences,* 38(2).

Rudakov, O. B., Ponomarev, A. N., Polyanskij, K. K., Lyubar', A. V., 2005. ZHiry. Himicheskij sostav i ekspertiza kachestva.

Hanuš, O., Samková, E., Křížová, L., Hasoňová, L., Kala, R., 2018. Role of fatty acids in milk fat and the influence of selected factors on their variability—a review. *Molecules,* 23(7), 1636.

Rudakov, O. B., Polyanskij, K. K., 2018. Prirodnaya izmenchivost' zhirnokislotnogo sostava pal'movogo masla. *Pererabotka moloka,* (4), 50-51.

Soyeurt, H., Dardenne, P., Gillon, A., Croquet, C., Vanderick, S., Mayeres, P., Gengler, N., 2006. Variation in fatty acid contents of milk and milk fat within and across breeds. *Journal of Dairy Science, 89(12), 4858-4865.*

Rudakov, O. B., Polyanskij, K. K., Rudakova, L. V., 2016. Kontrol'nye karty v pomoshch' ekspertu. *Pererabotka moloka*, (5), 28-31.

Rudakov, O. B., Polyanskij, K. K., Rudakov, YA. O., 2021. KONTROL'NYE KARTY V EKSPERTIZE SGUSHCHENNOGO MOLOKA S SAHAROM. *Pererabotka moloka,* (8), 16-18.

Rudakov, O. B., Selemenev, V. F., Plotnikova, T. V., Sezin, I. M., Dubinina, T. V., 2002. Statisticheskij podhod v opredelenii natural'nosti zhirov po hromatograficheskim dannym. *Sorbcionnye i hromatograficheskie processy*, 2(3), 295-303.

Methods of implementing the digital platform "Government as a Platform": status, problems, prospects

Makhova Larisa Afinogenovna[1], Polina Alexandrovna Sovina[2]
St. Petersburg Mining University of Empress Catherine II, 21st Line of Vasilievsky Island, St. Petersburg, Russia
polina.sovina.03@bk.ru

Keywords: Digital platform, states, prospects for the development of state digital platforms, problems in the implementation of state digital platforms.

Abstract: In the modern world, the level of digitalization of the state apparatus is a necessary component for preserving the sovereignty of the state and maintaining its global status. The transition to digital technologies makes it possible to increase not only the efficiency of public services, make information accessible and open, but also solve a number of problems, which determines the need for a thorough study of the topic “Government as a Platform”. The purpose of the article is to propose different methods of solving the problems of implementing the digital platform "Government as a Digital Platform". The theoretical and methodological basis of the study was formed by scientific works of Russian and foreign researchers in the field of government digitalization, as well as general methods of cognition: analysis, synthesis, generalization. As a result, it was revealed that the digitalization of the government is a necessary component for the effective work of the state. It is possible to overcome the problems of introducing digital technologies into the work of the state through the popularization of digital services, increasing trust in technologies among citizens, as well as increasing the level of security of personal data of citizens.

1 INTRODUCTION

In the second half of the twentieth century, there was a breakthrough in science, which led to the digital transformation of society. Digital transformation is a modern direction of socio-economic development that promises significant digital dividends to citizens and businesses around the world (Dobrolyubova, 2021). The digital platform, after the digitalization of society, should become the sole intermediary between buyers and sellers of goods or services (Orlova, 2021). The digital platform has shown its effectiveness. The world's leading companies (Apple, Google, Microsoft, Facebook, Alibaba, etc.) already consider themselves to be platform companies and, as statistics show, their profits in 2021 exceeded the profits of multinational corporations (Semyachkov, 2019).

Due to such business successes, the state began to develop digital platform projects that would help provide public services more efficiently and transparently, as well as combat a number of problems: corruption, inequality of citizens, high costs of bureaucracy, etc. Digitalization of public administration is a necessary condition for the economic and social development of every country. In this context, e-government is developing and diversifying the forms of its implementation, making a significant contribution to improving work efficiency (Litvinenko, Tsvetkov, Molodtsov, 2020).

According to the state program "Digital Economy", which has been implemented since 2018, the most important direction for the development of digital platforms for Russia is the creation of a state digital platform. To create it, a separate federal project "Digital Public Administration" was created, involving the creation of a digital platform "Government as a Digital Platform", for the

[1] https://orcid.org/0000-0001-8166-1326
[2] https://orcid.org/0009-0000-5177-8419

implementation of which 235.7 million rubles were allocated, which is 14.4% of the total budget of the national project.

The purpose of the study is to propose different methods of solving the problems of implementing the digital platform "Government as a Digital Platform".

Study objectives:

1) consider the general characteristics of digital platforms;

2) study the problems that states face during the digitalization of state functions;

3) analyze the solution to the problems of implementing the "Government as a Platform" using the example of several countries.

The object of the study is a digital platform.

The subject of the study is "Government as a Digital Platform".

2 METHODS

To achieve this purpose, general scientific methods were used: analysis of the thematic literature of Russian and international scientific libraries, generalization of information and sociological research, experience in implementing a digital state platform in other countries, comparison of the results of existing studies, identification of contradictions in them.

3 RESULTS

After a series of revolutions, including Industrial Revolution 4.0, the life of society has changed a lot. It has become impossible to imagine serving the needs of society without digital devices.

The digitalization process currently has three main trends: openness, accessibility and generativity (Nambisan, Wright, Feldman, 2019). One of the ways to implement this process is to create digital platforms and introduce them into public life.

There are several categories of different digital platforms (Babkin, Mikhailov, 2023). This article will consider only one of the groups of digital platforms - digital platforms for public administration.

A wide range of people are interested in this process, but we should not forget that the state is also interested in the process of digitalization of public services and the creation of an e-government, since the main goal of this project is to improve the quality and efficiency of public services by reducing the time it takes to process one application, increasing transparency and reducing costs and uninterrupted provision of services.

Organizing a digital state system is quite difficult, since it must cover all spheres of society.

The federal digital transformation policy operated in three directions: development of digital culture and the necessary skills for mastering new technologies, creation of infrastructure, and attraction of investments in digital ecosystems (Brunetti, Matt, Bonfanti, Longhi, Pedrini, Orzes, 2020).

The introduction of new technologies has changed the process of interaction between the state and stakeholders. Based on the type of interaction, all digital governments can be divided into 4 groups:

1. "Government to Citizens" (G2C);
2. "Government to Business" (G2B);
3. "Government to Employees" (G2E);
4. "Government to Government (G2G) (Joseph, 2019).

This classification of the type of digital government is the most interesting for the scientific community, since it helps to take into account the interests of the other party when developing a project, for example, for citizens these will be reception hours, receiving government services, receiving social benefits, etc.

The transition to digital government represents a complete change in the structure of processes, procedures, operations and organization of government agencies (Omar, Weerakkody, Daowd, 2020).

There have been attempts around the world to implement digital government at the local level. On the one hand, this is good, since a small project cannot cause great harm to society and set a large number of citizens negatively towards the process of digitalization of the state. On the other hand, local governments usually have a small budget to finance these projects, and digital transformation can only be achieved through the active involvement of managers and employees (Lapinskas, Sodnombalova, 2019).

When considering this option for implementing a digital government platform, it is worth paying attention to the fact that local governments are quite slow in introducing digital technologies into their work, since this requires an almost complete change in the structure of the organization, as well as the introduction of an integrated corporate system to support a high level of cooperation between stakeholders through process management. Unfortunately, only 10% of local governments have decided to do this (Pittaway, Montazemi, 2020), since this requires high costs and does not guarantee a positive result.

If new technologies are not introduced into the process of providing public services, one may soon encounter a number of difficulties:

1. inefficiency due to data duplication and lack of ability to process information in a timely manner; lack of understanding by stakeholders of their role in organizational processes spanning multiple departments;
2. difficulties in finding the most optimal mode of operation and providing services. To solve these problems, it is necessary to expand the range of know-how that can be used to optimize local government.

Not only local governments, but also larger government units face similar problems. The solution to this problem can be found in one of the articles, which proposes to carry out digitalization using the DT method, which consists of 7 blocks (Vial, 2019).

The first three blocks of the DT system are aimed at digitalizing a specific operation: identifying failures in the management model, developing a strategy to eliminate them, and only then implementing them into the overall process.

The fourth block is aimed at increasing the interest of citizens in this project: the creation of websites, applications, surveys, educational games, etc.

The fifth block involves structural changes in management: for the implementation of this block a separate program is being developed, which includes not only the structure of the organization and management, but also the creation of a special corporate culture.

The sixth block is aimed at identifying resistance to innovation and working with it. The seventh block is aimed at summing up, analyzing positive and negative consequences (Chen, Hu, Tseng, Juang, Chang, 2019).

People do not actively interact with e-government due to various reasons that will be discussed below, but one of them is the complexity of interaction, i.e. it is easier for people to contact directly than to leave a "digital trail". To solve this problem, it is proposed to:

1. minimize the complexity of the necessary digital trail for basic services;
2. ensure accessibility and fairness of the entire user process through inclusive design and impact assessment;
3. make the relationship between the public decision and the private provision clear and transparent in a public registry (Allmann, Radu, 2022).

One of the main tasks of the government is to implement e-government in an inclusive way so that everyone who needs it can receive public services online. It is important to note that older people and those with limited mobility rarely use Internet services, despite the fact that they need them the most. This, in turn, does not give them the opportunity to fully appreciate the potential of e-government. Currently, many countries have begun to develop and implement programs aimed at teaching people computer literacy, i.e., combating digital inequality among citizens. One of the articles analyzes and examines the evidence base, which demonstrates the need and importance of these programs, since they help make the implementation of digital government more accessible to all segments of the population (Lee, Porumbescu, 2019).

In the world, there is unevenness in the development of digital technologies, the level of digitalization culture, as well as the availability of these technologies for everyday use, which causes digital inequality. In the least developed countries in this regard, due to the importance of the transition to the digital platform "Government as a Platform", they are also trying to introduce new technologies and begin to broadcast information about the government through official websites and provide public services using special applications.

However, due to the uneven development in this area, they face a number of problems. According to experts, the most serious problems are: the digital divide, inadequate electronic infrastructure; lack of competent specialists to design and work in government applications; lack of skills in managing these systems and ensuring user security, as well as low digital literacy of citizens themselves. We managed to find statistics for 2019 in one of the articles, which shows the level of effectiveness of the implementation of e-government: 35% of the projects introduced were unsuccessful, 50% were partially successful and only 15% were successful (Sun, Luo, Ran, Jia, 2023). Having analyzed these data, we can conclude that countries are facing great difficulties, which lead to a number of problems that further slow down the process of government digitalization.

The failure of one such project entails the loss of time and money, as well as a positive image among citizens. The latter consequence is the most important, as it creates difficulties in the future. To implement new projects, the state will have to spend money not only on the development and implementation of the project, but also on increasing public trust in new projects and ideas of digitalization of the state apparatus.

The above statistics can be explained by 17 barriers to consider when implementing smart government that were identified in one of the scientific articles. Only 2 of them relate to technological difficulties, all the rest are related to institutional organization, level of education, readiness of society, digital literacy, etc. (Schedler, Asker, Frischknecht, 2019). Therefore, relevant actors such as public managers should not neglect non-technical barriers. The difficulty in eliminating these problems is that they affect the bases of the social and political sphere of society.

When developing a program to increase public trust in government digitalization, it is worth noting that, according to research, satisfaction from using the website, maintaining personal privacy, as well as the security of personal data have the greatest impact on the level of trust (Alsaghier, Ford, Nguyen, Hexel, 2021).

Currently, there is a problem of free access of all segments of the population to information about the state of the country and the world, and obtaining government information transparently and effectively. One of the solutions to this problem is the concept of "Open Government Data", which is based on the principles of clarity of government organization and transparency of management, openness of information, accountability and controllability of the authorities by the population (Rozhkova, 2021).

In democratic societies, transparency of state institutions is of paramount importance. Increasingly, developed or developing countries recognize that free access to information is fundamental to democracy (Androniceanu, 2021).

The principle of "Open Government Data" has been accepted all over the world, but the design on some websites does not meet the requirements, and therefore it is necessary to create an automated assessment of dynamic generated data. To develop this assessment, a study was conducted, during which it was determined that the assessment consists of three stages. The first stage is called "access", which involves scanning all government websites and storing their links, which can then be used as input. This stage is aimed at testing the principle of data openness. The second stage is "classification", which involves testing the site for a quick search of the necessary information: keyword search. This stage is necessary to assess the speed of collecting the necessary information, the number of clicks and the ease of using the site. The final stage is "decision making" – making an assumption about the relevance of the information on the site (Correa, de Souza, Silva, 2019).

In another article, one can find the opinion that by 2022, the use of the idea of open government data (OGD) has been limited, which prevents this concept from reaching its potential (Begany, Martin, 2020). However, open information about the actions of the state is necessary for citizens, first of all, for journalists, sociologists, politicians, and political figures. But it is worth noting that human capital needs to be developed in order for an open data system to work, as it will only work effectively if the data is used and understood in the same way by all people (Ansari, Barati, Martin, 2022).

The international experience of implementing digital government is extensive (Khan, Krishnan, Dhir, 2021).

Let's turn to the international experience of implementing e-government in Ibero-America. In his article, Gonzalo Paiva Diaz provides a detailed analysis of Ibero-America, a community of countries linked by strong historical and cultural ties. These include countries such as: Spain, Portugal, Argentina, Bolivia, Brazil, Chile, Colombia, etc. The author conducts research in which he analyzes the relationship between the level of education and the economy and the digitalization of the state apparatus. As a result, he identifies 4 groups of countries within the community. The first group accounts for the largest number of electronic publications (85.9%), as well as the highest rate of economic development. This group includes Spain, Brazil, Portugal and Mexico (Pavlyutenkova, 2019). It is worth noting that even within one community, one can trace a very strong digital inequality between countries, which arose due to the immaturity of politics, weakness of the economy and education. In this regard, this community of countries has set the main goal – to develop education within countries, as well as to introduce people to new technologies.

There is a study showing that there are still a number of important unresolved issues - the low percentage of use of e-government in European countries. During his research, the author came to the conclusion that this arises from a lack of trust in the government, as well as a lack of trust in new technologies that are not always able to preserve the confidentiality of information (Androniceanu, Kinnunen, Georgescu, 2020).

Russia is also interested in developing digital government. According to experts, the Russian Federation has quite positive experience in this area (Al-Mushayt, 2019).

The "Strategy for the Development of the Information Technology Industry in the Russian Federation for 2014–2020 and for the Perspective until 2025" sets the task of increasing the literacy of the population in the field of information technology. In 2017, the President of the Russian Federation signed a Decree approving the second "Strategy for the Development of the Information Society in the Russian Federation for 2017–2030." This Decree is intended to promote: the development of human potential, ensuring the security of citizens and the state, increasing the role of Russia in the global humanitarian and cultural space, increasing the effectiveness of the government, developing the economy and social sphere, as well as the formation of the digital economy (Ivanova, Poltarykhin, Szromnik, Anichkina, 2019; Cherepovitsyn, Tretyakov, 2023).

Despite the fact that Russia has achieved quite significant success in the digitalization of the state apparatus, a complete transition to a digital government has not yet occurred. This transition requires the launch of a unified state cloud platform to provide services that can improve the quality and security of interaction between departments and ensure financial savings by eliminating the need to create duplicate infrastructures in individual (Vartanova, Vikhrova, 2020) departments or regions. Instead of creating their own systems, regional public authorities and local governments should be given the opportunity to receive the high-quality digital services they need from government cloud resources. Such a system will provide standardized and scalable platforms for creating new digital services and, over time, will integrate existing government information systems into a common government resource for computing and data storage.

In addition, in Russia, the digital inequality between regions is too strong, which hinders the digitalization process in the country, and also reduces the quality of life in regions where there is a severe shortage of highly qualified personnel to implement the policy of digitalization of public services. To solve this problem, it is necessary to combat digital inequality in the regions, for example, by introducing a compulsory subject in schools and universities aimed at developing digital literacy, and creating free courses for older citizens. In addition, it is necessary to develop uniform requirements for the creation, content and operation of specialized online portals that allow the population to directly participate in the development of regions, as well as legislate these standards at the federal level (Vartanova, Vikhrova, 2020).

In Russia, during the Covid 19 pandemic, distance education was introduced, aimed at independent search for information by students. As one of the studies shows, students faced difficulties, which indicates a low level of digital literacy. To solve this problem, the author of the article recommends conducting special courses (Shestakova, Morgunov, 2023).

As the literature review has shown, investing in human capital has a strong positive effect on the development of government digitalization, therefore, these measures should help eliminate digital illiteracy of the population.

4 DISCUSSION

Before planning and implementing the "Government as a Platform" project, it is necessary to assess the society's readiness for this innovation.

As we have discussed earlier, there are 17 barriers to implementation and only 2 of them are related to the level of technology, therefore, when assessing the readiness of society to move to the digital stage, it is necessary to also assess the social components, which, as a rule, are quite difficult to assess objectively and in digital terms.

There are different assessments of the state's readiness to switch to digital government. One of the main ones was developed by the UN. There are supporters and opponents of this indicator.

The disadvantage of the indicator is that it shows only the technological readiness of the state. Usually, the liberal democracy index is used to clarify this indicator, but even a comprehensive analysis does not provide an objective assessment.

In one of his articles, Kabanov Yu. suggests using the deliberative index, which was proposed by the Varieties of Democracy (V-Dem) project, to obtain more accurate information.

According to the author of the article, it will be able to more objectively show the electronic participation of citizens in governing the country. But even it has a number of limitations, for example, it should only be used in countries with a high level of political culture. This index more reliably shows the public readiness for the transition to digital government. Although it should be noted that the initial purpose of developing this index was not to assess the electronic participation of citizens (Kabanov, 2022).

However, there is a study that proves that the introduction of digital government is greatly influenced by technological potential, while the organizational structure, culture, and distribution of responsibilities and tasks among employees are indirect indicators and have little influence (Tangi, Janssen, Benedetti, Noci, 2021).

Despite the high potential of the transition to e-government, this process has already generated new forms of inequality and social exclusion (Lee, Porumbescu, 2019).

Even in countries with a high level of trust in the government, standard of living and quality of life, difficulties may arise in implementing the "Government as a Digital Platform" project.

Denmark is one of the most striking examples. This country occupied high ranking positions in readiness for the transition to digital government, but the experience was not successful.

The author of one of the articles criticizes the government, which adheres to the policy "citizens should be digital by default", because it only worsens the stratification of society. There are centers in Denmark that help people socialize in the new digital environment. Most people who seek help have trouble navigating the Social Security system and using the self-service solutions designed for this purpose. In the article, the author argues that new forms of inequality can have very real consequences for citizens: digitalization will not solve the problem of exclusion of vulnerable segments of the population, it will create the risk of losing social benefits, since people will not be able to apply for them through government websites (Schoua, Svejgaard, 2019).

However, there is also positive experience in implementing digital government. Despite the fact that India has a lower economic potential and a lower level of social development, the country managed to successfully carry out a project to digitalize part of its public services.

To provide services to low-income groups, various benefits and privileges were initially allocated, but due to high levels of corruption, the use of these funds was deemed ineffective. Since 2009, a program has been implemented that is aimed at combating corruption and creating a transparent system for receiving public services. As part of this program, the Aadhaar platform was created, which identifies a person's identity. After registering on this platform, a person can buy discounted train tickets, receive social benefits, and use bank benefits, if they have such a right. This made it possible to solve the problem of personal identification, as well as reduce the level of corruption. In addition, this system is flexible, which allows it to quickly adapt to new challenges, and is also quite cheap to build and maintain, which is also a huge plus for India (Maphumula, Njenga, 2019).

REFERENCES

Dobrolyubova, E., 2021. Measuring Outcomes of Digital Transformation in Public Administration: Literature Review and Possible Steps Forward. *NISPAcee Journal of Public Administration and Policy.* Vol. 14 no 1. pp.61-86.

Orlova, L.S., 2021. Trends in the development and implementation of digital platforms. *Creative Economy.* Vol. 15, no 1. pp. 35–44.

Semyachkov, K. A., 2019. Transformation of economic relations in the context of the development of the digital platform. *Journal of Economic Theory,* Vol. 16, No. 3. C.

Litvinenko, V. S. ,Tsvetkov, P. S., Molodtsov, K. V., 2020. The social and market mechanism of sustainable development of public companies in the mineral resource sector EURASIAN MINING. *Business and International Management.* no.1. pp. 36-41.

Digital Public administration. Public Expenditure URL: https://spending.gov.ru/np/D/fp/D6/budget / (date of access: 04.02.2024).

Nambisan, S., Wright, M., Feldman, M., 2019. The digital transformation of innovation and entrepreneurship: Progress, challenges and key themes. *Research Policy.* no 48. pp. 103-112.

Babkin, A.V., Mikhailov, P.A., 2023. Digital platforms in the economy: concept, essence, classification. *Bulletin of the Academy of Knowledge.* Vol. 54, no 1. pp. 33-34.

Brunetti, F., Matt, D. T., Bonfanti, A., Longhi, A. D., Pedrini, G., Orzes, G., 2020. Digital transformation challenges: strategies emerging from a multi-stakeholder approach. *TQM Journal ahead-of-print(ahead-of-print).* Vol 32, no 4. pp. 697-724.

Joseph, R. C., 2019. A structured analysis of e-government studies: Trends and opportunities. *Government Information Quarterly.* no 30. pp. 435-440.

Omar, A., Weerakkody, V., Daowd, A., 2020. Studying Transformational Government: A review of the existing methodological approaches and future outlook. *Government Information Quarterly.* Vol. 37, no 2. pp. 101-123.

Lapinskas, A.A., Sodnombalova, T.G., 2019. Modern methodological approaches to the study of economic development directions. Actual problems of the development of modern society: Collection of scientific papers of the Interuniversity scientific Seminar on May 17, pp. 7-10

Pittaway, J.J., Montazemi, A.R., 2020. Know-how to lead digital transformation: The case of local governments. *Government Information Quarterly*. no 37. pp. 3-18

Vial, G., 2019. Understanding digital transformation: A review and a research agenda. *Journal of Strategic Information Systems.* no 28. pp. 2-19.

Chen, Y.C., Hu, L.T., Tseng, K.C., Juang, W.J., Chang, C.K., 2019. Cross-boundary e-government systems: Determinants of performance. *Government Information Quarterly.* no 36. pp. 449-459.

Allmann, K., Radu, R., 2022. Digital footprints as barriers to accessing e-government services. *Global Policy*. Vol. 14, no 5. pp. 84-94.

Lee, J.B., Porumbescu, G.A., 2019. Engendering inclusive e-government use through citizen IT training programs. *Government Information Quarterly.* no 36. pp. 69-76.

Sun, N., Luo, Q., Ran, L., Jia, P., 2023. Similarity matrix enhanced collaborative filtering for e-government recommendation. *Data and Knowledge Engineering.* Vol.145, no 11. pp. 281-298.

Schedler, K., Asker, A. G., Frischknecht, R., 2019. How smart can government be? Exploring barriers to the adoption of smart government. *Information Polity.* no 24(2). pp. 1-18.

Alsaghier, H.M., Ford, M., Nguyen, A., Hexel, R., 2021. Factors Affecting Trust in E-Government. *Journal of Government and Civil Society.* Vol. 5, no 2. pp. 263-276.

Rozhkova, M.A., 2021. "Public information", "open data" and "personal data authorized by the subject for dissemination" - what is it and how are they related? [Electronic resource]. Zakon.ru. January 13. URL: https://zakon.ru/blog/2021/1/13/obschedostupnaya_informaciya_otkrytye_dannye_i_personalnye_dannye_razreshennye_subektom_dlya_raspros (date of access: 04.03.2024).

Androniceanu, A., 2021. Transparency in public administration as a challenge for a good democratic governance. *Administratiesi Management Public.* no 36, pp. 149-164.

Correa, A.S., de Souza, R.M., Silva, F.S.C.D., 2019. Towards an automated method to assess data portals in the deep web. *Government Information Quarterly.* no 36. pp. 412-426.

Begany, G. M., Martin, E. G., 2020. Moving towards open government data 2.0 in U. health agencies: Engaging data users and promoting use. *Information Polity.* Vol. 25, no 3. pp.301–322.

Ansari, B., Barati, M., Martin, E.G., 2022. Enhancing the usability and usefulness of open government data: A comprehensive review of the state of open government data visualization research. *Government Information Quarterly* . no 39. pp. 117-132.

Khan, A., Krishnan, S., Dhir, A., 2021. Electronic government and corruption: Systematic literature review, framework, and agenda for future research. *Technological Forecasting & Social Change.* no 167. pp. 73-91.

Pavlyutenkova, M.Yu., 2019. Electronic government vs digital government in the context of digital transformation. *Monitoring of public opinion: Economic and social changes.* no 5 pp. 120-135.

Androniceanu, A., Kinnunen, J., Georgescu, I., 2020. E-Government Clusters in the EU Based on the Gaussian Mixture Models. *Administratiesi Management Public.* no 35. pp. 6-20.

Al-Mushayt, A. O., 2019. E-Government Services With Artificial Intelligence. *IEEE Access*. no 99(1). pp. 12-21.

Ivanova, V., Poltarykhin, A., Szromnik, A., Anichkina, O., 2019. Economic policy for country’s digitalization: a case study. *Journal of Entrepreneurship and Sustainability Issues.* Vol. 7, no 1. pp. 649-661.

Cherepovitsyn, A.E., Tretyakov, N.A., 2023. Development of New System for Assessing the Applicability of Digital Projects in the Oil and Gas Sector. *Journal of Mining Institute.* Vol. 262. p. 628-642.

Vartanova, E., Vikhrova, O., 2020. Authorities Digital Information Openness as a Tool for Overcoming Digital Divide in Russia. *Theoretical and Practical Issues of Journalism.* Vol. 9, no 4. pp. 575-594.

Shestakova, I., Morgunov, V., 2023. Structuring the Post-COVID-19 Process of Digital Transformatin of Engineering Education in the Russian Federation. *Education Sciences.* no 13(2). pp. 135-150.

Kabanov, Y., 2022. Refining the UN E-participation Index: Introducing the deliberative assessment using the Varieties of Democracy data. *Government Information Quarterly.* no 39. pp. 420-435.

Tangi, L., Janssen, M., Benedetti, M., Noci, G., 2021. Digital government transformation: A structural equation modelling analysis of driving and impeding factors. *International Journal of Information Management.* no 60. pp. 43-67.

Lee, J.B., Porumbescu, G.A., 2019. Porumbescu Engendering inclusive e-government use through citizen IT training programs. *Government Information Quarterly.* no 36. pp. 69-76.

Schoua, J., Svejgaard, A., 2019. Digital by default? A qualitative study of exclusion in digitalised welfare. *Social Policy & Administration.* Vol. 53, no 9. pp. 70-96.

Maphumula, F., Njenga, K., 2019. Innovation in tax administration: digitizing tax payments, trust and information security risk. *Open Innov.* no 156. pp. 304–311.

Methodological Approaches to the Use of Artificial Intelligence Technologies in Teaching

Deeney Irina Anatolyevna[1] [1], Reshetnyak Daria Alexandrovna[1] [2] Klyuchnikov Denis Alexandrovich[2] [3] Shurukhina Tatiana Nikolaevna[2] [4]

[1]*Moscow University Named after A.S. Griboyedov, Moscow, Russia*

[2]*FEFU. Far Eastern Federal University, Vladivostok, Russia*

Keywords: type of perception, artificial intelligence, foreign languages, teaching, methods.

Abstract: The ongoing research is dedicated to the problem of online education improvement. For this reason, the article touches upon the specific methods of teaching based on the student's cognitive perception type. Those types of perception (visual, auditory and kinesthetic) are described in the article in details and certain principles are enumerated to justify the didactic approach accordingly. It is stated that AI technologies are able to recognize the type of student's perception and adjust the didactic material in accordance with student's cognitive needs.

1 INTRODUCTION

The contemporary era of digital technologies being in its constant development, opens more and more horizons for scientific growth in various scholarly spheres including educational one. To refer to this aspect no one can deny the relevance of the teaching profession and special professional training required in terms of digital metamorphoses and globalization. In other words, the modern trend of an online learning environment development, ensuring accessibility of education with virtually no loss of quality, predetermines the competencies of a modern teacher, taking into account the focus on computer technology, on the one hand, and the appeal to basic didactic principles, on the other. At the same time, this circumstance does not mean at all that all future philological teachers must have computer knowledge to the level of creating neural network architecture. However, modern teachers should basicallly understand exactly how to formulate technical specifications to specialists in the field of IT technologies in order to obtain one or another online environment designed directly to meet the requirements for the educational process they are creating. In this context, the most daring and unusual didactic experiments are possible, including reference groups in research, pilot projects, etc. subject to basic methodological approaches and their skillful combination (Zhdanov, 2015). This idea has many times been emphasized by scholars all over the globe as well as the relevance of the online education throughout different educational levels (Kuprieva, 2020; Kuprieva, 2020 (1); Deeney, 2021).

2 MATERIALS AND METHODS

The ongoing research is mostly theoretical and does not require any specific empirical instruments. And at the same time, it is aimed at the search of the proper fundamental methods and ways to study the object of the research from different sides. Moreover, this study due to its complex nature bears a multidisciplinary character and allows to stick to linguistic and extralinguistic (computer) methodology. In other words, the authors take into account the anthropocentric scientific paradigm,

[1] https://orcid.org/0000-0002-1024-7053
[2] https://orcid.org/0009-0000-5480-3763
[3] https://orcid.org/0000-0002-0200-1942
[4] https://orcid.org/0000-0003-2331-6174

interdisciplinarity of research, linguistics, psycholinguistics, anthropology, psychology, ethnopsychology, anthropology, axiology, cultural linguistics, in addition, the methodology of teaching English as a foreign language.

3 RESULTS AND DISCUSSION

As it has been mentioned before, the study bears the methodological character and is based on the combination of knowledge, skills and abilities inherent in the teacher/teacher and aimed at a comprehensive study of the object. It is methodological approaches that predetermine didactic behavior in the chronotope, that is, at a certain stage of learning. However, it cannot be said that methodological approaches are equivalent to educational methods. One of their specific features is situational or relevance and the ability to be in tune with the didactic situation, in which traditional educational methods require adaptation and modernization to solve a number of practical problems. Another specific feature of methodological approaches is their unlimited adaptability to specific didactic tasks and the ability to act as alternative solutions. In addition, methodological approaches allow a combination of a theoretical basis and several practical didactic methods and techniques.

In the complex of the specific features positively described above, methodological approaches are aimed at selecting and adapting methods and techniques for competently solving a particular methodological problem within the framework of the corresponding task and are capable of performing the corresponding fundamental functions:

- studying the genesis of educational tools to find tools for solving a specific problem;
- forecast of the metamorphoses of the educational process, taking into account the available information obtained through a systematic analysis of the knowledge available in pedagogical science;
- carrying out scientific activities alongside with the educational process, taking into account the projection of this activity in order to optimize the process;
- fixation of the educational approach as a holistic process in a complex of all components;
- practice-oriented process and its direction in an applied direction;
- the process of relying on specialized technologies, technical and educational, or a complex of them.

It is the latter function that is essentially associated with the implementation of this project, which involves a combination of digitalization and a traditional approach to the educational process.

Among the methodological approaches, as follows from the analysis of the relevant literature, we can highlight some of the most fundamental ones that are directly related to this project. In other words, the methodological approaches that served as the didactic basis for this project, first of all. Let's start with a brief description of them.

Firstly, we are talking about an anthropological approach, which puts the human factor of educational activity at the forefront, which, in other words, means that the teacher takes an individual approach to each student and cultivates knowledge in each student, taking into account his individual talents and needs. In this project, as well as in any other based on Internet technologies and neural networks, this approach, despite being mediated by computer technology, is fully implemented. We are talking about the so-called individualization of learning by adapting the neural network to a specific student. In this case, the principle of adjusting the neural network to the needs of a specific student is implemented.

Another approach associated with this study is a cultural one, taking into account the cultural and creative ontogenesis of the student, allowing for the individual specificity of each student in the process of solving creative problems and creating in the process of educational activity. It was precisely this formulation of the question that predetermined the tasks set for specialists in the field of computer technology, which, first of all, boil down to adapting and personalizing the neural network to the creative abilities of each student.

An important role in the process of implementing this project is also played by the formative approach, which, in parallel with the process of transferring knowledge, skills and abilities, gives the teacher the right to influence the student in terms of education, the formation in each student of positive motivation for educational activities in general and for a specific subject. In our project, thanks to the implementation of this approach, we provide a special approach to each student according to his abilities and present the material from simple to complex. This approach makes learning understandable and, accordingly, interesting for the student.

The hermeneutic approach, being built into this project as a methodological basis, appeals to the feelings and emotions of the speaker, who independently or with the help of a teacher evaluates his educational activities in terms of needs, success, etc., reflects and carries out further goal setting. In this project, control over the assimilation of material is carried out automatically, that is, directly by the neural network itself, and manually, that is, under the action of the teacher. With all the positive qualities of neural networks, we must not forget about the positive role of the human factor in learning. The teacher, despite the almost complete automation of the process, plays a leading role both in the formation of the content of the discipline and in the individual assessment of the student. And if the neural network adapts the content taking into account the selection of the optimal option from the existing database (tasks), then the teacher can independently show creativity and control the student's educational activities.

The next fundamental and specific methodological approach implemented in this project is biogenetic. It is he who immanently takes into account the learner's mode of perception. This approach itself makes it possible to search for a correlation between the psycho type according to the type of perception of a student and his educational potential. In this project, as stated earlier, we rely on the understanding that there is a certain relationship between the leading type of perception (visual/auditory/kinesthetic) and the mastery of material for learning a foreign language. This idea in psychological research belongs to a whole galaxy of scientists who consider the psychological prerequisites for teaching children with different types of perception (Borisjonok, 2022; Navalihina, 2013; Puchkova, 2016; Rogozhnikova, 2011; Chibisova, 2010).

So, as has been repeatedly noted at different stages of the study, this project is built on proving the hypothesis (it is confirmed by experimental data) that students/learners with different types of information perception (visual, auditory, kinesthetic) learn information differently, respectively, the success of learning depends to a large extent on the nature of the material presented for study according to the leading channel of perception. The attraction of new computer capabilities is due to the need to quickly determine both the level of language proficiency and the specific mode of perception of each person. Computer technologies and forms significantly saved time for conducting experiments and testing, and also ensured objectivity of the process. Moreover, through such digital work, an appropriate database was created for subsequent training of the neural network. This possibility is based on the ability of neural networks to learn from samples of options, adapt to conditions and continue to improve based on the existing learning algorithm (Gavrilova, 2016).

So, understanding the fact that, taking into account the technologization of the process, one can count on the speed of task implementation, further work on solving the project's problems was built taking into account the setting of didactic tasks and methodological approaches, based on traditionally defined stages, including setting the goals of the topic being studied, explaining the material, training material for consolidation, generalization of material to bring it into the system, final control of assimilation and feedback, justification of the prospects for further training (Antamoshkin, 2012). And again, all stages were accompanied by training with the participation of a neural network, which automatically determined the mode of presentation of the material (emphasis on the perception channel) and adjusted to the specific needs of the student.

Experience in the project and the results obtained allow us to speak about the unconditional didactic and methodological potential of the neural network. However, as is obvious, such a positive result is possible taking into account high-quality planning, when all didactic stages are correctly followed, which are accompanied by the use of various methods of IT training, taking into account the potential for participation and activity of each student. Here, first of all, we are talking about the process of planning training and selecting material, verifying and preparing test tasks, and building a neural network architecture. It was precisely at this stage that the participation of the student was not expected, especially in the case of the present experiment, which was entirely aimed at proving the hypothesis about the dependence of the quality of learning on the priority channel of perception of the listener. It was at this stage that tasks were selected for the experimental group in order to obtain initial empirical data for constructing a neural network. These data subsequently predetermined the nature of the training system, the sequence, quality and quantity of tasks and test material offered to the student.

Let us dwell directly on the description of this task, which was solved in the project in order to achieve the general goal.

Initially, tasks were selected for the experimental group in order to obtain initial empirical data for constructing a neural network. In this case, we relied on a systematic analysis of literature in various branches of science and came to the conclusion that different people perceive information differently. This assumption is not new; it acquired a scientific form around the 6th century. BC. And if at the beginning the formation of this approach was based on the correlation of a person with society, that from about the 18th century, the personal benefit of a person and the assessment of all phenomena based on their usefulness and acceptance by an individual became paramount (Bentham, Smith). Further, during the development of social psychology in the 19th–20th centuries. psychology moved from a priori conclusions to laboratory experiments, and it was at this time that attempts to study the differences in people's perceptions began to appear as a priority. At this very time, tests appeared that predetermined different types of perception of people, which became a prerequisite for the emergence of socionics.

Modern teaching methods, including didactics of foreign languages, are based on the latest developments of scientists in related fields of science and are thereby being improved. Thus, one of the important areas of didactic dogma of today is the understanding of the existence and dominance of different types of perception (Borisjonok, 2022; Puchkova, 2016; Chibisova, 2010). In forming the hypothesis and constructing the subsequent research algorithm, we relied on scientifically proven facts that people with different types of perception perceive oral text, its graphic presentation, working with a book, computer, oral and written communication differently. Moreover, such people not only master tasks that are "suitable/unsuitable" for their temperament at different speeds, but also achieve results with varying degrees of success and strive to adapt to their own type of perception (Borisjonok, 2022; Rogozhnikova, 2011).

Determining the type of perception is a fairly simple process, and if a psychological test is carried out to clarify the type of perception, we can talk about a conditional independent subjective assessment by students of themselves. Such an assessment is possible mainly in the first stages. Further, it is possible to use already proven tests, one of which is, for example, a psychological test using the method of "Diagnostics of the dominant perceptual type" by S. Efremtsev. However, this is not the only or even the most ideal and absolute test available for establishing a person's type of perception. Such tests are endowed with a special error, which in the case of learning foreign languages has the most disastrous results.

Educators and psychologists, based on a variety of experimental data, note that, for example, the visual learner has difficulty perceiving by ear without illustrative graphic support, while the auditory learner is for the most part capable of perceiving oral information and correspondingly fixing it in memory. Taking these features into account, a teacher can build an individual learning trajectory, but at school/university there is often not enough time to identify the type of perception, which follows from generally accepted practice. It would be good if the teacher had the opportunity to conduct specific testing for the type of perception of the student or establish this circumstance during individual lessons (several lessons for the teacher are quite enough), but in view of the training program rushing forward, the teacher does not have enough strength or time to clarify corresponding sources (Rogozhnikova, 2011).

A systematic analysis of the scientific literature shows that it is traditionally possible to establish four basic types of perception. Here, of course, it should be noted that all of them are not the Absolute and undergo changes and are supplemented in the process of life. However, despite all the existing metamorphoses, students retain their innate type of perception.

Typical ways to determine the leading type of perception in modern science are testing, including the above-mentioned methodology, observation (vivid images and pictures are used by the visual; sensations are characteristic of kinesthetic; sounds and intonations are characteristic of auditory; logical connections and thoughts determine digital); associations (a person is given associations for a specific type of perception and his sensations are clarified); observation of speech (emphasis on words used). In the latter case, we are talking about verbs of visual perception for the visual, auditory for the auditory, emotional states for the kinesthetic and logical inferences for the digital. However, the latter observation is mostly complementary rather than fundamental (Puchkova, 2016; Chibisova, 2010).

So, based on the position that each type has its own characteristics that affect its perception of surrounding information, any educational processes, interaction with other people, to build a training sample and the architecture of the corresponding neural network, let us recall the initial parameters in the corresponding tables. Note that the initial diagnostic tracking of the student's activity will also add information to determine the type of perception. Approximate parameters for organizing the operation of the platform are reflected in the table below (see Table 1).

Table 1: Student activity in correlation with the type of perception.

Type of Perception	Communication	Preferable Internet Content	Internet Searches
Visual	Speech lacks prepositions and adverbs, consists of simple phrases	Prefers computer games with good graphical design	Formulates the internet searches thoroughly
Auditory	Speech is characterized by complicated and grammatically correct phrases	Prefers audio books, loves imagination games, has no difficulties in studying, reads the manuals before starting to work with something	Formulates the internet searches easily
Kinesthetic	Speech is characterized by short and grammatically incorrect sentences	Prefers physical contact to any other form of perception, would better memorize if touches the object	Formulates the internet searches with great difficulty

Let us recall that 850 students were involved in the experiment, who anonymously completed the task and passed on the information received to the developers so that they sorted the received data and passed it on to specialists for subsequent modeling of the neural network. The obtained data on the set of characteristics were checked for compliance of the completed task with the conditions of this task, ranked into groups and in the same form were transferred to specialists in the field of IT technologies for the purpose of subsequent modeling of the neural network. Based on the information received from specialists in the field of computer technology, the questions were adjusted and the theory was tested to determine the direction of the perception.

In the absence of contradictions in our theory (this conclusion is based on a preliminary report from specialists in the field of computer technology that the hypothesis was fully confirmed during the construction of the neural network), the directions for forming the content of the developed didactic resource were determined and the following facts in e-learning were taken into account:

- to fill resources addressed to the visual, special attention is paid to the graphic parameter (color, size, shape); texts are purely descriptive; tasks are described in as much detail as possible, examples are given; due to the nature of work with visuals, there is a frequent change of types of activities;

- to fill the kinesthetic resource, the concept of "game" and a large number of repetitions are at the forefront; at the initial level, exercises on comparing resource information and data coming from the environment are especially relevant; the focus is on the student's sensations and additional work involving motor activity;

- the auditory resource is saturated with musical and sound accompaniment of visual support (for beginners to learn a foreign language it is impossible to rely solely on auditory perception, visual supports are required); At the same time, the soundtrack is ranked from easy to difficult levels.

4 CONCLUSION

The listed principles formed the basis for the formation of the platform's content. At the same time, taking into account the mode, the selection of the content of educational activities is based on a combination of the most common approaches. The first of them involves direct material education, when the amount of information relevant to the student's perception is put at the forefront. Within the framework of this approach, work is carried out with a large volume of data and special requirements are imposed on the assimilation of encyclopedic knowledge, which is verified through testing and control measurements as a result of mastering a particular stage or section.

The second approach is the theory of formal education. As a result of this approach, the emphasis is placed directly on the formation in the student of a holistic understanding of the subject, a system of knowledge and skills in search scientific activity, the ability to operate with a large volume of data, to be based on methods of deduction and induction, analysis and synthesis of information. This approach is the most relevant in today's time, it has proven itself on the positive side and allows you to get quite impressive results from students. At the same time, we note that there is no absolute in this matter. This means that in both approaches we will encounter elements of each other. Moreover, working with computer teaching methods allows you to combine as much as possible all the positive aspects of both approaches and obtain the most impressive results.

What has been said and listed above, of course, is not an absolute, but it allows us to determine the directions for further improvement and filling of the resource, in principle, as well as work prospects. Moreover, due to the fact that the entire resource is correlated with neural network data, the entire process is automatically adjusted and improved in the process of individualization.

REFERENCES

Antamoshkin, O.A., 2012. Programmnaja inzhenerija. Teorija i Praktika [Jelektronnyj resurs] : Uchebnik. Krasnojarsk: Sib. Feder. un-t, 2012. - 247 p.

Borisjonok, I., 2022. Audialy, vizualy, kinestetiki i digitaly. URL: http://vseklass.ru/obshhenie/audialy-vizualy-kinestetiki-i-digitaly (Date of Access: 07.04.2024).

Chibisova, E. Ju., 2010. Obuchenie inostrannomu jazyku s uchetom modal'nostej vosprijatija studentov. URL: https://cyberleninka.ru/article/n/obuchenie-inostrannomu-yazyku-s-uchetom-modalnostey-vospriyatiya-studentov (Date of Access: 07.04.2024) [in Russian].

Deeney, I., et all, 2021. Some Aspects of Ai-Technologies in Education. Revista San Gregorio.

Gavrilova, T.A., 2016. Inzhenerija Znanij. Modeli i Metody. SPb.: Lan' 324 p.

Kuprieva, I. et all, 2020. Creation of the Simplest 3d Models for Additional Education. *Turismo-Estudos E Praticas.*

Kuprieva, I. et all, 2020. Difficulties of Educating People With Socio-Educational Needs. *Propósitos y Representaciones.*

Navalihina, A.I., 2013. Struktura Associativnogo Polja V Uslovijah Dominirovanija Raznyh Modal'nostej Vosprijatija. URL: https://cyberleninka.ru/article/n/struktura-assotsiativnogo-polya-v-usloviyah-dominirovaniya-raznyh-modalnostey-vospriyatiya (Date of Access: 07.04.2024)

Puchkova, E.S., 2016. Osobennosti podgotovki materialov prepodavateljami pedagogicheskih vuzov dlja provedenija vebinarov s uchetom osobennostej individual'nogo vosprijatija uchebnoj informacii studentami. URL: https:// cyberleninka.ru/article/n/osobennosti - podgotovki - materialov - prepodavatelyami-pedagogicheskih-vuzovdlya-provedeniya-vebinarov-s-uchetom-osobennostey (Date of Access: 07.04.2024).

Rogozhnikova, T.M., 2011. Dominantnye Modal'nosti Vosprijatija i ih Dinamika. *Vestn. Bashkir. un-ta. Ufa,* T. 16, № 2 - pp. 469-473.

Zhdanov, A.A., 2015. Avtonomnyj iskusstvennyj intellekt. 2-e izd. M.: BINOM. Laboratorija znanij, 350 p.

Formation of an Innovative Urban Environment in the Context of Implementing the "Smart City" Concept

Irina N. Tretyakova[1] [1], Tatiana S. Kolmykova[1] [2] , Irina G. Ershova[1] [3]
and Nadezhda A. Serebryakova[2] [4]
[1]Faculty of Economics and Management, Southwest State University, 50 let Oktyabrya str., Kursk, Russia
[2]Faculty of Economics and Management, Voronezh State University of Engineering Technologies, 19, Revolution Av, Voronezh, Russia
iren_sin@list.ru, t_kolmykova@mail.ru, ershovairgen@yandex.ru, nad.serebryakova@mail.ru

Keywords: Digitalization, innovative environment, innovative urban environment, smart city, digital technologies.

Abstract: Currently, digital transformation affects all sectors of the economy concentrated in cities, directly contributing to their vitality. In order to create sustainable favorable living and business conditions for both current and future generations, a complex of digital solutions and organizational measures are being implemented in urban spaces to realize the main directions of the "Smart City" concept. The formation of an innovative city depends on components such as dynamism, management, environment, and people, along with convenient application interfaces, diverse and accessible services including healthcare, transportation, intelligent education, and energy. Digital data serves as the foundational platform for the effective functioning of all these components. The efficiency of generating, collecting, storing, analyzing, and processing data within urban spaces influences the effectiveness of the entire "smart" city system. The aim of the research is to identify the features of forming an innovative urban environment in the context of implementing the "Smart City" concept. Through theoretical analysis, abstraction, induction, and deduction, the study generalizes and structures elements that reveal the content of the innovative urban environment. It is established that digitalization is a significant factor in shaping a smart city. The analysis conducted in the study proves that rapid progress towards building an innovative urban environment within the "Smart City" concept is facilitated by dynamic internet development in the region, innovative technologies, and active interaction with socio-economic systems. The scientific novelty lies in refining theoretical positions and developing practical recommendations for improving the formation of the innovative urban environment under the implementation of the "Smart City" concept.

1 INTRODUCTION

Currently, the formation of urban environments is associated with transformational processes occurring in the context of digitalization. Modern transformation processes in urban environments occur amidst the rapid proliferation of digital services and technologies, expanding the potential of urban spaces.

T.S. Kolmykova et al. argue that digitalization contributes to achieving a complex of positive effects, namely creating new business models, forming a basis for breakthrough innovations, and ensuring long-term competitiveness (Kolmykova, Klykova, Makarov, 2020). A.I. Shinkovich, T.V. Malysheva, and I.G. Ershova affirm that digitalization fundamentally changes the principles of urban community functioning and enables addressing the development challenges of socio-economic systems (Shinkevich, Malysheva, Ershova, 2023). According to A.S. Obukhova et al., digitalization, in general, contributes to increasing the efficiency of managing urban environment development (Obukhova, Sitnikova, 2019).

[1] https://orcid.org/0000-0001-6227-0848
[2] https://orcid.org/0000-0002-5633-4283
[3] https://orcid.org/0000-0002-0675-0764
[4] https://orcid.org/0000-0002-2952-9587

In the author's interpretation, the innovative environment is a comprehensive concept reflecting the interrelation of changing resources and factors as harmonized elements in a state of internal stability. Moreover, the innovative environment dynamically changes, with flexible external boundaries, influencing all participants in the innovation process.

The active integration of innovations in cities is a necessary component for enhancing the efficiency of urban space livelihoods. Studies by researchers such as T. Nam, T.A. Pardo (Nam, Pardo, 2011), H. Partridge (Partridge, 2004), S. Harrison, B. Ekman, R. Hamilton, P. Hartswick, J. Kalaignanam, J. Parashak, and P. Williams (Harrison, Eckman, Hamilton, Hartswick, Kalagnanam, Paraszczak, Williams, 2010) reflect the issues of studying the structural components of the innovative city and the basic problems of smart city formation.

We affirm that the innovative urban environment consists of a series of elements in functionally coordinated relationships. We consider the innovative urban environment as a hierarchical space formed under the influence of external and internal factors, aimed at increasing the efficiency of socio-economic, ecological, technological, and organizational processes at micro-, meso-, and macro-levels.

Overall, the development of the innovative urban environment goes hand in hand with creating the best conditions for implementing effective innovations. To achieve this, it is necessary to form an innovative environment and create the most favorable conditions for innovative activities (Merzlyakova, Goncharov, Gribov, 2022).

Despite the high significance of the results obtained by scientists and practitioners, there is currently a need to research the specifics of forming an innovative urban environment in the context of implementing the "Smart City" concept.

2 MATERIALS AND METHODS

Various methods aimed at achieving the stated goal were applied within the framework of the study.

In the first part of the research, through critical analysis of previously published scientific works, the authors formulated their own vision of the innovative urban environment and identified the need for its digitalization. The logically justified exposition of theoretical aspects of the research is based on the application of methods of abstraction, induction, deduction, generalization, and structuring.

The second part of the research was carried out at an empirical level. Qualitative and quantitative research methods allowed identifying that the formation of the urban environment in the context of digitalization is directly related to the spread of the internet and the development of new technologies, which serve as tools for creating balanced socio-economic systems.

Purposeful and systematic application of various methods allowed the authors to identify the features of forming the innovative urban environment in the region, outline directions for its transformation, and propose recommendations for its improvement.

Overall, the scientific research complies with generally accepted methodological principles, and the structure and research design enable achieving the desired result.

3 RESULTS

The city of Kursk, like many cities in Russia, is oriented towards creating an innovative urban environment. Its formation follows the key directions of the "Smart City" concept. "Smart cities" form an innovative ecosystem aimed at expanding the boundaries of social interaction, creating economic value through the collection, processing, analysis, and utilization of data. The formation of an innovative ecosystem cannot be imagined without an integrated information system (Shkarupeta, Kolmykova, Serebryakova, 2023).

The dynamic development of the internet in the region contributes to the establishment of an innovative urban environment within the framework of the "Smart City" concept. According to the results of 2022, approximately 80% of enterprises and 83.4% of the population in the Kursk region have access to the internet (Figure 1).

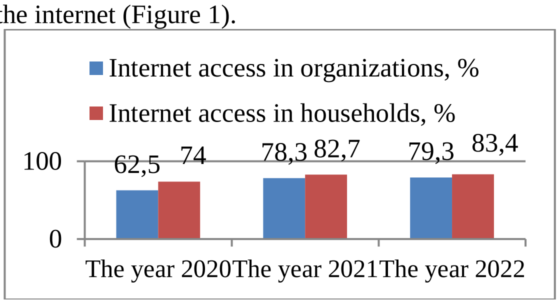


Figure 1: Internet access usage in organizations and households (as a percentage of the total).

It is important to note that digital technologies are considered as one of the possible responses to the challenges associated with sustainable urban environment formation. According to statistics, in the Kursk region in 2022, expenses for the implementation and utilization of digital technologies amounted to over 5 billion rubles, with internal expenses accounting for 3.9 billion rubles and external expenses approximately 1 billion rubles.

Table 1 illustrates the dynamics of digital technology usage in organizations in the Kursk region.

The implementation of digital technologies in the urban environment contributes to the creation of entirely new conditions for the city's existence, applying principles of citizen social involvement in decision-making, interaction, partnership, and social innovations (Kazarenkova, Obukhova, Maslov, 2021).

Table 1: Usage of digital technologies in organizations (as a percentage of the total number of organizations) in the Kursk region.

Digital technologies	2020	2021	2022	Change over the period
Personal computers	86,7	86,8	85,2	- 1,5
Servers	38,7	33,9	36,6	- 2,1
Local area networks	53,2	54,2	56,8	+ 3,2
Cloud services	22,2	25,2	29,0	+ 6,8
Big data collection, processing, and analysis technologies	18,5	18,7	23,0	+ 4,5
Internet of Things	6,3	8,6	6,9	+ 0,6
Artificial intelligence technologies	3,8	5,4	3,8	0
Digital platforms	15,3	12,5	12,7	- 2,6

Within the framework of the regional project aimed at creating an innovative urban environment under the implementation of the "Smart City" concept, the following directions are operational:

Smart Home: Equipping with smart meters, motion sensor lights, surveillance cameras, solar panels, and energy storage. Active application of NB-IoT smart development: digital barriers, smart intercoms, room temperature adjustment according to weather conditions; automatic lighting control; visualization of system management through 3D models.

Smart Housing and Utilities Management (HUM): Implementation of systems for monitoring and controlling emergencies and emergencies in municipal networks; intelligent systems for tracking communal resource consumption; electronic applications for participating in important matters from the management company (voting); voice assistant.

Smart Healthcare: The region operates a Unified Information System for ambulance services, a system for purchasing drugs using digital technologies, a Unified Pharmacy Information Center. IT applications have been introduced, allowing electronic prescriptions, maintaining electronic medical records, opening or closing electronic sick leave. The radiological reference center operates. Electronic appointment scheduling with a doctor. Testing of "Voice Services" technology.

Smart Society and Smart Education: A digital educational environment of e-learning has been formed, Smarteduction educational content is active, the Digital Educational Resource "Native Edge, Forever Beloved" is in demand, the Kursk region's Digital Educational Portal and the Kursk Center for Distance Education "New Technologies" are operational. The IT Cube operates (Secondary School No. 60, Kursk). "Digital Literacy Lessons" (Secondary Schools of the Kursk region) are actively conducted.

Smart Transportation and Safe City: The Unified Emergency Services Call System (Rostelecom) operates around the clock. Video surveillance with license plate and facial recognition (Rostelecom). "Platon" system, GLONASS/GPS navigation. Smart traffic lights, T7 solar-powered traffic lights. Smart bus stops equipped with digital devices that provide information on urban transport movement along the specified route.

Smart Economy: Financial sector: Sberbank's digital ecosystem, Tinkoff Bank; manufacturing sector: LLC "Sovtest ATE" produces MEMS sensors for security and monitoring systems; agricultural sector: LLC "Mirotrorg-Kursk" applies smart bolus sensors. "Digital State Management" - 84 MSU.

The regional project "Smart City" is formed with the aim of improving the quality of urban resource management. Within the project, tasks related to creating favorable living conditions for people, establishing a comfortable and safe environment, and expanding and increasing the efficiency of urban infrastructure are to be solved.

The analysis conducted showed that the implementation of the "Smart City" concept in the Kursk region is at a challenging stage, requiring understanding and concrete actions to enhance the effectiveness of digital technology implementation and create a platform for forming an innovative urban environment. It is innovative solutions in the urban environment that will create conditions for more comfortable living, make the urban community more cohesive in addressing social and community issues. Key components are digital intelligent systems (cloud technologies, data warehouses, social networks), which are progressive in creating balanced socio-economic systems.

4 DISCUSSION

The questions of creating an innovative environment as a necessary platform for establishing an innovative urban space are dictated by modern aspects of digitization. The significant push toward digitization is associated with the spread of the COVID-19 coronavirus infection. Self-isolation has stimulated all sectors of the economy to transition to a new working format and rapidly develop channels and services for conducting business online (Obuhova, Merzlyakova, Sokolov, Chernykh, 2019). This situation has created a new approach to building urban space and actively engaged users in the process of digitization. Under the influence of digitization, a clear trajectory for implementing the "Smart City" concept has emerged, both at the level of individual regions and the country as a whole.

A critical analysis of the experience of developing "smart" cities has shown that their construction is influenced by several factors. Let's highlight some critical factors that shape the directions for transforming the urban environment within the "Smart City" concept:

- Institutional factors, forming norms for the use of digital systems within the development strategy of municipalities.

- Economic factors, linked to the city's competitiveness growth and the well-being of its citizens.

- Organizational and managerial factors include project management issues in the field of smart city formation, taking into account the specifics of a particular municipality.

- Technological factors, associated with the possible use of various technological solutions, their availability, integration into the existing digital city model, etc.

- Environmental factors, involving the use of technologies to address environmental issues, efficient use of natural resources, protection of natural objects.

- Social factors, implying consideration of the interests of the city's residents and its communities.

The formation of the "Smart City" of Kursk is based on the model of the existing city, taking into account the factor of digitization. The state's policy regarding the formation of "smart cities" is directly related to the economy and its reforms. Requirements are directly set for the construction of new organizational structures that will correspond to the current level of market relations and will be combined with state regulation of investment processes, as well as create conditions for attracting various investments, including state, commercial, private, and foreign investors (Sitnikova, Tretyakova, Kazmin, Zimina, 2020). A significant aspect is the necessity of implementing interconnected subsystems. First and foremost, e-government systems should be transformed, aimed at increasing the efficiency of communication between the city administration, various institutions, and residents.

Digital systems, functioning based on big data analysis, serve as a connecting component of the unified information environment of the "smart city." They facilitate real-time information processing and quick decision-making (Serebryakova, Solomatina, Dorokhova, 2020). The system consists of various subsystems of urban economy sectors: smart parking and informational alerts for residents, low-emission vehicles, smart surveillance and security, energy-efficient lighting, rational waste management, remote property management, innovative water purification methods, and much more. The use of these technologies contributes to increasing the efficiency of urban services and ultimately improves the quality of service to the population .

Despite the existence of a program for implementing elements of the "smart city" concept and the implementation of some digitization projects, it is necessary to prioritize and solve tasks for forming an innovative urban environment for the city of Kursk and the region as a whole.

It is worth noting that the formation of an innovative urban environment and the implementation of the "Smart City" concept are possible only with the simultaneous fulfillment of a number of conditions:

- Synchronization of actions in developing and adopting management decisions in the implementation of the "Smart City" concept.

- Increasing the level of innovation activity of all market participants involved in the development, implementation, and implementation of the "Smart

City" concept through the development of appropriate stimulation and motivation tools.

- Adaptation of the conceptual provisions of the "Smart City" project to the needs and conditions of a specific urban environment, as well as to the potential of specific sectors of the urban economy.
- Determination and justification of temporary stages for the gradual systematic implementation of projects within the "Smart City" concept in relation to the conditions of a specific urban environment.
- Formation of qualified personnel for the implementation and development of projects within the "Smart City" concept on an innovation-technological basis, including the use of distance learning technologies and online learning opportunities.
- Conducting assessment and monitoring of the effectiveness of the state management system of the process of implementing projects of the "Smart City" concept.

5 CONCLUSION

Overall, the Kursk region is in the process of establishing a digital space and is oriented towards creating an innovative urban environment. However, despite the activity in the digitization sphere and the construction of a "smart" city, most projects suffer from insufficient funding. In this regard, seeking external investors and increasing the region's innovative attractiveness become the leadership's top priorities. It is precisely the lack of funding and digital inequality, which reflects the real situation regarding the availability of communication tools and solutions implemented at the regional level, that are inhibiting factors in the path towards building an innovative urban space within the framework of implementing the "Smart City" concept.

Within the scope of this study, it has been determined that digital technologies create the prerequisites for the successful implementation of the "Smart City" concept. Integration into the digital process and the creation of an innovative urban space open up new horizons for successful operation and development. Active engagement with citizens in addressing important city life issues serves as the starting point for city reform under the "smart" city system. If the shortcomings do not deter the city's residents, where modernization is planned under the "Smart City" concept, the result will be an attractive city for living, integrated into regional and international intellectual networks, which will be able to maximize the use of available resources and information within its limited territory efficiently.

REFERENCES

Kolmykova, T. S., Klykova, S. V., Makarov, N. Y., 2020. "Digitalization as a new paradigm of socio-economic development. *Economics and Management: problems, solutions*. Vol. 5, No. 11(107). pp. 5-9.

Merzlyakova, E. A. Goncharov, A. Yu., Gribov, R. V., 2022. Modern features of the formation and development of the innovative potential of economic systems. *Organizer of production.* Vol. 30, No. 3. pp. 58-66.

Obukhova, A. S., Sitnikova, E. V., 2019. Features of innovation process management. *Bulletin of the North Caucasus Federal University.* No. 2(71). pp. 57-61.

The official website of the governor and the government of the Kursk region. Regional project "Smart City" [Electronic site] 2024. // Access mode: https://kursk.ru/region/projects/natsionalnaya-programma-tsifrovaya-ekonomika-rossiyskoy-federatsii/regionalnyy-proekt-umnyy-gorod/?ysclid=lu4aru63i1561386369

The official website of the Federal State Statistics Service [Electronic resource] 2024. // Access mode: https://rosstat.gov.ru/folder/210/document/13204

Smart Cities - cities of the future? [Electronic resource] 2024. // Access mode: URL: http://greencapacity.ru/ru/information/smart-cities.

Sitnikova, E. V., Tretyakova, I. N., Kazmin, A. Yu., Zimina, E. A., 2020. Investment Aspects of Business Development in Russia. Education Excellence and Innovation Management: A 2025 Vision to Sustain Economic Development during Global Challenges : Proceedings of the 35th International Business Information Management Association Conference (IBIMA). Spain: International Business Information Management Association (IBIMA), P. 9489-9494.

Kazarenkova, N., Obukhova, A., Maslov, A., 2021. Implementing the Social Functions of Business in the Digital Economy. SHS Web of Conferences : International Conference on Economics, Management and Technologies 2021 (ICEMT 2021), Yalta, Russia, 17–19 мая 2021 года. Vol. 110. Yalta, Russia: EDP SCIENCES, – P. 01031.

Nam, T., Pardo, T. A., 2011. Conceptualizing smart city with dimensions of technology, people, and institutions. Proceedings of the 12th Annual International Conference on Digital Government Research. P. 282–291.

Serebryakova, N. A., Solomatina, E. D., Dorokhova, N. V., 2020. Resources for Innovative Development of the Region in the Context of Digital Economy. Vol. 148, P. 253-256.

Partridge, H., 2004. Developing a human perspective to the digital divide in the smart city. In Proceedings of the Biennial Conference of Australian Library and information Association. http://eprints.qut.edu.au/1299/1/partridge.h.2.paper.pdf

Shinkevich, A. I., Malysheva, T. V., Ershova, I. G., 2023. Selection of Potential Regions for the Creation of Intelligent Transportation Systems Based on the Machine Learning Algorithm Random Forest. *Applied Sciences (Switzerland).* Vol. 13, No. 6. P. 4024.

Shkarupeta, E., Kolmykova, T., Serebryakova, N.. 2023. Cenological approach in industrial ecosystem research in transition to industry 5.0 . E3S Web of Conferences, 371, 03054

Obuhova, A., Merzlyakova, E., Sokolov, A., Chernykh, Ya., 2019. Technology and Prospects of Digital Economy Development. Vision 2025: Education Excellence and Management of Innovations through Sustainable Economic Competitive Advantage : Proceedings of the 34rd International Business Information Management Association Conference, IBIMA 2019. Madrid: International Business Information Management Association, P. 13648-13655.

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., Williams, P., 2010. Foundations for smarter cities. *IBM. Journal of Research and Development.* Vol. 54, № 4. P. 1–16.

Factor Quantitative and Qualitative Analysis of the GDP Dynamics of Russia and China

Vladimir Fedotov[1][a], Svetlana Pshenichnikova[2][b] and Ekaterina Naumova[2][c]
[1]Saint Petersburg State University of Industrial Technologies and Design Saint Petersburg, 191186, Russian Federation
[2]Saint Petersburg University of Economics, Saint Petersburg, 191023, Russian Federation
fedotov.vladimir@yahoo.com, sveta_nikolaevna@list.ru, ekaterinaumova20@yandex.ru

Keywords Economic growth, sanctions, Quantitative analysis of factors, GDP dynamics, Russian economy, Chinese economy, Competitiveness.

Abstract The article, based on the use of econometric modeling, identifies the most important factors of GDP dynamics in the Russian and Chinese economies. Particular attention is paid to the approach and experiences of the two countries during the "sanctions life", as well as the common goal gaining momentum – strengthening international cooperation, including in the economic sphere.

1 INTRODUCTION

To compare the results of the functioning of the economies of different countries in order to analyze their economic activity, competitiveness, and economic growth, a universal macroeconomic indicator is needed, which currently acts as GDP (gross domestic product).

In general, the history of GDP research indicates the continuous improvement of the methodology and understanding of the essence of this indicator. The introduction of this concept by S. Kuznets was an important step in the "new" measurement of the state of national economies. S. Kuznets first conducted research on measuring the volume of national production in the 1930s in the United States. It follows that such an indicator as GDP can give an extensive description of the economic situation in a country, and it is also convenient for conducting various studies and cross-country comparisons. Later in this article, this indicator will be used for modeling purposes.

China and the Russian Federation occupy the most significant economic position in the international arena among the BRICS, SCO and the Eurasian space as a whole. India also shows positive GDP dynamics and active participation in international cooperation, we expect to further carry out a factor analysis of GDP dynamics in this country. We consider it important to identify the factors that most significantly affect the dynamics of GDP in Russia and China for the period 2011-2022. In the course of the study, two econometric models were built based on five quantitative and qualitative indicators, each of which will be discussed in detail later.

2 MATERIALS AND METHODS

There are direct and inverse relationships in the economic system. The volume and dynamics of GDP directly determines all the main parameters of the functioning of the economy, in particular, the volume of exports and the country's capabilities in terms of imported goods and services, the amount of R&D costs, the volume of investments in fixed assets, human capital, and financial assets.

In this context, the mechanism of distribution of products and income will play a significant role. As you know, the reproduction of a product can be carried out on the same scale, and there may also be situations of a decrease in its volume or growth. We believe that the separately considered export and

[a] https://orcid.org/0000-0002-3529-6230
[b] https://orcid.org/0000-0001-5186-718X
[c] https://orcid.org/0009-0004-7437-3958

import flows, changes in their dynamics and correlation with GDP volume give a completer and more detailed picture in this analysis than using such a parameter as net exports or net imports, since these parameters are most sensitive to the global conjuncture and geopolitical transformations.

The first stage of building the model was to determine the type of function. The linear regression model is widely used and convenient in calculations, the general form of which can be represented as follows:

$$Y = b_0 + b_1x_1 + b_2x_2 + \cdots + b_nx_n \qquad (1)$$

The dependent variable (Y) is the volume of GDP of Russia and China based on statistics from the information sites of the Federal State Statistics Service and the World Bank Group.

Table 1: Dynamics of GDP of Russia and China for the period 2011-2022.

Years	The volume of Russia's GDP, billion rubles	The volume of China's GDP, billion dollars
2011	60114,0	7551,55
2012	68103,4	8532,19
2013	72985,7	9570,47
2014	79030,0	10475,62
2015	83087,4	11061,57
2016	85616,1	11233,31
2017	91843,2	12310,49
2018	103861,7	13894,91
2019	109608,3	14279,97
2020	107658,2	14687,74
2021	135295,5	17820,46
2022	153435,2	17963,17

In general, there is a gradual increase in the volume of domestic GDP, but it should be noted that there are fluctuations in its dynamics. The restrictions 2022 also affected the sphere of trade, and there are noticeable changes in the volume of exports and imports. However, according to the Federal State Statistics Service, the dynamics of Russia's GDP at current prices turned out to be positive by the end of 2022, reaching the highest value of 153 435,2 billion rubles during the study period. In terms of this, it amounts to 2,22 trillion dollars, which corresponds to the ninth place in terms of GDP in the world ranking. At the same time, in terms of GDP in terms of purchasing power parity, the Russian Federation ranked fifth in the world with a value of 5,33 trillion dollars, with a small margin from Japan, which ranks fourth in this parameter (5,7 trillion dollars). China ranks first (30,3 trillion dollars), the second is the United States – 25,5 trillion dollars, the third is India – 11,8 trillion dollars.

Regarding China, it is important to note that there are also certain restrictions on its economic activities, initiated by the United States since the 1990s. However, even under severe restrictions, the "economic miracle" of the Chinese economy has not gone unnoticed. The sanctions were mainly aimed at reducing China's exports, the tariff system suffered, a ban on the import of high-tech products was introduced, and the issue of Taiwan's status is currently acute. Despite such political difficulties for the functioning of the economy, the Chinese government is finding ways to solve socio-economic problems through rather harsh reforms combining elements of planned and market economies.

Let's move on to the analysis of factors affecting the dynamics of GDP in the studied countries. First, let's start with the volume of exports and imports for the period 2011-2022. These factors have a strong impact on the volume of national production, stimulating its growth, activating international cooperation, in particular, inter-country, interregional and global trade.

The Russian Federation is the main exporter of natural resources, a significant part of which is occupied by energy resources, products of the agricultural and food sectors. If we talk about the country's imports, there is a predominance of mechanical engineering products, as well as intermediate raw materials necessary for the production of final goods already in the country, for example, for assembly plants, the preparation of beverages from concentrates, various components for the pulp and paper industry (for example, "bleach" for paper), etc.

Regarding China, it is known that the basis of the country's exports is industrial equipment and machinery, for example, machine tools or electronic equipment. The country is also a major supplier of electronics, computers, and computing machines. Plastic and rubber products, textile industry products, the manufacturer of which is China, can be found in the markets of any country. The structure of imports is dominated by energy resources, for example, China imports a significant amount of oil, gas, coal and other minerals. There is also a need for agricultural products capable of meeting the needs of a large number of the population, namely 1,411 billion people as of 2023. During the period of severe sanctions pressure, the PRC faced the task of increasing its resources for the production of high-tech products. For these purposes, foreign specialists were invited to the country, and the government invested large sums in the creation of laboratories and centers in such major cities as Beijing, Shanghai and Guangzhou.

Let's turn to Table 2, which presents indicators characterizing the volume of exports and imports in Russia and China for the period 2011-2022. Based on the statistics, it can be concluded that the turning points for Russia were 2014, 2019, showing a decrease in exports. They are related to the imposed sanctions, the ongoing "trade war" between the United States and China, the Covid-19 pandemic, "... the general increase in geopolitical tensions" (Ignatov, 2022). However, 2022 showed an incredible growth in Russian exports, reaching 591,5 billion dollars according to the Federal Customs Service, which is 26,6% of Russia's GDP for 2022 at current prices in dollar terms:

$$591{,}5 : 2220 * 100\% = 26{,}6\% \qquad (2)$$

The country's trade balance turned out to be in surplus and amounted to 332,4 billion dollars, which corresponds to the value of net exports (net exports = exports – imports).

Table 2: Dynamics of export and import volumes of the Russian Federation and China for the period 2011-2022.

Years	The volume of Russian exports, million dollars	The volume of Russian imports, million dollars	The volume of China's exports, billion dollars	The volume of China's imports, billion dollars
2011	516718	305760	1898,39	1743,39
2012	524735	317263	2048,78	1818,20
2013	525976	315298	2209,01	1949,10
2014	497359	287063	2342,29	1959,23
2015	343512	182902	2273,47	1679,56
2016	285652	182448	2097,64	1587,92
2017	357262	227870	2263,37	1843,79
2018	450278	238710	2486,44	2133,61
2019	424261	244573	2499,21	2079,29
2020	337295	232138	2589,10	2069,57
2021	493096	293531	3362,30	2684,36
2022	591459	259083	3593,60	2715,10

Imports to Russia amounted to standard values from exports during the study period – 45-60%. Thus, based on the methodology for calculating GDP by expenditure for an open economy, which includes total household consumer spending, firm investment spending, government spending and net exports, we obtain that for the Russian economy, net exports (in billions of dollars) in 2022 amounted to almost 15%:

$$332{,}4 : 2220 * 100\% = 14{,}97\% \qquad (3)$$

This is quite understandable, since investment costs have decreased in general due to a decrease in the volume of foreign investment. For comparison, at the beginning of the study period, in 2011, the country's net exports reached 210,958 million dollars, and GDP in foreign currency at current prices amounted to 2 044,618 billion dollars. Then we get that the share of net exports in the volume of domestic GDP by expenditure in 2011 reached only 10.3%:

$$210{,}9 : 2044{,}6 * 100\% = 10{,}31\% \qquad (4)$$

Thus, despite the imposed sanctions and restrictions, Russia's international trade with the countries of the world continues to develop actively, which is reflected by the presented calculations on the positive dynamics of exports and net exports to the Russian Federation.

However, for comparability of parameters for the Russian economy, it is necessary to translate data on exports and imports, expressed in dollars, into rubles, for which we will use the average annual exchange rate according to the Central Bank of the Russian Federation (Table 3). The ratio of exports to GDP of Russia, expressed in the Russian national currency (trillion rubles) remained the same, which in the case of calculating these parameters in dollars, which was presented above. The percentage of exports to gross domestic product in the Russian economy in 2022 is 26.4% (Table 1 and 3):

$$40{,}514 : 153{,}435 * 100\% = 26{,}4\% \qquad (5)$$

Table 3: Dynamics of export and import volumes of the Russian Federation for the period 2011-2022.

Years	The volume of Russian exports, million dollars	The volume of Russian imports, million dollars	The average annual exchange rate of the Central Bank of Russian Federation, RUB/USD.	The volume of Russian exports, billion rubles	The volume of Russian imports, billion rubles
2011	516718	305760	29,3	15139	8958
2012	524735	317263	31.0	16266	9835
2013	525976	315298	31,8	16726	10026
2014	497359	287063	38,4	19098	11023
2015	343512	182902	61,2	21022	11193
2016	285652	182448	67,1	19167	12242
2017	357262	227870	58,3	20828	13284
2018	450278	238710	62,6	28187	14943
2019	424261	244573	64,6	27407	15799
2020	337295	232138	72,1	24318	16672
2021	493096	293531	73,6	36291	21603
2022	591459	259083	68,5	40514	17747

We turn to the following indicators, which in our opinion have a significant impact on the volume and dynamics of gross domestic product (Table 4): 1. The share of capital investments directed to fixed assets in the Russian Federation and China for the period 2011-2022; 2. The Human Development Index of Russia and China for the period 2011-2022, expressed in %.

Table 4: Macroeconomic indicators reflecting the dynamics of capital investments in Russia and China; HDI of the Russian Federation and China for the period 2011-2022.

Years	Capital investments in fixed assets in Russia, billion rubles	Capital investments in fixed assets in China, USD billion	The Human Development Index of Russia, %	The Human Development Index of China, %
2011	11 035,7	3 462	0,808	0,700
2012	12 586,1	4 085	0,811	0,709
2013	13 450,2	4 775	0,817	0,717
2014	13 902,6	4 800	0,818	0,725
2015	13 897,2	4 782	0,824	0,733
2016	14 748,9	4 788	0,828	0,740
2017	16 027,3	5 295	0,833	0,747
2018	17 782,0	6 085	0,841	0,755
2019	19 329,0	6 176	0,845	0,762
2020	20 302,0	6 369	0,830	0,764
2021	22 945,0	7 687	0,822	0,768
2022	27 865,2	8 560	0,822	0,768

China also pays great attention to investment potential, during the period under study, the volume of investments in fixed assets increased 2,3 times (Table 4). In 2022, 109 projects were approved, mainly related to the sectors of transport, energy, water conservation and information technology. In addition, it is important to note that the trend of attracting foreign capital and becoming part of the global investment flow is present in both countries.

Characterizing the following indicator, the HDI (human development index), we can note a positive growth trend in the values of this parameter, both in the Russian Federation and in the PRC. This indicator is used to assess the standard of living, prosperity and socio-economic development of various countries around the world. It is based on three indicators: 1) life expectancy; 2) education level; 3) income level. HDI is a valuable tool for formulating policies and developing development strategies, identifying priorities and areas that require special attention and investment. The last factor is R&D spending in the Russian Federation and in China (Table 5).

Table 5: Dynamics of R&D expenditures in Russia and China for the period 2011-2022.

Years	R&D expenses in Russia, billion rubles	R&D expenditures in China, billion dollars
2011	610,4	226,0
2012	699,9	233,0
2013	749,8	246,0
2014	847,5	249,0
2015	914,7	251,0
2016	943,8	264,0
2017	1019,2	270,0
2018	1028,2	370,0
2019	1134,8	321,0
2020	1174,5	378,0
2021	1301,5	441,0
2022	1435,9	456,0

In the domestic economy, R&D expenditures increased 2,4 times during the study period.

China's R&D spending is more significant, 21 times higher than Russia's R&D spending in 2022 (456,0 billion dollars and 20,9 billion dollars accordingly; 1 435,9 billion rubles: 68,5 RUB/USD = 20,96 billion dollars). For a long period of time, China has given priority to the scientific field, which affects the increase in these costs in total GDP, as well as the enormous return on R&D, which causes, among other things, unprecedented growth of the Chinese economy over the past decades.

Thus, based on the feedback principle, we will identify which factors will most affect the dynamics of GDP in Russia and China for the period 2011-2022. This dependence can also be used to predict the dynamics of national production in the studied countries, depending on the quantitative and qualitative characteristics of GDP. Having considered all the factors, we proceed to the analysis of the econometric function for the Russian economy. Summary Table 6 provides information on changes in the indicators of the most significant factors from our point of view. Each of them is denoted by variables x_n, the dependent function Y is the value of GDP in the period under consideration. In its original form, the function has the form:

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 \quad (6)$$

, where b_0, b_1, b_2, b_3, b_4, b_5 are the coefficients of the function. All parameters are expressed in billions of rubles, with the exception of the HDI calculated according to the UN methodology as a percentage.

Table 6: Macro-variable functions of the Russian economy for the period 2011-2022

Years	The volume of GDP (Y)	The volume of exports (x_1)	The volume of imports (x_2)	The Human Development Index (x_3)	Capital investments in fixed assets (x_4)	R&D expenses (x_5)
2011	60114,0	15139	8958	0,808	11 035,7	610,4
2012	68103,4	16266	9835	0,811	12 586,1	699,9
2013	72985,7	16726	10026	0,817	13 450,2	749,8
2014	79030,0	19098	11023	0,818	13 902,6	847,5
2015	83087,4	21022	11193	0,824	13 897,2	914,7
2016	85616,1	19167	12242	0,828	14 748,9	943,8
2017	91843,2	20828	13284	0,833	16 027,3	1019,2
2018	103861,7	28187	14943	0,841	17 782,0	1028,2
2019	109608,3	27407	15799	0,845	19 329,0	1134,8
2020	107658,2	24318	16672	0,830	20 302,0	1174,5
2021	135295,5	36291	21603	0,822	22 945,0	1301,5
2022	153435,2	40514	17747	0,822	27 865,2	1435,9

The entire calculation part is carried out in MS Excel using "Data Analysis" package. The first stage is to determine the degree of influence of each factor on the dependent variable Y, in our case it is the volume of GDP. Using the Correlation function, we get values that range from +1 to -1, since there are different types of correlation dependence. Modulo values exceeding or equal to 0.7 characterize the closeness of the correlation as high according to Pearson. We get the following values (Table 7).

Table 7: The magnitude of the correlation between the function and the factors.

	Correlation value
Y	1
x_1	0,982527
x_2	0,930419
x_3	0,425235
x_4	0,776049
x_5	0,979877

It can be concluded that the first, second, fourth and fifth factors have the most significant impact on the volume of GDP in the Russian economy. Then our formula is transformed as follows:

$$Ycal. = b_0 + b_1x_1 + b_2x_2 + b_4x_4 + b_5x_5 \quad (7)$$

In Table 8, we will reflect the necessary data for constructing a multiple linear regression, with which we will find the values b_0, b_1, b_2, b_4, b_5 (the data analysis tool "Regression").

Table 8: Significant variables affecting the function of GDP in the Russian Federation for the period 2011-2022, billion rubles.

Years	The volume of GDP (Y)	The volume of exports (x_1)	The volume of imports (x_2)	Capital investments in fixed assets (x_4)	R&D expenses (x_5)
2011	60114,0	15139	8958	11 035,7	610,4
2012	68103,4	16266	9835	12 586,1	699,9
2013	72985,7	16726	10026	13 450,2	749,8
2014	79030,0	19098	11023	13 902,6	847,5
2015	83087,4	21022	11193	13 897,2	914,7
2016	85616,1	19167	12242	14 748,9	943,8
2017	91843,2	20828	13284	16 027,3	1019,2
2018	103861,7	28187	14943	17 782,0	1028,2
2019	109608,3	27407	15799	19 329,0	1134,8
2020	107658,2	24318	16672	20 302,0	1174,5
2021	135295,5	36291	21603	22 945,0	1301,5
2022	153435,2	40514	17747	27 865,2	1435,9

The result $b_0 = 3176{,}4$, $b_1 = 1{,}5$, $b_2 = 1{,}37$, $b_4 = -0{,}94$, $b_5 = 54{,}09$. The x_4 coefficient is negative, which indicates the opposite correlation, so this figure we must exclude from our function and make a new regression analysis. Thus, for the Russian economy, we get the following coefficients $b_0 = 174{,}45$, $b_1 = 1{,}77$, $b_2 = 0{,}08$, $b_5 = 53{,}18$, and the calculated model of the dependence of GDP on exports and R&D expenditures is as follows:

$$Ycal. = -174{,}45 + 1{,}77x_1 + 0{,}08x_2 + 53{,}13x_5 \quad (8)$$

The next stage is the verification of the received function. To do this, it is necessary to analyze three indicators, namely the coefficient of determination (R^2), the Fisher's exact test to check the significance of the regression model and the Student's t-test to check the significance of the parameters.

The coefficient of determination R^2 in this model is 0,9, which indicates that the relationship between the volume of GDP and the presented factors is significant. We can consider this regression model to be successful.

Let's move on to the Fisher's exact test. To do this, we use the function (=FINV), with which we calculate F-distribution = 4,07 (the number of observations is 12) and check the hypothesis that the coefficient of determination is not equal to 0, that is, there is a connection between the function and the arguments x_1, x_2 and x_5. The “Data Analysis” package calculates F = 685.63. It follows that F>F-distribution, therefore, there is a statistical significance of the coefficient of determination.

Next, we analyze the data on the Student's t-test, we get the following values of t-statistics: : tx_1 = 8,22, tx_2 = 0,18, tx_5 = 6,55. To calculate t-distribution, we use the formula (=TINV) => t-distribution = 2,3. Since tx_1> t-distribution and tx_5> t-distribution, therefore, the coefficients b_1 and b_5 are statistically significant, and the coefficient b_2 is not statistically significant, since tx_2< t-distribution, therefore our econometric model is transformed into the following form:

$$Ycal. = -174{,}45 + 1{,}77x_1 + 53{,}13x_5 \quad (9)$$

The calculation results are presented in Table 9.

Table 9: Calculation of Ycal. for the function of the change in the volume of GDP for the Russian economy for the period 2011-2022.

Y	The factor (x_1)	The factor (x_5)	Ycal.
60114,0	15139	610,4	58973,2
68103,4	16266	699,9	65711,5
72985,7	16726	749,8	69170,4
79030,0	19098	847,5	78547,0
83087,4	21022	914,7	85514,0
85616,1	19167	943,8	83773,0
91843,2	20828	1019,2	90709,2

103862,7	28187	1028,2	104211,6
109608,3	27407	1134,8	108480,8
107658,2	24318	1174,5	105117,4
135295,5	36291	1301,5	133040,6
153435,2	40514	1435,9	147638,5

Let's turn to Figure 1, which presents linear graphs based on data from Table 9, reflecting the correspondence of the calculated value (Ycal.) to the actual value of GDP for the Russian economy for the period under study.

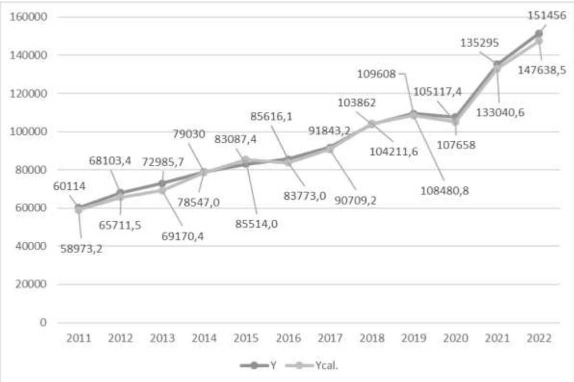


Figure 1: The dynamics of the actual volume of GDP and the calculated value of GDP for the Russian Federation for the period 2011-2022.

In general, both graphs are located quite close to each other, there are minor discrepancies, one of which falls on the year 2022 of interest to us. During this period, the impact of sanctions and a significant structural change in the Russian economy caused by these restrictions can be traced. With regard to the first factor in our model, namely exports, despite the reduction in its volumes with the EU countries, there is a significant increase with "friendly" countries, including China, Turkey, India, Kazakhstan, etc. Taking into account this "substitution", the new chosen direction of Russia's international trade has strengthened. Thus, exports, and in the case of the Russian economy, this is a significant amount of net exports, contributes to the inflow of foreign exchange earnings into the country, increasing the profitability of the business sector as participants in foreign economic activity. At the same time, investment spending, consumer spending and government spending in the national currency are growing due to the low exchange rate. The domestic market is not narrowing, but rather expanding, and overall aggregate demand is growing. It's no secret that economic growth is linked to innovation. Regarding science and technology, we note that over time, the share of R&D expenditures in Russia's GDP increases, in 2022-2023, the urgency of building technological potential is noted, which can also be useful in activating the process of replacing foreign goods with Russian analogues.

Consequently, the dynamics of Russian GDP is significantly influenced by such a quantitative parameter as the volume of exports. The qualitative component of increasing GDP in the present and future includes the volume of R&D expenditures, which allows us to create innovations, thereby contributing to the growth of high-tech industries in the country, the growth of added value from high-tech complex industries, the growth of the level of competitiveness of the economy and its progressive development.

We will conduct econometric modeling for the Chinese economy using the same parameters as for the Russian economy. Our goal is to identify the most significant factors affecting the dynamics of GDP. Let's turn to table 10, which includes summary data on the Chinese economy.

Table 10: Macro-variable functions of the Chinese economy for the period 2011-2022, billion dollars.

Years	The volume of GDP (Y)	The volume of exports (x_1)	The volume of imports (x_2)	The Human Development Index (x_3)	Capital investments in fixed assets (x_4)	R&D expenses (x_5)
2011	7551,55	1898,39	1743,39	3 462,0	0,700	134,4
2012	8532,19	2048,78	1818,20	4 085,0	0,709	162,9
2013	9570,47	2209,01	1949,10	4 775,0	0,717	191,4
2014	10475,62	2342,29	1959,23	4 800,0	0,725	211,9
2015	11061,57	2273,47	1679,56	4 782,0	0,733	227,8
2016	11233,31	2097,64	1587,92	4 788,0	0,740	235,9

2017	1231 0,49	226 3,3 7	1843, 79	5 295,0	0,7 47	260 ,9
2018	1389 4,91	248 6,4 4	2133, 61	6 085,0	0,7 55	297 ,3
2019	1427 9,97	249 9,2 1	2079, 29	6 176,0	0,7 62	352 ,5
2020	1468 7,74	258 9,1 0	2069, 57	6 369,0	0,7 64	378 ,0
2021	1782 0,46	336 2,3 0	2684, 36	7 687,0	0,7 68	481 ,1
2022	1796 3,17	359 3,6 0	2715, 10	8 560,0	0,7 68	520 ,9

Based on the methodology for calculating GDP by expenditure for an open economy, which includes total household consumer spending, firm investment spending, government spending and net exports, we obtain that for the Chinese economy, net exports in 2022 amounted to almost 5%:

$$(3593{,}6 - 2715{,}1): 17963{,}17 * 100\% = 4{,}89\% \quad (10)$$

For the domestic economy, the previously performed calculation showed, as of 2022, the share of net exports was almost 15%:

$$332{,}4: 2220 * 100\% = 14{,}97\% \quad (11)$$

At the beginning of the period, in 2011. The share of net exports for the Chinese economy was only 2%:

$$(1898{,}39 - 1743{,}39): 7551{,}55 * 100\% = 2{,}05\% \quad (12)$$

Thus, despite the imposed sanctions and restrictions, China's international trade with the countries of the world continues to develop actively, which is reflected by the presented calculations on the positive dynamics of exports, imports and net exports.

The main commodity export groups from China in 2022 were such as machinery and equipment, television and sound equipment, telephones, computers, integrated circuits (26%), nuclear reactors, boilers (15,3%), means of land transport (4,18%), as well as plastics, furniture, textiles, metal products ferrous metals, games, toys, clothes, etc. In 2022 such commodity groups as electric machinery and equipment (23,0%), oil, fuel (19,7%), ores (8,2%), nuclear reactors (7.4%), as well as precious and semi-precious stones, optical and photographic devices, tools, copper, seeds, grain, etc. were imported to China. In 2021, exports from China accounted for 28% of all world trade, but in 2022 this share decreased sharply, amounting to about 7%. According to the customs service, exports from China in 2022 increased by 7% compared to 2021, imports – by 1,1%, to 2,71 trillion dollars. However, a more significant increase in these parameters was in 2021: exports increased by 29,9% and amounted to 3,36 trillion dollars, while imports increased by 30,1% to 2,68 trillion dollars. It is interesting to see the share of capital investments in the Chinese economy, which at the beginning of the period was 46,66%. Subsequently, it gradually decreased to 42,90% in 2022, but this value is very significant throughout the entire period of the study, which determines the industrial power of the Chinese economy, on the basis of which it is possible to expand the service sector (Table 11).

Table 11: GDP, share of capital investments in fixed assets and R&D expenditures for the Chinese economyfor the period 2011-2022.

Years	The volume of GDP, billion dollars	The share of investments directed to fixed assets, as a percentage of GDP	R&D expenses as a percentag e of GDP
2011	7551,55	46,66	1,78
2012	8532,19	46,23	1,91
2013	9570,47	46,40	2,00
2014	10475,62	45,82	2,02
2015	11061,57	43,23	2,06
2016	11233,31	42,63	2,10
2017	12310,49	43,01	2,12
2018	13894,91	43,79	2,14
2019	14279,97	43,25	2,24
2020	14687,74	43,37	2,40
2021	17820,46	43,14	2,70
2022	17963,17	42,90	2,90

Thus, based on the feedback principle, we will identify which factors will most affect the dynamics of China's GDP for the period 2011-2022. This dependence can also be used to predict the dynamics of national production in the studied countries, depending on quantitative and qualitative characteristics. Having considered all the factors, we proceed to the analysis of the econometric function for the Chinese economy. Summary Tables 10 and 11 provide information on changes in the indicators of the factors that are most significant from our point of view. Each of them is denoted by variables x_n, the dependent function Y is the value of GDP in the period under consideration. In its original form, the function has the form:

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 \quad (13)$$

, where b_1, b_2, b_3, b_4, b_5 are the coefficients of the function. All parameters are expressed in billions of dollars, with the exception of the HDI calculated according to the UN methodology as a percentage. Let's determine the correlation between the factors and the dependent variable Y. We get the following values (Table 12).

Table 12: The correlation between function and factors for China for the period 2011-2022.

	Correlation value
Y	1
x_1	0,925315
x_2	0,852735
x_3	0,953586
x_4	–0,74358
x_5	0,953068

According to Table 12, it can be concluded that, in addition to the x_4 factor, all the others have a positive high correlation according to Pearson, since the results obtained exceed the value of 0.7. The resulting formula is transformed as follows:

$$Ycal. = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_5x_5 \quad (14)$$

In Table 13, we will reflect the necessary data for constructing a multiple linear regression, with which we will find the values b_0, b_1 , b_2, b_3 and b_5 (the data analysis tool "Regression").

Table 13: Significant variables affecting the function of GDP in China for the period 2011-2022, billion dollars.

Years	The volume of GDP (Y)	The volume of exports (x_1)	The volume of imports (x_2)	HDI (x_3)	R&D expenses (x_5)
2011	7551,55	1898,39	1743,39	0,700	134,4
2012	8532,19	2048,78	1818,20	0,709	162,9
2013	9570,47	2209,01	1949,10	0,717	191,4
2014	10475,62	2342,29	1959,23	0,725	211,9
2015	11061,57	2273,47	1679,56	0,733	227,8
2016	11233,31	2097,64	1587,92	0,740	235,9
2017	12310,49	2263,37	1843,79	0,747	260,9
2018	13894,91	2486,44	2133,61	0,755	297,3
2019	14279,97	2499,21	2079,29	0,762	352,5
2020	14687,74	2589,10	2069,57	0,764	378,0
2021	17820,46	3362,30	2684,36	0,768	481,1
2022	17963,17	3593,60	2715,10	0,768	520,9

As a result, we get the following coefficient values: $b_0 = -54161{,}5$, $b_1 = 2{,}33$, $b_2 = 0{,}42$, $b_3 = 79296{,}2$, $b_5 = 4{,}08$. The calculated function of the dependence of GDP volume for the Chinese economy is as follows:

$$Ycal. = -54161{,}5 + 2{,}33x_1 + 0{,}42x_2 + 79296{,}2x_3 + 4{,}08x_5 \quad (15)$$

The next stage is the verification of the received function. To do this, it is necessary to analyze three indicators, namely the coefficient of determination (R^2), the Fisher's exact test to check the significance of the regression model and the Student's t-test to check the significance of the parameters.

The coefficient of determination R^2 of this model is 0.9, which indicates that the relationship between the volume of GDP and the presented factors is significant. We can consider this regression model to be successful.

Let's move on to the Fisher's exact test. To do this, we use the function (=FINV), with which we calculate F-distribution = 2.96 (the number of observations is 12) and check the hypothesis that the coefficient of determination is not equal to 0, that is, there is a connection between the function and the arguments. The "Data Analysis" package calculates F = 738.4. It follows that F>F-distribution, which means that there is a statistical significance of the coefficient of determination.

Next, we analyze the data on the Student's t-test and get the following values of t-statistics: tx_1 = 2,38, tx_2 = 1,24, tx_3 = 16,06 and tx_5 = –0,04. To calculate the table, we use the formula (=TINV) => t-distribution = 2,36, since tx_1> t-distribution and tx_3> t-distribution, the coefficients b_1, b_3 are statistically significant. In turn, the coefficients b_2 and b_5 are statistically insignificant, so these factors x_2 and x_5 can be excluded from the function. Therefore, there is a need to build a new multiple linear regression. After performing this step, the function takes the following form:

$$Ycal. = -57025{,}4 + 3{,}07x_1 + 83546{,}81x_3 \quad (16)$$

Using this econometric model, we find the Ycal., the results of which are presented in Table 14. Thus, for the Chinese economy, two parameters turned out to be the most significant factors of GDP dynamics, namely the volume of exports, which can be conditionally attributed to a quantitative parameter, and taking into account the structure of exported goods, it acquires a qualitative characteristic. In 2022, China invested 18,9% more in high-tech industries than before. This is 13,8% more the growth rate of other investments. The second significant parameter of economic growth and progressive development of the Chinese economy is the human development Index (HDI), which we attribute to the qualitative characteristics of GDP dynamics. In China, this parameter increased by 9,7% over the period 2011-2022.

Table 14: Calculation of Ycal. for the function of the change in the volume of GDP for China for the period 2011-2022.

Y	The factor (x_1)	The factor (x_3)	Ycal.
7551,55	1898,39	0,700	7151,97
8532,19	2048,78	0,709	8355,05
9570,47	2209,01	0,717	9504,11
10475,62	2342,29	0,725	10572,32
11061,57	2273,47	0,733	11034,23
11233,31	2097,64	0,740	11091,56
12310,49	2263,37	0,747	12173,57
13894,91	2486,44	0,755	13511,15
14279,97	2499,21	0,762	14134,28
14687,74	2589,10	0,764	14571,04
17820,46	3362,30	0,768	17224,83
17963,17	3593,60	0,768	17918,73

Let's turn to Figure 2, which shows a linear graph for the Chinese economy, reflecting the correspondence of the calculated value (Ycal.) to the actual one (Y). The values of the two graphs of the GDP function, real and calculated, are as close as possible to each other, which indicates the accuracy of the econometric model for China.

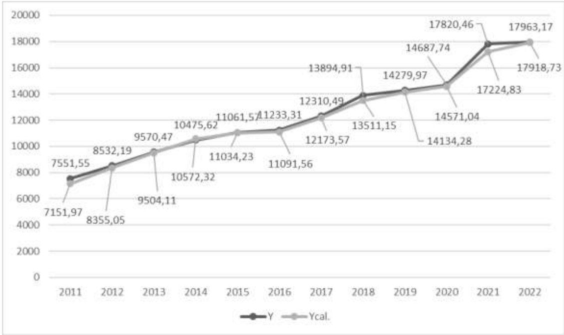


Figure 2: The dynamics of the actual volume of GDP and the calculated value of GDP for China for the period 2011-2022.

The second factor, namely HDI, is, of course, one of the priorities. Due to an increase in the level of education, for example, with an increase in government spending on education or the opening of new educational institutions, this indicator is constantly growing, despite the highest population in the world. Accordingly, affordable education opens up ways to train a highly qualified workforce capable of creating innovations for high-tech industries. Increasing the output of high-tech products contributes to the growth of exports, as well as saturation of the domestic market with innovative goods and services. Increased expenses over time lead to an increase in the incomes of macroeconomic entities, in particular, households. The positive dynamics of the population's income leads to an increase in life expectancy and an increase in the socio-economic well-being of the population.

3 CONCLUSION

The 21st century is becoming a turning point in many ways, especially the period from 2022, which shows the relevance of interstate cooperation, the increased relevance of the process of de-dollarization, the development of new land and sea routes, as well as the expansion of international cooperation. Currently, In the report of the president of the CITIC Foundation for Reform and Development Studies, Kun Dan, delivered at SPIEF 2023, the idea was expressed to stimulate market flexibility, enrich financial and currency instruments and strengthen cooperation in the regional sphere, strengthen the role of such alliances as BRICS, SCO, VREP, etc.

Despite some negative consequences due to the imposed sanctions and restrictions, the Russian economy has over time implemented structural transformations that contribute to the growth of industrial production, including high-tech. There is a diversification of resources, a search for alternative solutions for the sale of products, an increase in the volume of all resources directed to the technological sphere, research and development. As noted earlier, 2022 showed an incredible growth in Russian exports, reaching 591,5 billion dollars according to the Federal Customs Service, which is 26,6% of Russia's GDP for 2022 at current prices in dollar terms:

$$591{,}5 : 2220 * 100\% = 26{,}6\% \qquad (17)$$

In the course of the analysis, an econometric model of the dependence of Russia's GDP on various factors was built, the values of which were calculated for the period 2011-2022. Two factors have the most significant direct impact on GDP in the Russian economy – exports and R&D spending.

Regarding China, it is important to note that despite the sanctions imposed on the country since the 1990s, the PRC is showing amazing results, which have been called the "Chinese economic miracle." The most influential factors on the dependent variable (GDP) are the volume of exports and the human development index. The human development index in the Chinese economy has a more significant impact on GDP dynamics than in Russia. The calculated functional dependence showed the possibility of using this econometric model to calculate the volume of national GDP, the influence of the most significant factors on it, as well as forecast GDP dynamics for the medium and long term.

1. REFERENCES

Capital investments, percentage of GDP – Classification of countries, Available online: URL https://ru.theglobaleconomy.com/rankings/Capital_investment

Federal State Statistics Service. Statistical publications, Available online: URL https://rosstat.gov.ru/folder/210/document/13238.

GDP (current US$) / Data, Available online: URL https://api.worldbank.org/v2/en/indicator/NY.GDP.MKTP.CD?downloadformat=excel.

Global economy, world economy / TheGlobalEconomy.com, Available online: URL https://ru.theglobaleconomy.com/rankings/Capital_investment /.

How sanctions restrictions have made China a world leader, Available online: URL https://rapsinews.ru/incident_publication/20220505/307930925.html.

How will the BRICS' weight in the global economy grow after the expansion, Available online: URL https://www.rbc.ru/economics/25/08/2023/64e76eff9a794732ef6cee82 ?from=copy.

Ignatov A.A., “Internet Governance on the BRICS agenda”, Bulletin of International Organizations 17 No. 2, 86-109 (2022).

Kommersant website. Russia has entered the top five economies in the world in terms of purchasing power parity, Available online: URL https://www.kommersant.ru/doc/6146763.

National Bureau of Statistics of China >> Yearbook, Available online: URL http://www.stats.gov.cn/english/Statisticaldata/yearbook /.

Research and development expenditure (% of GDP) – China / Data, Available online: URL https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS ?end=2020&locations=CN&start=2011.

Rosstat – National Accounts, Available online: URL https://rosstat.gov.ru/storage/mediabank/VVP_god_s_1995-2022.xls.

Russian foreign trade: 1994 – 2023, Available online: URL http://global-finances.ru/vneshnyaya-torgovlya-rossii/.

Russia's GDP by year: 1991 – 2023, Available online: URL http://global-finances.ru/vvp-rossii-po-godam/.

Specific country data / Human Development Reports, Available online: URL https://hdr.undp.org/data-center/specific-country-data#/countries/RUS.

Specific country data | Human Development Reports, Available online: URL https://hdr.undp.org/data-center/specific-country-data#/countries/CHN.

The Central Bank's website. Currency converter, Available online: URL https://www.kursvaliut.ru/средний-курс-валют-за-месяц-2022.

The export of Russian goods in 2022 set a record, Available online: URL https://www.rbc.ru/economics/14/03/2023/640f35739a7947254d6f8154.

The volume of China's foreign trade increased by 4.4 percent by the end of 2022, Available online: URL https://1prime.ru/state_regulation/20230113/839460749.html.

The World Bank. Capital investments, in dollars, are a classification of countries, Available online: URL https://ru.theglobaleconomy.com/rankings/capital_investment_dollars/Asia/.

TrendEconomy is an open data portal, Available online: URL https://trendeconomy.ru/data/h2/China/TOTAL.

TrendEconomy is an open data portal, Available online: URL https://trendeconomy.ru/data/h2/Russia/TOTAL. /

One of the Approaches to Natural Language Prompting for the Large Language Model Using the University of Tyumen Document Storage

Timur Damirovich Nizamov[1] [1], Daniil Davidovich Dekanadze[1] [2] ,
Marina Sergeevna Vorobeva[2] [3] and Anna Valerevna Glazkova[2] [4]
[1]School of Computer Sciences, University of Tyumen, 6 Volodarskogo Street, Tyumen, Russia
[2]Department of Software, University of Tyumen, 6 Volodarskogo Street, Tyumen, Russia
mail@nizamovtimur.ru, dekanadze2103@gmail.com, m.s.vorobeva@utmn.ru, a.v.glazkova@utmn.ru

Keywords: Retrieval augmented generation, chatbot, virtual assistant for students, wiki system, Sentence Transformer, large language model

Abstract: The following paper explores the application of Retrieval augmented generation (RAG) for answering questions posed by students at the University of Tyumen using the large language model (LLM) and the corporate wiki system. To enhance the precision of document retrieval for question-answering purposes, the sentence embedding model is fine-tuned on the set of questions that has been generated by the LLM to corporate university documents. The results demonstrate improved performance compared to using embeddings from a third party LLM service. As a result the microservice for answering students' questions has been developed and tested for using it throughout the UTMN Virtual Assistant.

1 INTRODUCTION

At the University of Tyumen (UTMN) work is underway to digitize student support, including increasing activity on social media. For example, the Student Affairs Office has launched chatbots in VK and Telegram that provide reference information to students by pre-prepared scheme. However, freshmen and foreign students might not know which section contains information of interest, furthermore, the amount of instructions and regulations is increasing every year.

For providing reference information to students online chatbots are being developed and implemented at Russian and foreign universities (Sukhanova and Vezhelis, 2022). The researcher from the University of Hagen in the article (Hartrumpf, 2004) for question-answering system development examined the approach based on semantic networks.

Large language models (LLM) development based on Transformers (Vaswani et al., 2017) opens a wide range of possibilities for making various services including chatbots, virtual assistants, question-answering systems (Galeev and Panishchev, 2022). Retrieval augmented generation (RAG) is being used for making LLM providing actual and reliable information (Lewis et al., 2020). Prompt to LLM is being supplemented with the text relevant to the question using the proximity of embeddings. Furthermore, because of model token limits text chunking must be provided.

RAG is possible to use in various domains. For example, in papers (Al Ghadban et al., 2023) and (Ke et al., 2024) possibilities of using RAG for increasing of medical service provision quality are highlighted, in this case ready solutions to get embeddings are used during document extraction stage: pretrained on the medicine text corpus ClinicalBERT model (Wang et al., 2023) or API for getting embeddings from LLM services.

The objective is development of the Retrieval augmented generation system for answering UTMN students' questions by instructions and regulations published in corporate wiki system. There is the hypothesis that fine-tuning of the sentence embedding model on the set of questions to corporate documents that has been generated by the LLM will

[1] https://orcid.org/0009-0006-3246-6712
[2] https://orcid.org/0009-0004-3343-2632
[3] https://orcid.org/0000-0002-1508-4089
[4] https://orcid.org/0000-0001-8409-6457

increase the documents retrieving accuracy for answering questions compared to using embeddings from a LLM service.

Given the question $Q = \{q_1, q_2, ..., q_n\}$ — the set of tokens in question, a set of document chunks $D = \{d_1, d_2, .. d_m\}$, $\forall\, d_i \in D$: $d_i = \{d_{i1}, d_{i2}, ..., d_{ik}\}$ — the set of tokens in a chunk. Furthermore, $|Q| \leq K$, $|d_i| \leq K$, where K — the feature extraction model token limit.

Generate the answer $A = \{a_1, a_2, ..., a_l\}$ — the set of tokens depending on the question Q and the chunk $d_j \in D$, $j = argmax_{p=1..m}\ similarity(Q, d_p)$, where *similarity* — the proximity function (measure). Furthermore $|Q| + |d_j| + |A| \leq L$, where L — the model token limit.

Thereby, it is necessary to solve two subtasks:

1. retrieving the chunk d_j that is nearest to the question Q;
2. generating the answer A to the question Q by the chunk d_j.

For retrieving the chunk d_j it is required to get embeddings for Q and every element of the set D. Furthermore, it is important to consider the feature extraction model limit K, so documents violating this limit are needed to go through chunking. The proximity measure similarity is cosine similarity between embeddings of token sets that is not affected by characteristic for natural language texts data sparsity.

When the chunk d_j is found, it is necessary to generate the answer A to the answer Q. Answer generating is carried out by the large language model. Furthermore, it is important to consider the generative model token limit L.

2 MATERIALS AND METHODS

Retrieval augmented generation (see Figure 1) assumes the presence of a tokenizer for document chunking, the document from the set D chunks feature extraction method and the question Q for getting embeddings, vector storage for the set D, large language model for generating the answer A and the prompt.

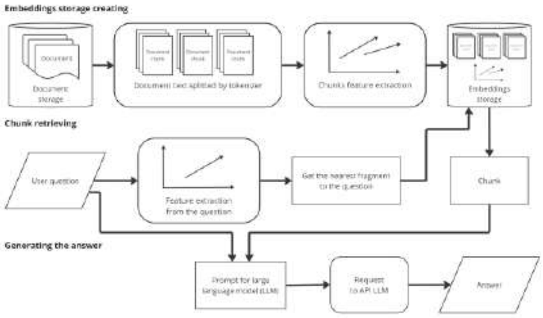


Figure 1: Flow diagram of the Retrieval Augmented Generation.

The following methods for getting embeddings are examined: TF-IDF (Sparck Jones, 1972) based on bag of words, Doc2vec (Mikolov and Le, 2014) developed based on Word2vec (Mikolov et al., 2013), Transformer-based Sentence BERT (Reimers and Gurevych, 2019), taking into account the context of words at the sentence level.

To assess the compliance of found or generated with reference texts metrics such as BLEU (Papineni et al., 2002) and ROUGE (Lin, 2004) are being used. Initially developed for assessment of machine translation quality, BLEU measures similarity between reference text and generated text using n-grams. ROUGE is developed for assessment of summarizing text quality and based on n-grams, furthermore compared to BLEU it is based on recall, so it assesses how generated tokens are relevant to reference ones. Since the required information may be contained in several documents and the recall of the required information is important, the ROUGE-L metric evaluating the longest common subsequence is used to assess the quality of the d_j retrieving.

As a large language model for solving the response A generation subtask, the Lite model (with a limit on the number of tokens L = 4096) of the GigaChat from Sber, which is an ensemble of RuGPT-3.5 and FRED-T5 1.7B finetune models, was used (Zmitrovich et al., 2023). As of March 2024, the FRED-T5 model ranks 3rd in the ranking of large language models for text processing in Russian (Shavrina et al., 2020), second only to the model from the Mistral AI project (by a fraction of a thousandth) and the human benchmark.

To test the quality of generating answer A to question Q for a document from set D, the BERTScore metric is used, based on the cosine measure of similarity of BERT embeddings, which allows taking into account the semantic proximity of the generated result and the standard (Zhang et al., 2020).

The university's corporate wiki system is used as a data source, which stores documents that represent reference information or local regulations.

Texts obtained from the corporate wiki system in HTML or PDF format 38 instructions and regulations for students are splitted into 52 chunks using the tokenizer of the Sentence BERT cointegrated/rubert-tiny2, the number of tokens satisfies the limitation of the feature extraction model K = 2048 tokens. The chunks are stored in a database controlled by PostgreSQL using the PGVector extension for storing embeddings. Synchronization with documents from the corporate wiki system is carried out once a day.

Using chatbots on VK and Telegram, questions from students were collected; for each question, experts selected a fragment of a document from the corporate wiki system. Also, using the GigaChat from Sber, questions were generated for documents, without using standard forms (applications, consent, etc.) or blocked by the service chunks due to being blacklisted. For each question-document pair from the test sample, the answer to the question on the document was manually written. The final distribution of questions and document chunks is shown in Table 1.

Table 1: Distribution of test and train datasets objects.

Dataset	Question source	Question count	Unique chunk count
Train	Chatbot users, GigaChat	355	42
Test	Chatbot users	67	27

Test and train datasets are published on the Hugging Face.

3 RESULTS

To retrieve a document chunk d_j from set D, containing 52 document fragments from a corporate wiki system, embeddings were built using the TF-IDF method, the Doc2vec algorithm, the pretrained Sentence BERT model and the GigaChat API. When using TF-IDF and Doc2vec, texts are lemmatized, cleared of stopwords and punctuation using the ru_core_news_sm model from the SpaCy library. The Doc2vec algorithm uses the following parameters: vector_size=150, window=5, min_count=1.

As a representative of Sentence BERT, the cointegrated/rubert-tiny2 model, pretrained on a Russian-language text corpus, was considered and fine-tuned. Multiple negatives ranking was selected as a loss function, intended for a corpus of pairs of nearest texts (batch_size=8, num_epochs=10).

To evaluate each method using the Accuracy and ROUGE-L metrics, the found document chunks were compared with the reference ones from the test sample (see Table 2).

Table 2: Metrics of document retrieving results using embeddings.

Method	Acc.	ROUGE LCS Recall	ROUGE LCS Precision	ROUGE LCS Fmean
TF-IDF	0.45	<u>0.63</u>	0.54	0.54
Doc2vec	0.06	0.19	0.19	0.16
Sentence RuBERT	0.37	0.49	0.51	0.48
API GigaChat	<u>0.54</u>	0.61	<u>0.65</u>	<u>0.62</u>
Fine-tuned Sentence RuBERT	**0.70**	**0.77**	**0.76**	**0.75**

Vectors obtained using the GigaChat API outperform the embeddings of TF-IDF, Doc2vec and Sentence RuBERT in most metrics. Fine-tuning of the Sentence RuBERT model from the text on the set of questions for corporate documents generated by LLM increased the accuracy of document retrieving to answer the question.

The fine-tuned model was uploaded on the Hugging Face and used in a microservice that implements the RAG. To develop the microservice, Python 3 frameworks were used: SQLAlchemy for ORM queries to vector storage, GigaChain for assembling prompt (see Table 3) and sending request to LLM, Aiohttp for processing HTTP requests.

Table 3: Prompt template for generating answers using language large model.

Prompt template	Действуй как Вопрошалыч — виртуальный помощник студента ТюмГУ. Используй следующий текст в тройных кавычках, чтобы кратко ответить на вопрос студента.

	Не придумывай и не изменяй ссылки, адреса и телефоны. Если ответа в тексте нет, напиши "ответ не найден". \"\"\" {context} \"\"\" Вопрос студента: {question}
Variables	context — the chunk for answer the question; question — the user question.

The microservice provides an API to generate a response to a user message. For example, if a user asks the question "Как выбрать электив?" ("How to choose an elective?" in Russian), the generated answer and a link to a retrieved document, which describes the process of choosing elective disciplines at the university, from the corporate wiki system will return:

```
# curl -X POST http://qa:80/qa/ -H 'Content-Type: application/json' -d '{"question":"Как выбрать электив?"}'

{"answer": "Рекомендую почитать отзывы на сервисе «Отзывус» по ссылке: https://electives.utmn.ru. Там же можно написать о своем опыте изучения элективных дисциплин.",
"confluence_url": "https://confluence.utmn.ru/pages/viewpage.action?pageId=86479065"}
```

If the LLM reports that there was no response, an exception will return. Questions and answers are saved to a database for further analysis. Testing the RAG pipeline is shown in Table 4.

Table 4: The examined approach test results.

Test type	Count of samples	BERTScore Precision	BERTScore Recall
All generated cases	67	0.61	0.64
Not including cases when answer is not found	50	0.81	0.86

The test results were influenced by the quality of document retrieving and the quality of response generation. Separately, cases were considered when the large language model was able to generate an answer in the proposed text, that is, retrieving a document to answer the question was successful.

4 DISCUSSION

The hypothesis, that fine-tuning of the sentence embedding model on the set of questions to corporate documents that has been generated by the LLM will increase the documents retrieving accuracy for answering questions compared to using embeddings from a LLM service, has been confirmed.

In terms of semantic similarity, the generation results have moderate overlap with human question responses, but still leave room for improvement in both document retrieval and answer generation.

The following study examines questions and documents only in text format in Russian related to regulations of the educational process at the university. Owing to computational resource limits, only using third party LLM services was possible.

Developed microservice is being used by chatbots in VK and Telegram of the UTMN Virtual Assistant that is being implemented at the University of Tyumen for replacing Student Affairs Office chatbot.

5 CONCLUSIONS

The Retrieval augmented generation has been examined for answering UTMN students' questions by instructions and regulations published in corporate wiki system using natural language prompting for the large language model.

Students' questions have been collected, the dataset of questions to corporate documents has been generated by LLM, feature extraction methods have been examined and Sentence RuBERT has been fine-tuned. The RAG microservice has been developed and tested.

Using named-entity recognition for increasing document extraction accuracy is planned to be in the future. In addition, transfer several document chunks to LLM input can be examined. At the same time, earlier sent questions and answers should also be taken into account in future work.

REFERENCES

Al Ghadban, Y., Lu, H. Y., Adavi, U., Sharma, A., Gara, S., Das, N., Hirst, J. E., 2023. Transforming healthcare education: Harnessing large language models for frontline health worker capacity building using retrieval-augmented generation. medRxiv, 2023-12.

Galeev, D., Panishchev, V. S., 2022. Experimental study of language models of "Transformer" in the problem of finding the answer to a question in a russian-language text. Informatics and Automation, 21(3), 521-542.

Hartrumpf, S., 2004. Question answering using sentence parsing and semantic network matching. In Workshop of the Cross-Language Evaluation Forum for European Languages (pp. 512-521). Berlin, Heidelberg: Springer Berlin Heidelberg.

Ke, Y. H., Jin, L., Elangovan, K., Abdullah, H., Liu, N., Sia, A. T. H., Ting, D. S. W., 2024. Development and Testing of Retrieval Augmented Generation in Large Language Models.

Le, Q., Mikolov, T., 2014. Distributed representations of sentences and documents. In International conference on machine learning (pp. 1188-1196). PMLR.

Lewis, P., Perez, E., Piktus, A., Petroni, F., Karpukhin, V., Goyal, N., Kiela, D., 2020. Retrieval-augmented generation for knowledge-intensive nlp tasks. Advances in Neural Information Processing Systems, 33, 9459-9474.

Lin, C. Y., 2004. Rouge: A package for automatic evaluation of summaries. In Text summarization branches out (pp. 74-81).

Mikolov, T., Sutskever, I., Chen, K., Corrado, G. S., Dean, J., 2013. Distributed representations of words and phrases and their compositionality. Advances in neural information processing systems, 26.

Papineni, K., Roukos, S., Ward, T., Zhu, W. J., 2002. Bleu: a method for automatic evaluation of machine translation. In Proceedings of the 40th annual meeting of the Association for Computational Linguistics (pp. 311-318).

Reimers, N., Gurevych, I., 2019. Sentence-bert: Sentence embeddings using siamese bert-networks. Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing. Association for Computational Linguistics. Shavrina, T., Fenogenova, A., Emelyanov, A., Shevelev, D., Artemova, E., Malykh, V., Evlampiev, A., 2020. RussianSuperGLUE: A Russian language understanding evaluation benchmark. In Proceedings of the 2020 Conference on Empirical Methods in Natural Language Processing (EMNLP) (pp. 4717–4726). Association for Computational Linguistics.

Sparck Jones, K., 1972. A statistical interpretation of term specificity and its application in retrieval. Journal of documentation, 28(1), 11-21.

Sukhanova, N. T., Vezhelis, T. M., 2022. Using Chatbots to Automate the Provision of Reference Information to Applicants and University Students [Ispolzovanie chat-botov dlya avtoma-tizatsii predostavleniya spravochnoy informatsii abiturientam i studentam vuzov]. Problems of Modern Pedagogical Education [Problemy sovremennogo pedagogicheskogo obrazovaniya], 178-181.

Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., Polosukhin, I., 2017. Attention is all you need. Advances in neural information processing systems, 30.

Wang, G., Liu, X., Ying, Z., Yang, G., Chen, Z., Liu, Z., Chen, Y., 2023. Optimized glycemic control of type 2 diabetes with reinforcement learning: a proof-of-concept trial. Nature Medicine, 29(10), 2633-2642. Zmitrovich, D., Abramov, A., Kalmykov, A., Tikhonova, M., Taktasheva, E., Astafurov, D., Fenogenova, A., 2023. A family of pretrained transformer language models for Russian.

Zhang, T., Kishore, V., Wu, F., Weinberger, K. Q., Artzi, Y., 2020. Bertscore: Evaluating text generation with bert. ICLR (2020).

Methodology for Predictive Modeling and Correction Public Transport Times

Finogeev A. Anton[1][a], Finogeev G. Alexey[1][b], Parygin S. Danila[2][c] and Mayorov S. Ruslan[1][d]

[1]*Department of Computer-Aided Design, Penza State University, 440026, Krasnaya Street, 40, Penza, Russia*

[2]*Department of digital technologies in urbanism, architecture and construction, Volgograd State Technical University, 400005, Lenin Avenue, 28, Volgograd, Russia*

fanton3@ya.ru, alexeyfinogeev@gmail.com

Keywords: Time forecast, Arrival time, Traffic density, Traffic congestion, Traffic jams, Public transport stops, Average speed, Route.

Abstract: The article discusses the problem of analyzing and predicting the arrival time of public transport at intermediate and final points of routes. The main requirement is to take into account the traffic congestion of urban road sections at different times of the day. To solve the problem, a methodology and tools for analyzing the movement of vehicles have been developed for predictive assessment of the average speed of movement on sections of the route. The goal is to increase the accuracy of forecasting the arrival time of public transport at stopping points along the routes. The efficiency criterion is the average absolute deviation of the predicted time of arrival of transport at intermediate and final points of routes under current road congestion conditions. The software proposal is designed to predict and adjust the timing of public transport along a route.

1 INTRODUCTION

In modern urban environments, efficient management of public transport is becoming one of the important aspects of everyday life. With the increase in population mobility and the development of urban infrastructure, there is a need for innovative approaches to optimizing vehicle schedules. The work examines the development of a methodology for predictive modeling and calculation of public transport traffic parameters. The speed of public transport in an urban environment depends on the congestion of city highways, on the average speed of vehicles, on road traffic accidents along the route, and on the operation of traffic lights. To assess the impact of traffic parameters, critical events and traffic light regulation, it is necessary to quickly collect data on traffic flows, accidents, the number and speed of vehicles on route sections.

The main task is to analyze the congestion of road sections on public transport routes in order to predict the time of arrival at intermediate and final points of the route and possible regulation of its movement. Solving the problem is necessary to automate the processes of dispatch control of traffic flows in an urban environment with the ability to promptly inform passengers at stopping points about the possible waiting time for public transport. The last function, the most important for the population, is based on predicting the time of arrival of transport at a stop. Information should be available not only to dispatchers of a motor transport enterprise, but also to users of passenger transport through electronic signs at stops, through the system’s website or through a mobile application. Such systems today are actively integrated with navigation services, such as, for example. Yandex Maps, where you can monitor the movement of public transport on a city map in real time. However, the task of predicting the arrival time of public transport of various routes at each stop and notifying passengers about this remains relevant.

[a] https://orcid.org/0000-0001-8280-1474
[b] https://orcid.org/0000-0002-4777-3364
[c] https://orcid.org/0000-0001-8834-5748
[d] https://orcid.org/0000-0000-0000-0000

The purpose of the study is to develop a model and methodology for predictive modeling and correction of the arrival time of urban public transport at stops based on the collection and analysis of GPS data. To achieve the goal, the following tasks are solved:

a) identification and analysis of factors influencing the speed and time parameters of public transport,

b) synthesis of a forecasting model,

c) development of a methodology for calculating the speed and time parameters of public transport, taking into account the influence of possible factors on changes in the average speed of movement,

d) development of a software application to implement the methodology,

e) testing the operation of the application, assessing the accuracy of the modeling and adjusting the input data in order to select the optimal parameters of the predictive model.

Public transport time forecast has a wide range of applications. First of all, this is important for city residents who depend on public transport for everyday trips. Accurately predicting arrival times allows passengers to plan their time more efficiently and avoid unnecessary waits at stops. The method for calculating public transport traffic is used in urban planning and transport infrastructure management. It can be used to optimize vehicle schedules, as well as to make decisions on making changes to routes or regulating traffic depending on the current traffic load.

2 THEORETICAL REVIEW

Most methods for determining movement intervals and arrival times of vehicles (vehicles) at intermediate and final points of routes work based on GPS tracking technology as a data source. The GPS module provides real-time information about the location of the vehicle, which allows you to accurately predict its location at the next time. One example of the implementation of this approach is the widely used means of calculating travel time in the navigation services Yandex and Google. The time is calculated based on the current state, taking into account traffic jams, the number of traffic lights, and the average speed of vehicles on the intended route (Suardinata, Rusmi, Lubis, 2022). Navigation systems make it possible to obtain current and accurate information about the GPS coordinates of most vehicles along the route, determine their average speed based on changes in coordinate data, and calculate travel time and time of arrival at the final point of the route.

he task of accurately predicting the time of arrival of a vehicle at an intermediate or final point of a route comes down to estimating time of arrival (ETA) at a given point on the route. The ETA must correspond most closely to the real time of arrival (RTA). There are several approaches to predicting vehicle arrival times. These include a forecasting method based on archival data (Pogrebnoy Fadeev 2013), a method based on real-time monitoring of GPS data (Agafonov, 2012), a forecasting technique based on statistical analysis (Igumnov, Sonkin, 2016), forecasting methods using machine learning (Agafonov, 2019), such as the support vector machines (Ma, 2011) and neural networks (Zargaryan, Zargaryan, 2021), forecast method using Kalman filtering (Chu, 2005), etc.

The method, based on archival data, makes it possible to predict the time of movement along a selected section in a certain period of the day based on the average time of passage of this section by other vehicles in the same period over the previous days of observation (Padmanaban, 2009). In contrast, methods using real-time data predict the arrival of a vehicle based on its current position and speed (Pu, 2009). However, the disadvantage of the methods is the inability to quickly respond to changes in the road situation and traffic routes. Statistical approaches mainly use regression models to predict the time it takes for vehicles to travel between stops on a road network and then calculate the time of arrival at their final destinations. The regression functions of such models depend on variables, which include parameters of the current road situation, weather data, traffic jams on routes, the number of traffic lights, passenger pick-up and drop-off times, etc. The main disadvantages are related to the presence of correlated variables and the requirement of a large amount of data for adjustment.

Forecast models with filters (Vanajakshi, 2009; Shalaby, 2004; Chen, M. 2004)are mainly used for short-term forecasting of the current state of traffic flow and best solve this problem in combination with a neural network (Zaki, 2013). The use of neural networks makes it possible to take into account nonlinear relationships between various factors that have a significant impact when predicting arrival time (Jeong, 2004). Another machine learning method is support vector machine, which is also used to predict the arrival time of public transport (Bin, 2007; Wu, 2004). However, these methods require lengthy training, correct selection of input variables and determination of algorithm parameters, and have computational complexity.

Integrating different approaches to solving a problem often gives good results. Hybrid approaches may include two or more forecasting models. In particular, (Van Lint, 2005) proposes combining a linear regression model and a locally weighted regression model to improve accuracy. In (Zheng, 2006), the authors used a combination of a Bayesian model and a neural network model to estimate travel time along a road section. Authors of the work (Yang, 2005) proposed an algorithm that uses a Kalman filter to track vehicle location and statistical models to predict arrival time.

3 MATERIALS AND METHODS

This article discusses a method for predicting the arrival time of public transport at points on the route. The algorithm is based on adjusting the traffic schedule taking into account the assessment of changes in the average speed of vehicles between intermediate stops. The method is an innovative approach to solving the problem of predicting arrival time. It is distinguished by its simplicity and consideration of dynamic factors affecting traffic movement. When calculating travel time on routes, navigation services use information about the predicted speed of movement on sections of the route according to GPS coordinates. The coordinates come from GPS modules of vehicles or modules of mobile communication devices for drivers and passengers. When calculating the expected travel time, the service takes into account real data on the average speed of vehicles received from the GPS modules of cars that have previously passed this section. Several factors can influence traffic speeds, particularly traffic density and volume, which change dramatically during peak morning and evening traffic times. This determines the seasonality factor in the predictive analysis of travel time between stops. If a sudden obstacle to traffic occurs, the speed of traffic slows down and the recalculation of the average speed on the section occurs with a delay. Changes in the average speed in sections are also influenced by accidents, traffic jams, the work and passage of special equipment, changes in traffic light cycles at adaptive traffic lights, etc. Therefore, the arrival time when traffic parameters change is not determined accurately. However, for a new transport unit it will be automatically adjusted based on an estimate of the average absolute deviation of the forecast and real time.

To calculate the predicted travel time between stops and arrival, a technique is used to estimate the average speed of movement on each section of the route. The estimate is constantly recalculated based on incoming coordinate data from passing vehicles. Public transport routes are modeled by a directed graph. The weighted edges of the route graph represent road sections between stops and intersections. The edge arrows show the directions of traffic movement. There may be several edges between the vertices of the graph that model traffic lanes. Public transport stops and intersections are the vertices of the graph. Calculation of distance weights between vertices is carried out using the GPS coordinates of stops and intersections. In addition to the distance weights, the weights of the road section indicators, which influence the traffic pattern, can be taken into account. Such weights can be the speed limit, the number of unregulated intersections and pedestrian crossings, the average congestion of the area, the number and duration of phases of traffic light cycles, the average waiting time at a traffic light, when entering a main road, before an unregulated pedestrian crossing, before stopping when it is occupied by other vehicles, average passenger boarding/disembarking time, etc. All weights are normalized and the total edge weight is determined as the convolution of all normalized weights. A route on a graph is represented by traversing the vertices along the weighted edges of the graph.

Since public transport follows a predetermined route, which it can change only in emergency situations, for it on the graph there is one route around the vertices for which the travel time is calculated. This time depends on the value of the weighting coefficients at a particular point in time. At specified intervals, the weight coefficients are updated and the total weight for each edge is recalculated. Changes in weighting coefficients and total weight are represented by time series, the changes of which are seasonal depending on the time of day. The developed algorithm can also be used to find the optimal path on the route graph based on the minimum travel time between given points. Such results are necessary for vehicles that are not strictly tied to a predetermined route, for example, for a taxi. In this case, the algorithm lays out possible paths sequentially one step at a time along all edges of the graph incident to the current vertex of the point, calculates the travel time for each edge and selects the section with the minimum time.

At this stage of research, the following time indicators are used as input data for estimating public transport travel times:

1. Travel time between stops on the route;
2. Passenger boarding/disembarking time;

3. Start and braking time before stopping;
4. Waiting time to pass through traffic lights;
5. Travel time at uncontrolled intersections in case of leaving a secondary road;
6. Travel time between stops, taking into account delays caused by traffic jams, the operation of special equipment, weather conditions, accidents, changes in road congestion during time intervals with seasonal fluctuations, etc.

The data is specified in the form of initial values, which at the first stage of predictive modeling are selected experimentally while monitoring the operation of public transport in a specific area. In the future, they are adjusted as transport operating conditions change, taking into account fluctuations during peak load hours. For example, at the initial stage the following data was specified:

- time of boarding/disembarking passengers at the stop $T_{boarding}$ = 10 c,
- start and braking time before stopping T_{start_brake} = 10 c,
- travel time through intersections $T_{crossing}$ = 10 c.

The main calculation data are the following indicators:

1. Travel time between stops i and j:

$$T^{ij}_{distance} \frac{D^{ij}_{stop\_by\_stop}}{V^{ij}_{average}} * \mathrm{w}_{ij},$$

where $D^{ij}_{stop\_by\_stop}$ – distance between stops according to the route graph, $V^{ij}_{average}$– average speed on a road section, w_{ij} – general weighting factor to take into account various factors influencing the calculation of travel time.

2. The average speed can be determined from the current speeds received from GPS modules. However, in our case, the time when the vehicle passes neighboring stops and intersections with GPS coordinates is recorded. Next, the travel time of a vehicle section over a time interval is determined and the average speed is calculated based on the known length of the edge and the average travel time of all recorded vehicles between stops:

$$V_{average} = \frac{D^{ij}_{stop\_by\_stop}}{K \cdot T^{ij}_{averadge}} \quad , \quad T^{ij}_{averadge} = \sum_{m=1}^{K} (T^j_m - T^i_m),$$

where T^j_m, T^i_m – arrival time TC by i and j stops based on GPS data, K – number of vehicles passing between both stops during the time interval.

The main problem is the lack of transport passage within a given time interval. In this case, the time interval is simply increased or the speed for an earlier time interval is taken.

3. Estimated arrival time T^j_{wait} on j stop is defined as:

$$T^j_{wait} = T^{ij}_{distance} + T^{ij}_{boarding} + T^{ij}_{start\_brake} + \sum_{n=1}^{S_{ij}} T^{cross}_n,$$

where $T^{ij}_{boarding}$ - passenger boarding/disembarkation times, $T^{ij}_{start\_brake}$ - start and deceleration time before stopping, T^{cross}_n - travel time through intersections, S_{ij} – travel time through intersections i and j stops.

4. To calculate the time of arrival at the final point of the route, the total travel time along all edges of the route is calculated based on the average speed.

During operation, average speeds in different areas are constantly changing due to various influencing factors. In addition, the weighting coefficients that determine the contribution of each factor to the calculation of travel time between stops are changed. Also influenced is the seasonality factor, which determines two time periods during the day when a sharply increasing intensity of road traffic leads to traffic jams and an increase in travel time between stops. To compensate for the seasonality factor, an increase in the number of vehicles on routes is required.

To assess the accuracy of the predicted arrival time at the j-th stop, the metric of mean absolute deviation in percentage (Mean Absolute Percentage Error, MAPE) is used. The metric shows by what percentage on average the forecast time differs from the real time, which is measured using GPS data from the actual arrival of the vehicle:

$$MAPE = \frac{1}{N} \sum_{i=1}^{N} \left| \frac{T^j_{wait} - T^j_{real}}{T^j_{real}} \right|.$$

Using a metric solves the problem of interpreting the results, since there is no need to estimate the duration of movement along the entire route. In the first sections of the route, you can understand how well the average speeds were determined and the weighting coefficients were selected in order to assess the increase or decrease in the forecast error and adjust the model parameters.

4 RESULTS

The forecasting technique is implemented in a software application. The application performs predictive modeling and correction of public transport schedules based on GPS data. The application uses the following functions.

1. Definition of the GPSData and Schedule classes. The application defines two data classes: a) the GPSData class for collecting and storing GPS data, b) the Schedule class for collecting and storing information about the public transport schedule, including passenger pick-up/drop-off times, start and end times of traffic at stops, travel time through intersections, delay time at unplanned points on the route (unregulated intersections and pedestrian crossings, at accident sites, at places where special equipment is working, etc.).

2. GPS data analysis. The analyze_gps_data function works with GPS data, predicted speed changes, distances between stops, intersections on routes, time delays and weight changes. Based on the results of the analysis, the average speed on the road section is corrected to recalculate the travel time of the section, which is recorded in the database for each edge of the road graph.

3. Forecasting the time of arrival at stops and adjusting the transport schedule. The forecast_and_correct function accepts a schedule object (TS), adjusted average speeds on sections, travel time intervals and distances between stops. For each stop, the waiting time for transport is predicted, taking into account the adjusted average and current speeds, and the public transport schedule is adjusted taking into account time delays.

4. Predictive modeling. The run simulation function creates an observable object with GPS data and calls the analysis function, which returns the adjusted vehicle speeds. Next, a schedule object is created and the motion schedule correction function is called. The updated schedule with new arrival times at intermediate and final points of the route is displayed on the screen.

To test the operation of the application, we selected the real route of bus No. 130 in the city of Penza with stops marked on the map (Fig. 1)

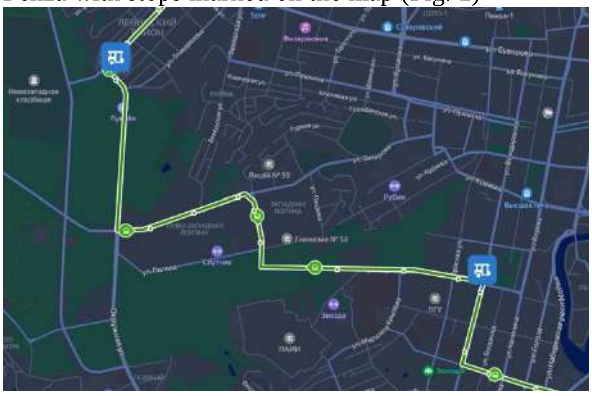


Figure 1: Example of a fragment of a bus route.

There are 10 stops on a fragment of the route to demonstrate how the application works. For predictive modeling, the interval A = 15 minutes and other input data are specified (Fig. 2). The obtained time estimation results showed how the bus speed changes at different intervals depending on the empirical delay (Fig. 3).

```
weight_factor = 3
# Временные интервалы для каждого типа (A, B, C, D, E, F)
interval_values = {'A': 15 * 60, 'B': 30 * 60, 'C': 1 * 60 * 60, 'D': 3 * 60 * 60, 'E': 12 * 60 * 60, 'F': 24 * 60 * 60}

# Предсказанные изменения скорости для каждой остановки
predicted_speed_changes = [1, 1, -10, -0.2, 0.1, 0.05, -0.15, 0.25, -0.2, 0.15]

# Расстояния между остановками
distances = [1600, 400, 400, 250, 300, 900, 600, 500, 300, 400]

# Названия остановок
stop_names = ['Окружная', 'Мира', 'НИИ Контрольприбор', 'ЖК Фаворит', 'Ленинградская', 'Дом Офицеров',
              'Перинатальный центр', 'ПГУ', 'Красная', 'Куйбышева']

# Время посадки/высадки пассажиров на каждой остановке
boarding_time = [20] * 10

# Время старта и торможения перед остановочными пунктами
start_brake_time = [6] * 10

# Время проезда через перекрестки
crossing_time = [10] * 10
```

Figure 2: Example input data.

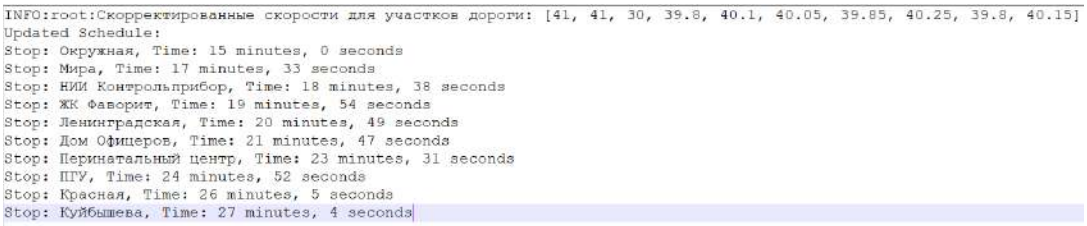

```
INFO:root:Скорректированные скорости для участков дороги: [41, 41, 30, 39.8, 40.1, 40.05, 39.85, 40.25, 39.8, 40.15]
Updated Schedule:
Stop: Окружная, Time: 15 minutes, 0 seconds
Stop: Мира, Time: 17 minutes, 33 seconds
Stop: НИИ Контрольприбор, Time: 18 minutes, 38 seconds
Stop: ЖК Фаворит, Time: 19 minutes, 54 seconds
Stop: Ленинградская, Time: 20 minutes, 49 seconds
Stop: Дом Офицеров, Time: 21 minutes, 47 seconds
Stop: Перинатальный центр, Time: 23 minutes, 31 seconds
Stop: ПГУ, Time: 24 minutes, 52 seconds
Stop: Красная, Time: 26 minutes, 5 seconds
Stop: Куйбышева, Time: 27 minutes, 4 seconds
```

Figure 3: Predictive Modeling Results.

5 CONCLUSION

The use of the methodology and software application makes it possible to effectively take into account traffic conditions, which helps to increase the accuracy of calculating the time of arrival of public transport at intermediate and final points of the route. The ease of integration with dispatch control systems and adaptation to various road conditions make it a tool for optimizing traffic schedules and informing the urban population about changes in public transport schedules. Further work on the methodology and application involves integrating into the methodology the architecture of a recurrent neural network with a transformer mechanism for predicting the values of weighting coefficients from time series of data on previously recorded delays due to the influence of various factors. It is proposed to train and test the predictive model in urban conditions using data on changes in the intensity and density of automobile and pedestrian traffic in areas. It is also planned to add the ability to respond to the appearance of unplanned obstacles during the movement of public transport along the route and in the event of a forced change of route under unforeseen circumstances. An expanded methodology and a combined predictive model will expand the functionality of the application, increase the efficiency and accuracy of estimating time indicators of urban public transport. Currently, the module for predictive assessment of travel and arrival times of public transport is implemented in the system of intelligent monitoring of urban road transport infrastructure.

ACKNOWLEDGMENTS

The study was supported by the Russian Science Foundation grant №20-71-10087, https://rscf.ru/project/20-71-10087/.

REFERENCES

Suardinata, S., Rusmi, R., Lubis, Mu., 2022. Determining Travel Time and Fastest Route Using Dijkstra Algorithm and Google Map. SISTEMASI. 11. 496.

Pogrebnoy V. Yu., Fadeev A. S., 2013. Algorithmization of forecasting the time of arrival of passenger transport in the city of Tomsk at a stop using a model based on historical and real data. Internet journal “Naukovedenie”, No. 6 (19). https://naukovedenie.ru/PDF/100TVN613.pdf.

Agafonov, A.A., 2012. Forecasting traffic parameters of urban passenger transport based on satellite monitoring data. Computer optics. T. 36, No. 3. P. 453-489.

Igumnov, A.O., Sonkin, D.M., 2016. Development of a methodology for constructing a forecast of arrival time using statistical and actual data on the movement of vehicles based on the principle of template selection.Internet journal “Naukovedenie”, Vol. 8, No. 3.

Agafonov, A.A., 2019. Comparison of machine learning methods in the problem of predicting public transport traffic / Agafonov A.A., Yumaganov A.S. // Collection of works ITNT-2019: V international. conf. and youth. school "Information technologies and nanotechnologies" - Samara: New technology, 2019 T. 4: Data Science. pp. 761-768.

Ma, Zh., 2011. An Aggregation Method for Dynamic Bus Arrival Time Prediction. AISS. Vol. 3, N 6. P. 37-48.

lamir Haider Sagban Hussein, Zargaryan, E.V., Zargaryan, Yu.A., 2021. A model for forecasting traffic flow based on neural networks for predicting traffic on roads.News of the Southern Federal University. Technical science.. No. 6 (223). URL: https://cyberleninka.ru/article/n/model-prognozirovaniya-transportnogo-potoka-na-osnove-neyronnyh-setey-dlya-predskazaniya-trafika-na-dorogah (date of access: 03/03/2024).

Chu, L., 2005. Adaptive kalman filter based freeway travel time estimation.In 84th TRB Annual Meeting, Washington,

Padmanaban, P., 2009. Estimation of Bus Travel Time Incorporating Dwell Time for APTS Applications. IEEE Intelligent Vehicles Symposium. V. 2. P. 955-959.

Pu, W., 2009. Real-Time Estimation of Urban Street Segment Travel Time Using Buses as Speed Probes. Research Record: *Journal of the Transportation Research Board*. Vol. 2129. – P. 81-89.

Vanajakshi, L., 2009. Travel time prediction under heterogeneous traffic conditions using global positioning system data from buses. *IET Intelligent Transport Systems.* V. 3. P. 1-9. 9.

Shalaby, A., 2004. Prediction Model of Bus Arrival and Departure Times Using AVL and APC Data. *Journal of Public Transportation.* V.7(1). P.41-63. 10.

Chen, M. A., 2004. dynamic bus-arrival time prediction model based on APC data. *Computer-Aided Civil and Infrastructure Engineering*. V. 19(5). P. 364-376.

Zaki, M., 2013. Online Bus Arrival Time Prediction Using Hybrid Neural Network and Kalman filter Techniques. International *Journal of Modern Engineering Research*. V. 3, Issue 4. P. 2035-2041.

Jeong, R., 2004. Bus arrival time prediction using artificial neural network model. IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC. P. 988-983.

Bin, Y., 2007. Bus arrival time prediction using support vector machines. *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations*. - V. 10, Issue 4. P. 151-158.

Wu, C.-H., 2004. Travel-time prediction with support vector regression. IEEE *Transactions on Intelligent Transportation Systems.* V. 5(4). P. 276-281.

Van Lint, J.W.C., 2005. Accurate freeway travel time prediction with state-space neural networks under missing data. *Transportation Research Part C: Emerging Technologies.* V. 13(5-6). P. 347-369.

Zheng, W., 2006. Short-term freeway traffic flow prediction: Bayesian combined neural network approach. *Journal of Transportation Engineering.* –V. 132(2). P. 114-121.

Yang, J.-S., 2005. Travel time prediction using the GPS test vehicle and Kalman filtering techniques. *Proceedings of the American Control Conference*. V. 3. P. 2128-2133.

Introduction and Development of Digital Technologies in Agriculture of the Kyrgyz Republic at the Present Stage

M.A. Bolotova[1], N.M. Dooronbekova[2], B.B. Sasykulov[3]
KSTU named after I. Razzakov, Department of Management, Bishkek, Kyrgyz Republic
maxabat.bolotova@mail.ru, dooronbekova80@mail.ru, bolot661@rambler.ru

Keywords: digital economy, digitalization, agriculture, digitization, information and communication technologies, Internet.

Abstract: This article discusses the problems and prospects of digitalization in agriculture of the Kyrgyz Republic. The main problems of the introduction of ICT (information and communication technology) in agriculture, and distinctive indicators of digitalization in an integrated economy were shown. The possibilities of using information systems for the transformation of the domestic agricultural sector in the Eurasian Economic Space were shown. Agriculture in the Kyrgyz Republic has its own characteristics. First of all, this is a small-scale commodity type - agro-industrial complexes. In Kyrgyzstan, more than 440 thousand commodity producers with an area of agricultural land from 2 acres to several hectares are engaged in agricultural production. This requires the development and adaptation of individual digital solutions aimed at developing the capabilities of agricultural cooperation and standardization of product quality. Digitalization of the agricultural sector, covering agriculture, crop production, animal husbandry, fisheries and related areas, has led to a sharp increase in the flow of digital data. Thanks to data obtained from a variety of devices in fields, on farms, sensors, agricultural machinery, weather stations, satellites, drones and third-party systems, including cloud industry platforms, it is possible to obtain fundamentally new information.

1 INTRODUCTION

The age of information and computerization is based on the digital representation of information, which leads to an increase in the economic efficiency of an enterprise and an improvement in the quality of work on the scale of the economic and social life of an individual country and the whole world.

The Kyrgyz Republic is located in Central Asia, where more than three quarters of the country's territory is mountainous and landlocked, which is heavily dependent on agriculture, especially in rural areas, where 62% of its population lives. Agriculture in Kyrgyzstan, mainly family-owned, is focused on small-scale cultivation of crops such as potatoes, sugar beet, corn, wheat, along with animal husbandry. In recent years, Kyrgyzstan has begun to pay more attention to the development of digitalization through the introduction of modern information technologies in order to increase the efficiency of agricultural development. Despite these successes, the agricultural sector is lagging behind in the development of digitalization, leaving untapped opportunities for socio-economic growth and development.

Currently, it is impossible to imagine the work of all sectors of the economy, including agriculture, without information and communication technologies. A necessary condition for the digitalization of the economy and agriculture is the achievement of a high level of informatization and automation.

Digitalization creates prerequisites for choosing new directions for the development of the economy of states and entire regions through ensuring the coordinated work of all economic structures, as well as the public administration system.

The transition to the digital economy is manifested in the automation of business processes,

[1] https://orcid.org/0009-0005-7302-3021
[2] https://orcid.org/0009-0001-3256-0753
[3] https://orcid.org/0009-0000-1155-3848

the introduction of computer technologies into the production activities of agricultural enterprises, service organizations, government agencies, financial institutions and others.

2 MATERIALS AND METHODS

In the Kyrgyz Republic, the starting point for the development of the digital economy can be considered the decision of the Supreme Eurasian Economic Council "On the main directions for the implementation of the digital agenda of the Eurasian Economic Union until 2025" No. 12 dated 11.10.2017. In 2018, the National Strategy for Sustainable Development of the Kyrgyz Republic for 2018-2040 was adopted, as well as the concept of digital transformation “Sanarip Kyrgyzstan” 2019-2023 (Digital Kyrgyzstan 2019-2023), which outlined the contours of the country's digital transformation (Vasilenko, 2017).

In the modern market economy of the Kyrgyz Republic, leading agricultural enterprises consider digital tools as a reserve for increasing productivity and saving production resources. Stimulating the introduction of digital technologies in agriculture will increase the quantity and quality of products produced in the agricultural sector of the Kyrgyz Republic.

Produced high-quality products help provide for the population, increase the profitability of agricultural production and strengthen the stability and sustainable development of agriculture as a whole (Fig. 1.).

Figure 1 shows that the gross domestic product (GDP), according to preliminary estimates, in 2023 amounted to more than 808 billion soms and increased by 4.2% compared to 2022.

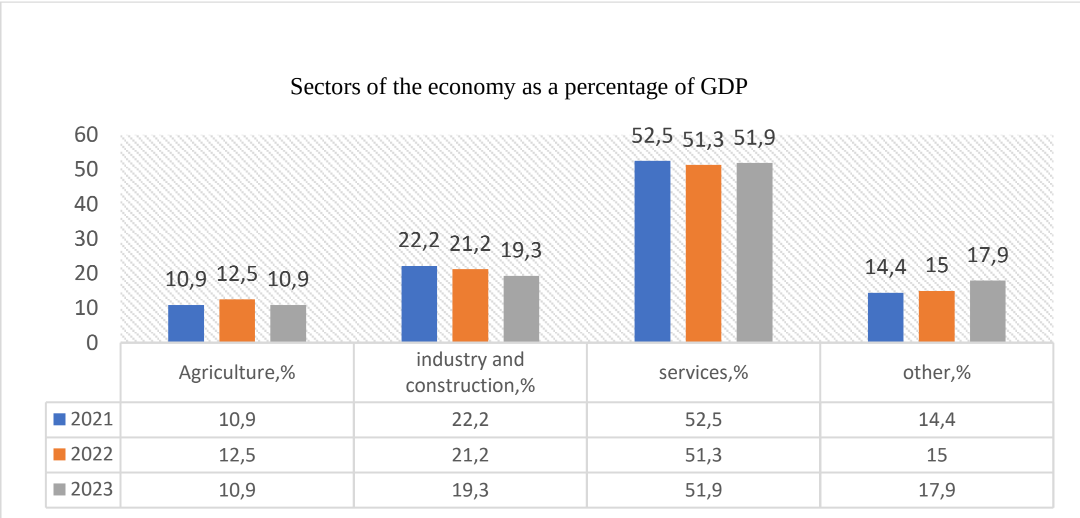


Figure 1: Food security and poverty information bulletin - B.: National Statistical Committee of the Kyrgyz Republic, 2023. Compiled by the author.

According to Figure 2, it can be seen that the gross output of agriculture, forestry and fisheries in 2023 amounted to 293.6 billion soms, while the physical volume index was 100.1%.

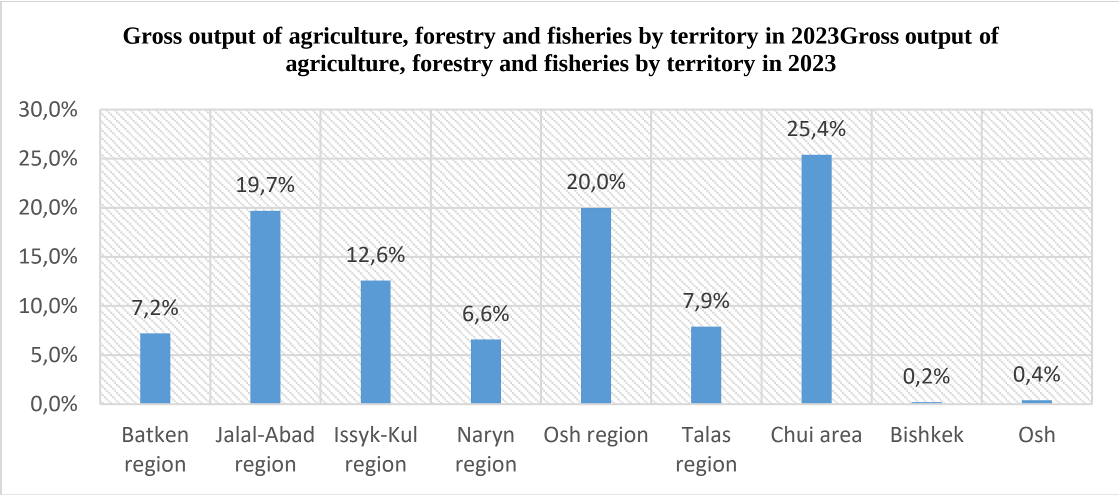


Figure 2: Food security and poverty information bulletin - B.: National Statistical Committee of the Kyrgyz Republic, 2023. Compiled by the author.

In the total volume of gross output of agriculture, forestry and fisheries of the republic, the Chuy region occupies the largest share (more than 25%) (Fig.2).

The development of agricultural production in Kyrgyzstan and increasing the efficiency of agricultural production to a world-class level are impossible without the introduction of advanced (digital) technologies.

Digitalization of agriculture is a necessary condition for increasing its competitiveness.

The transformation of the agricultural sector includes the digitalization of all branches of agricultural production: crop production, animal husbandry, fishing, poultry farming, industry and other areas.

The digital economy has been actively developing in Kyrgyzstan since 2020 during and after the COVID-19 pandemic, when many agricultural enterprises, realizing the opportunities that open up to them, were forced to actively use digital technologies and Internet resources, which allowed to increase the number of enterprises in agriculture.

There are more than 150 developed information systems in the Kyrgyz Republic, which are actively used in more than 70 government agencies, including ministries, departments, agencies and agricultural units. However, the lack of a single state register of information systems makes it difficult to accurately assess the number of systems used (Fig. 3).

In general, the development of information systems in the Kyrgyz Republic is rapid, and the improvement of technologies and automation of processes are becoming an integral part of the activities of government agencies.

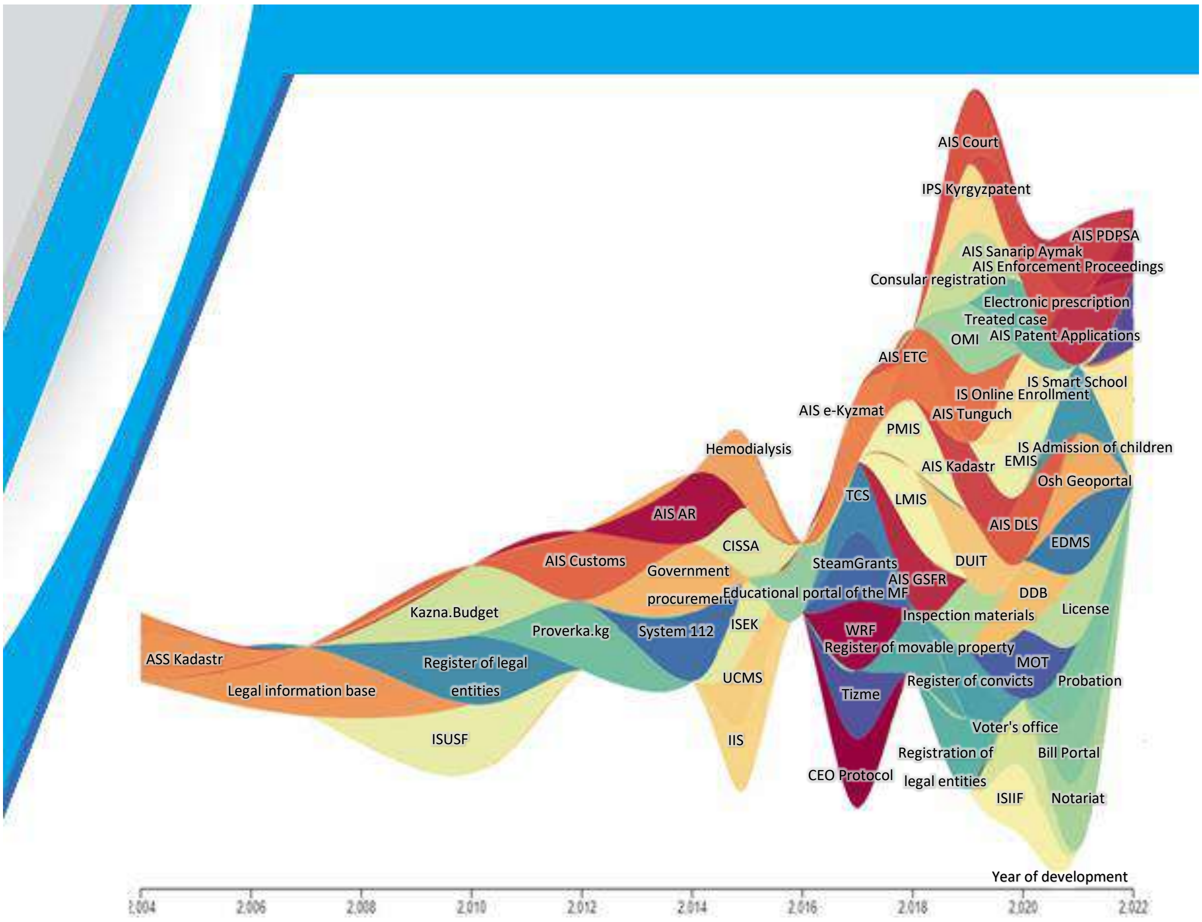


Figure 3: Chronology of development of information systems in the Kyrgyz Republic by year up to 2022.

Digitalization is the development of new business lines, online trade in professional computer equipment and new working specialties, services and functions for training in the use of an intelligent system in agriculture.

There are many factors that contribute to the development and use of digital technologies. Let us note the main factors influencing the agricultural sector:

- globalization of trade;
- population growth
- changes in consumer preferences.

Agriculture and the agro-industrial complex of the country are the key sectors of the economy in which the majority of the working-age population of the country is employed. Digital technologies in this area are developing so rapidly that Kyrgyzstan needs to consider the development and implementation of digital technologies in agriculture in order to ensure faster growth, which will significantly affect the increase in productivity and growth of the entire agricultural sector.

Digital agriculture allows farmers to enhance the uniqueness of their products and improve their quality. Through the use of advanced technologies, farmers can control and optimize growing conditions, including moisture, lighting and nutrients, to create optimal growth conditions for each crop.

This results in products with better taste, texture and nutritional properties. In addition, digital technologies allow farmers to track and control the production process, from sowing and caring for plants to harvesting and storing products. Monitoring and automation systems allow farmers to receive information about the condition of their fields and plants in real time, allowing them to quickly respond to any problems such as diseases or pests.

As a result, farmers can offer unique and high-quality products to their consumers. This can be especially valuable in the context of the growing demand for natural and organic products, as well as products with certain properties, for example, without certain allergens or rich in certain nutrients.

In general, digital agriculture provides farmers with tools and resources to increase the efficiency and quality of their production, which helps to increase the uniqueness and competitiveness of their products in the market, which in turn affects the solution of the country's food security.

Digital technologies can be used not only for the development of agriculture, but also in animal husbandry. Electronic identification, monitoring, the use of Internet technologies to track animal health, collection and analysis of data on the state of pastures and changes in weather conditions will significantly affect the increase in productivity of farmers in Kyrgyzstan.

Digitalization is an integral part of agriculture: from crop planning, irrigation automation and digital plant modeling to calculating feed for feeding animals.

Agricultural technology has seen a huge increase in investment in the last decade. The main innovations relate to livestock farms, which are becoming more technologically advanced, using automated control systems and modern software.

An important aspect is the marketing of agricultural products. Digitalization should help farmers obtain appropriate electronic quality certificates and other documents that will allow them to trade both inside and outside the country without problems. It is important to note the role of digital platforms in promoting the sale of farm products, coordinating farmers in their interaction with local and regional logistics centers, which will allow farmers to increase sales through electronic trading platforms and reduce risks through the development of insurance instruments.

Digitalization of deep processing of agricultural products can affect the increase in added value. This industry will require the use of digital technologies for traceability and automation of processes in order to conduct detailed monitoring of the quality of products, inventory and sales processes. Together, the digitalization of agriculture and the promotion of innovation in this industry will make it possible to make strategic and tactical decisions based on data analysis and optimization of production and supply chain of agricultural products.

Technologies such as connected sensor systems, automatic seeders and harvesters, systematic data collection and transmission, as well as aerial photography of agricultural land.

Digital technologies play a key role in agriculture and processing enterprises, enabling the collection and analysis of data for strategic decision-making. They also help farmers increase productivity by monitoring animals, soil, and weather. It is also important to provide farmers with appropriate certificates for convenient trade. The digital platform facilitates sales and coordination with logistics centers, and the demand for digital skills in the Kyrgyz economy is high, especially in the communications and information services sector.

As noted above, electronic identification monitoring, the use of Internet technologies to monitor the condition of livestock, the collection and analysis of data from the ground, weather changes – all these factors have had a major impact on increasing the productivity of farmers. An equally important issue is the sale of agricultural products.

The introduction of digital technologies is accompanied by farmers receiving the corresponding electronic quality certificate, as well as other documents that make it easy to trade inside and outside the country.

The role of the main sectors of the economy in creating demand for digital skills. It has been determined that the main sectors of the economy of the Kyrgyz Republic need specialists with digital skills at different levels, both in quantity and quality. The level of technological complexity of these industries strongly affects the overall competitiveness of the products of these industries in the international market.

Agriculture plays an important role in providing employment and requires workers to have basic digital skills. However, achieving the indicators of the agricultural sector of Sanarip Kyrgyzstan, as noted above, means increasing labor productivity, automating production processes and reducing the share of employment in this sector. Therefore, to achieve the set goals, a smaller number of more qualified personnel with advanced ICT skills is required, which leads to an increase in income.

Digitalization of agricultural products can also affect the increase in the cost of additional products. It is necessary to use digital technologies to calculate and automate the processes of detailed quality control and labeling of products manufactured in this industry.

The use of digitalization in agriculture involves solving the following tasks:
- increase in labor productivity;
- increase in export revenues;
- increase in the cost of products of enterprises;
- increasing the rate of economic growth in industries;

- creation of an effective supply chain from producer to consumer; integration into related sectors of the digital economy;
- increasing the attractiveness of agriculture and increasing the income of farms.

It is extremely important for agricultural businesses to make the most of innovative Internet technologies to increase profitability. Therefore, one of the main factors in the development of agriculture in order to reduce costs, increase productivity and optimize the labor process is the introduction of digitalization. To achieve this, agricultural producers need to implement better applications in the near future, such as:

– Cropstream - an application that facilitates collaboration between agricultural producers and enterprises through coordination, communication and synchronization of crop production activities. It brings together farmers, seed sellers, service providers, consultants, retailers and often manufacturers, helping them grow their business and simultaneously keep track of all discussions, products, photos and places related to them;

– FieldCheck - an application that helps pesticide application specialists find special crops and insect hive locations using their mobile devices;

– Kugler Timing - a farm management application that provides fertilizer planning and provides tips on a wide range of crops with 11 additional options that cover every stage of plant development from seed to harvest;

– RRXtend Spray helps farmers plan spraying more effectively by providing weather forecasts and risk probability;

– Agrellus app is a marketplace that brings together buyers and sellers of agricultural materials and protective equipment. This solution allows users to request numerous offers from dealers, customize requests, select targets such as insect type, weed type, seeding or defoliation, select the rate per hectare, receive advice on regulatory requirements to produce the best product to meet the needs of stakeholders, as well as specify delivery dates.

3 CONCLUSIONS

The importance of introducing digital technologies in the agricultural sector for Kyrgyzstan is that it will reduce risks, increase crop yields, as well as reduce the cost of production, improve its quality and competitiveness in the market.

Thus, the acceleration of digital transformations in agriculture and the formation of a digital agricultural sector of the economy largely depends on the investment climate in the country and the increase in investment in this industry.

REFERENCES

Nacional'nyj statisticheskij komitet Kyrgyzskoj Respubliki. Institut statisticheskih issledovanij i povysheniya kvalifikacii. Ocenka cifrovoj transformacii v Kyrgyzskoj Respublike 2023 g. https://www.stat.kg/media/files/2d3ce15c-2581-42cf-b693-8c9dbe33ecdf.pdf.

Vasilenko, N.V., 2017. Cifrovizaciya kak osnova evrazijskoj ekonomicheskoj integracii. Gosudarstvo i rynok: mekhanizmy i instituty evrazijskoj integracii v usloviyah usileniya global'noj giperkonkurencii. kollektivnaya monografiya. - Sankt-Peterburg, 152 c.

Informacionnyj byulleten' po prodovol'stvennoj bezopasnosti i bednosti. B.: Nacstatkom Kyrgyzskoj Respubliki, 2023. 59 s. https://www.stat.kg/media/publicationarchive/582751af-fccc-4935-a0ec-e2f4113dcc71.pdf (data obrashcheniya 01.04.2024 g.).

Informacionnyj byulleten' po prodovol'stvennoj bezopasnosti i bednosti. B.: Nacstatkom Kyrgyzskoj Respubliki, 2023 – 59 s. https://www.stat.kg/media/publicationarchive/582751af-fccc-4935-a0ec-e2f4113dcc71.pdf (data obrashcheniya 01.04.2024 g.).

Obzor gosudarstvennyh avtomatizirovannyh informacionnyh sistem 2023 g. file:///C:/Users/Talant/Desktop/OBZOR-GOSUDARSTVENNYH-AVTOMATIZIROObzor-GOS-INFORMACIONNYH-SISTEM-1.pdf.

Obzor tendencij razvitiya sel'skohozyajstvennyh tekhnologij v 2024 godu. https://stfalcon.com/ru/blog/post/digitalization-farm-trends .

Analiticheskaya zapiska. Ocenka cifrovoj transformacii v Kyrgyzskoj Respublike 2020 g. S. 8-9. https://www.stat.kg/media/files/2d3ce15c-2581-42cf-b693-8c9dbe33ecdf.pdf.

Emel'yanovich, I., 2016. Gosudarstvennye standarty cifrovoj ekonomiki. *Nauka i innovacii.* № 157. S. 10-12.

Sokolova, A. A., 2019. Sovremennoe sostoyanie i perspektivy innovacionnogo razvitiya agrarnogo sektora regiona. *Ekonomika Professiya Biznes.*

Monahov, S.V., 2022. Cifrovaya transformaciya transfera tekhnologij v sel'skom hozyajstve: sozdanie i ispol'zovanie cifrovyh. *APK: ekonomika, upravlenie.* № 6. S. 25–32.

Nonlinearity of Innovative Development and Digital Transformation of Industry in the Irkutsk Region

Sergey Vitalievich Chuprov[a]
Department of Management and Service, Baikal State University, Lenin St., 11, Irkutsk, Russian Federation
ChuprovSV@yandex.ru

Keywords: Development, Digitalization, Industrial enterprise, Innovation, Instability, Nonlinearity, Region.

Abstract: Trends in modern development and digital transformation of industry in the Irkutsk region in a non-stationary environment of geopolitical and innovative disturbances are discussed. From the perspective of fluctuations in the index of industrial production and the share of innovative goods, works, services in the total volume of goods shipped, works performed, services of industrial production organizations in the region, a brief analysis of the features of their dynamics is carried out and a conclusion is formulated about the high variability of indicators as a consequence of the increasing effect of disturbing factors of the global and the Russian economy. Along with this, from the standpoint of nonlinear dynamics and synergetics, the features of instable development and the problems of digitalization of industry in the Irkutsk region are revealed using the results of modeling the national economy under three scenarios of its receptivity to innovations and financing of the intellectual sphere. In conclusion, the directions of industrial development in the regional Strategy in the field of digital transformation of sectors of the economy, social sphere and public administration are characterized..

1 INTRODUCTION

In the current highly disturbed economic environment, the functioning of industrial enterprises is undergoing non-trivial transformations caused by the influence of obstacles and trends in the global and domestic economy. In the space of their destructive and innovative impact and chaotization of the regional industry, scientific interest in the theoretical, methodological and practical equipment of the technology of adaptive management of industrial enterprises in a non-stationary environment is growing. Meanwhile, with the rooting of non-linear views in the field of research of evolving economic systems, the absolutization and preference for their instable innovative development have become the subject of critical revision. And yielding to a balanced dual approach, it is legitimate to take advantage of the instrumental achievements of the teachings of nonlinear dynamics and synergetics on self-organization and instable development of such systems.

In this context, the trends in the variability of a number of indicators of the regional industry and its digital transformation within the framework of the innovative development of industry in the Irkutsk region are noteworthy. The use of mathematical modeling makes it possible to assess and interpret scenarios for the national economy's susceptibility to innovations with changes in the conditions for financing the country's intellectual sphere.

2 MATERIALS AND METHODS

The theoretical and methodological basis of the study was a symbiosis of natural science and economic teachings: nonlinear dynamics and synergetics, theories of evolution, chaos, stability and catastrophe, regional, innovation and production management, computer modeling technology.

[a] https://orcid.org/0000-0001-8581-9733

3 RESULTS AND DISCUSSION

The purpose of the study is to provide a trend analysis and interpretation of the nonlinear evolution of the regional industry of the Irkutsk region under the influence of geopolitical and innovative disturbances of the non-stationary environment and to discuss scenarios for modeling the development of the national economy in line with the priorities of innovative modernization and digital transformation of Russian industry.

The dominant imperatives of our time – the growing innovative modernization and digital transformation of the Russian economy and its industries – are accompanied by the updating and expansion of the agenda of ongoing scientific research, filling it with the design, production and development of intelligent production and management technologies. Meanwhile, the idea of promoting such developments has required a rethinking of the concept of innovation management, which primarily meets the conditions of a relatively regular and predictable, stationary environment. At the same time, adherence to the principles of systems analytics involves the development of theoretical, methodological and practical support for the processes of diffusion and innovation in industry on the basis of non-linear paradigms addressed to the nature of sudden and large-scale changes in the extraordinary behavior of systems.

Transitional processes against a disturbed background and the problems of forming an innovative economy explain the attractiveness of research topics on the stability of economic systems (Babkin, etc., 2017), analytics of the processes of ensuring the stability of innovative development in an uncertain and dynamic external environment (Khudyakova, etc., 2018), the influence innovations in industry on structural changes in the Russian economy (Akberdina, etc., 2021) and the formation of a new technological structure of economic organizations (Alekseeva, etc., 2020).

Publications on activating the innovation and investment potential of industrial enterprises in the regions (Vorontsova, etc., 2023), technological aspects of the formation of a unified information space of the enterprise and the transition from the data economy to the knowledge economy are devoted to the increase in scientific knowledge (Khitrova, etc., 2023), neurocomputerization of the production process, digital web transformation and promotion of digital products and technologies (Shtiller, etc., 2023), etc.

With the aggravation of interstate relations and sanctions pressure from Western countries and the United States, the space of the world and Russian economies is changing qualitatively, experiencing unprecedented pressure from competition in commodity markets, disruption of material, technical and financial flows between countries. The “invasion” of these disturbances into the economic environment of the Irkutsk region entails wide fluctuations in the indicators of its functioning, in particular, the index of industrial production of the region in 2011-2023, which reveals high unevenness in the range from 97.0% in 2023 to 109.4% in 2012 and fragmented cyclicity.

The trend of change in this index shows its sharp drop from 112.7% in 2013 to 103.0% the following year due to the outbreak of the financial crisis, after which its monotonous growth was replaced in 2017 by a decrease and increase, starting in 2020. This variability of the index is explained by the weak protection of the regional industry from the vicissitudes of the market and the complicated situation on the world markets for the sale of industrial products.

Against this “raging” disturbed background, the dynamics of the indicator of the share of innovative goods, works, services in the total volume of goods shipped, works performed, services of industrial production organizations of the Irkutsk region does not exceed 3 percent and is instable, having a large amplitude of fluctuations values from 0.1% to 3.0%.

It is known that in the concept of synergetics, the phenomena of self-organization and the emergence of order in nonlinear systems are generated by the dissipation and interaction of ordered and chaotic processes. As a result, the cooperative behavior of parts of the system is accompanied by a change in its stable and instable stages and the emergence of fundamentally new properties of the system. In continuation, we note that the effect of fluctuations on it in a disturbed environment not only excites the system and undermines its stability, but over time, organization grows in the chaotic system and it gains stability. The universality of synergetic patterns provides a logical basis for the desire to comprehend them in the knowledge and interpretation of the perestroikas of self-organizing economic systems in interaction with the innovative environment. “Nonlinear thinking” masters economists when they step into the world of slow and fast, smooth and abrupt changes in the nonlinear behavior of economic systems.

In the course of evolution, innovative fluctuations in the business environment can significantly shake the dynamics of the stationary functioning of an industrial enterprise, triggering the transition process of introducing promising projects on it. In particular, the production and implementation of technological and product innovations can introduce anomalies into the smooth flow of production activities of an enterprise: disruptions in the supply of purchased equipment or components, disruptions in the intra-shop flow of material resources and modernization or "linking" of the manufacturing technology of innovative products, pauses in the transition to its release or development of serial (mass) production, etc. Obviously, this kind of deviation from the prescribed mode of operation serves as a source of chaos and metamorphosis in the evolution of an industrial enterprise.

The concept of nonlinear dynamics allows that even small external influences lead to radical perestroikas in the activities of an industrial enterprise with branching trajectories. However, having information about the bifurcation point, it becomes possible to influence the evolutionary process of the enterprise (Akhromeeva, etc., 2007, p. 16).

The hypothesis that the pattern of increasing orderliness and efficiency of an enterprise's activities is inherently cyclical, dictated by the nonlinear evolution of an industrial enterprise within the framework of the interpretation of the theory of perestroikas looks very plausible (Arnold, 1990, p. 100). Thus, its innovative modernization with the application of entrepreneurship (Fig. 1, axis P_1) entails a wave-like ascent to higher economic efficiency (axis P_2) with a change in stable states. At the same time, with the available resources and efforts of managers, it is necessary to first remove the enterprise from an ineffective ("bad") stable state, and then, with its loss, along a curvilinear trajectory, direct the evolution of the enterprise to the target ("good") stable state.

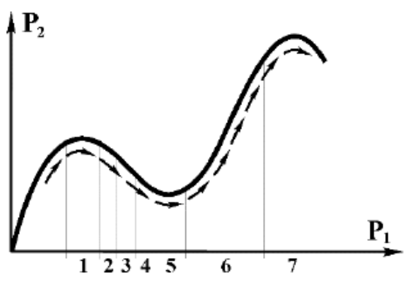


Figure 1: Perestroika economic system from the point of view of the theory of perestroikas (Arnold, 1990).

And paradoxically, it is easier for an underdeveloped industrial enterprise to undergo such a metamorphosis, since it is less resource-intensive to transfer it at the initial stage to an instable mode of operation due to the relative weakness of the forces that keep the enterprise in a "bad" stable state.

Theoretically and practically valuable results were obtained in the process of modeling the development of higher education in Russia, taking into account the susceptibility of the economy to innovations (Akhromeeva, etc., 2007, p. 442 – 444). Based on the views of nonlinear dynamics and UN statistics, the problem of forecasting the industrial development of the country and the contribution of science and education to it was solved on the basis of computer analysis of discrete mapping for three variables: resources, production (gross domestic product) and science with education. The macromodel showed that two key variables determine the modeling picture: the lag time, which characterizes the time interval from the success of science and education to the reaction of the economy to them (from 3 to 5 years), and its susceptibility to innovations.

Visually, the three modeling scenarios illustrate the macroeconomic trajectories presented in Fig. 2-4. Using their curves, one can estimate the dependence on time (*t*-axis in years) of resources (dashed curve), production volume (solid curve) and scientific and technical potential (dashed curve) in conventional units.

It is striking that in an economy that is not receptive to innovations (despite the active development of science), the surge in production volume (Fig. 2) quickly fades away, while in an economy that is receptive to innovations (Fig. 3), there is a "technological breakthrough" and substitution influence of resources in the intellectual sphere.

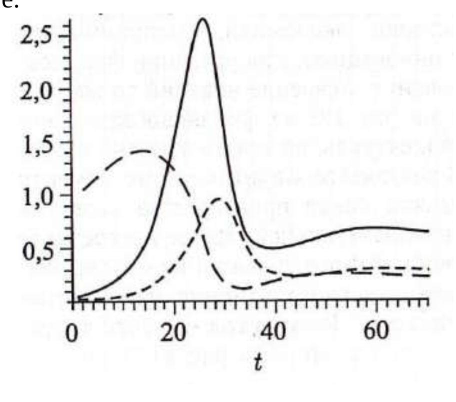


Figure 2: Macroeconomic trajectory immune to economic innovations (Akhromeeva, etc., 2007).

Finally, in an economy receptive to innovations, when funding for science and education is cut in half (Fig. 4), rapid growth in production volume is replaced by a decline. With the formation of a kind of "vicious circle" with direct and feedback coverage, the intellectual sphere does not "feed" innovations to the economy, and the latter degrades and limits financial investments in the intellectual sphere.

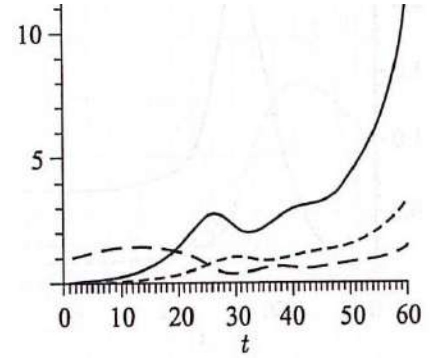


Figure 3: Macroeconomic economic trajectories, receptive to innovations (Akhromeeva, etc., 2007).

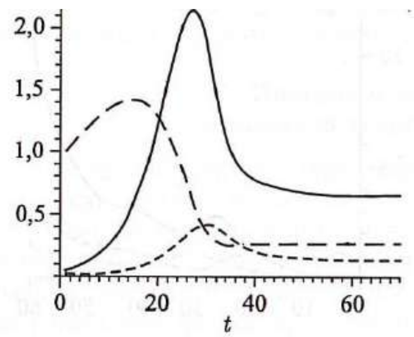


Figure 4: Macroeconomic economic trajectories, receptive to innovations, when funding is cut (Akhromeeva, 2007).

The economy of the Irkutsk region in this aspect does not yet inspire much optimism, but it provides valuable material for analytics: usually inertial in a stationary environment, now the region's industry is subject to the influence of destruction and evolves nonlinearly with low susceptibility to innovations. Under the pressure of stress disturbances, the basic indicators of the Baikal region industry vary widely, demonstrating a range of trends in their changes and the instability of the observed values.

Returning to the dynamics of innovative development of industry in the Irkutsk region, we note the non-linear nature of changes in the indicator of the share of costs for innovation activities in the total volume of goods shipped, work performed, and services in 2010–2022 with intermittent growth rates. At the same time, comparing it with the dynamics of the level of innovative activity of organizations, we find the same trend: asynchronous variation in rates in 2014–2015 and 2018–2020 and synchronous in other years.

In general, the country's digital transformation is gaining momentum as a national priority: according to the Russian government, in 2022 the digital maturity of the most significant sectors of the economy and social sphere reached 65.8% against the planned 56.2%, the share of mass digital socially significant services is 99.97 % against the planned 65.0%, and the share of households with broadband Internet access is 86.1% against the planned 80.0%. The volume of investments in domestic IT solutions also exceeded expectations, amounting to RUB 521.9 billion with an increase of 157.4% against the planned 156.0%.

An optimistic scenario for digital transformation with expanded government support, provision of investments and financing of full-fledged commercial projects aims to create conditions for the immediate creation of alternative solutions and software. Whereas in a pessimistic scenario with increasing negative trends and insufficient government support, the advancement of digital transformation will lose its previous pace, burdened by the timing of import substitution and the speed of development of new products. The outflow of a significant number of IT specialists from Russia, as well as the limited resources of Russian IT companies, integrators and equipment manufacturers when creating digital transformation tools, cannot be ruled out.

The dominant vector of innovative development of the regional industry obliges us to accelerate the digitalization of the socio-economic space of the Baikal region. Adopted in 2022, the Strategy in the field of digital transformation of sectors of the economy, social sphere and public administration of the Irkutsk region, among the existing development reserves, fixes the problems of processing big data and their objectivity, on the basis of which management decisions are made, as a result of the lack of integrated information systems, as well as insufficient dissemination of tools and practices for using data for making management decisions.

According to the mentioned Strategy, in a tense situation of unpredictable geopolitical risks and a deterioration in the price situation in commodity markets, insufficient volumes and inefficient use of financial resources, a high degree of depreciation of fixed assets due to the lag in digital transformation in regional industry, economic losses increase. Among them are low labor productivity and efficiency of production capacity, irrational use of resources, a long cycle of bringing products to market, the lack of a single source of complete and reliable information on the financial and economic activities of industrial enterprises, the complexity of processes for ensuring cybersecurity and the safety of data of industrial enterprises, undeveloped and insufficiently developed research base in the industrial sector.

It is expected that during the implementation of the Strategy measures the following promising technologies will be introduced: artificial intelligence, digital communications, big data technologies, etc. Thanks to this, stimulating demand for industrial products in the domestic market will be achieved, creating conditions for increased investment in research and development – design work (including the development of new industrial technologies) and increasing the level of cooperation between Russian enterprises, stimulating the integration of Russian manufacturers into global supply chains and exports of industrial products. The strategy provides for the creation of digital passports of industrial enterprises on the platform of the state industrial information system with an increase in the share of large and medium-sized manufacturing enterprises in the region that have generated digital passports in this information system.

4 CONCLUSIONS

The main trends in innovative development and digital transformation of the Russian economy are influenced by intense flows of geopolitical and innovative disturbances, saturating the non-stationary space of industrial enterprises with destructive influences and motivating incentives for digitalization and gaining the advantages of a new technological order. A quick analysis of regional industrial dynamics reveals the features and phenomena of the dynamic picture of changes in indicators of industrial production and the manufacture of innovative products in the Irkutsk region.

In a space replete with tricky interferences, the functioning of regional industry is subject to nonlinear evolution and industry development trends are instable with poor susceptibility to innovations. With the involvement of concepts and analytics of nonlinear dynamics (Akhromeeva, etc., 2007; Chuprov, 2016) and synergetics (Prigogine, etc., 2005; Haken, 1985), tools for mathematical modeling of transition processes, understanding and argumentation of metamorphoses and perestroikas of activities and digital transformation of regional industrial businesses in a highly disturbed economic environment.

Further research is intended to create theoretical, methodological and applied tools for ensuring adaptation and innovative development of industrial enterprises based on the use of principles and models of theories of evolution, chaos, stability and catastrophe (Moiseev, 1987; Gleick, 2023; Arnold, 1990; Chuprov, 2021).

REFERENCES

Akberdina, V., Smirnova, O., 2021. Innovations in Industry as a Factor of Structural Changes in the Economy: Russian Experience. *SHS Web of Conferences,* 110, 01051.

Akhromeeva, T., Kurdyumov, S., Malinetskiy, G., Samarsky, A., 2007. *Structures and chaos in nonlinear environments.* Moscow, FIZMATLIT Publ.

Alekseeva, N., Babkin, A., Makhmudova, G., Yung, A., 2020. Research and Assessment of Innovatively-Active Industrial Cluster Development. *Proceedings of Peter the Great St. Petersburg Polytechnic University International Scientific Conference on innovations in digital economy*, 38, 1-6.

Arnold, V., 1990. *Catastrophe theory.* Moscow, Nauka Publ.

Babkin, A., Tashenova, L., Chuprov, S., 2017. Management of sustainability and development of systems in the context of the synergetic paradigm. *Proceedings of 2017 IEEE 2nd International Conference on Control in Technical Systems*, CTS 2017.2, 318 – 321.

Chuprov, S., 2016. Nonlinear dynamics and sustainable development of industrial enterprises within the framework of synergetic paradigm. *RPTSS 2015 – International Conference on Research Paradigms Transformation in Social Sciences 2015*. SHS Web of Conferences 28, 01022.

Chuprov, S., 2021. Knowledge in the model of dynamics and stability of an industrial enterprise. *Northern Sustainable Development Forum 2020 SHS*. Web of Conferences, 112, 00034.

Gleick, J., 2023. *Chaos. Making a new science*. Moscow, AST Publ. House: CORPUS.

Haken, H., 1985. *Synergetics: Hierarchy of instabilities in self-organizing systems and devices.* Moscow, Mir.

Khitrova, T., Khitrova, E., Peshkova, O., 2023. Technological aspects of the concept of forming a

unified information space of a modern enterprise. *News of Baikal State University*, 33(4), 735–743.
Khudyakova, T., Shmidt, A., 2018. Methodical approaches to managing the sustainability of enterprises in a variable economy. *Espacios*, 39(13).
Moiseev, N., 1987. *Development algorithms*. Moscow, Nauka.
Prigogine, I., Stengers, I., 2005. *Order out of chaos. New dialogue between man and nature.* Moscow, KomKniga.
Shtiller, M., Trushkevich, I., 2023. Neurocomputerization as a Challenge of the Digital Economy. *Baikal Research Journal*, 14(1), 267–277.
Vorontsova, M., Isaeva, A., Krasnikov, A., 2023. Assessment of the innovative activity of industrial enterprises in the region in the context of structural transformations of the national economy. *Baikal Research Journal*, 14(1), 130–140.

Theoretical Justification for the Development of Methodological Recommendations for Holding Karate Competitions in a Remote Format

A.V. Stafeeva[1], S.S.Ivanova[2], I.Yu. Burkhanova[3], O.A. Musin[4], M.E.Mokhova[5]
"Minin Nizhny Novgorod state pedagogical university (Mininsky university)", Nizhny Novgorod, Russia
staffanastasiya@yandex.ru, svetlana-604@mail.ru, irina2692007@yandex.ru, mysin332@mail.ru, masya232007@yandex.ru

Keywords: karate competitions, remote format of competitions, methodological principles of training judges, approaches to online evaluation of competition results.

Abstract: The article examines the problem of holding competitions in a remote format. The relevance of the study is due to the increasing interest in holding competitions in an online format in various sports and the lack of regulatory and methodological support for the training process, as well as modern methods of training judges, objective requirements for video recording, criteria and indicators for assessing various types of athletes' fitness. The purpose of the study is a theoretical justification for the development of methodological recommendations for holding karate competitions in a remote format. As a result of the study, existing approaches to conducting and assessing athletes' performances at karate competitions in the usual "live" format were analyzed, the key differences between the two types of performances affecting the objectivity of athletes' assessment during the judging process were studied, recommendations were developed for judges participating in judging such competitions and for athletes to prepare for the performance in order to get the best possible result for their level.

1 INTRODUCTION

The relevance and importance of studying and developing theoretical and methodological foundations for holding karate competitions in a remote format are due to changes in the geopolitical situation in the world, difficulties in the geographical movements of athletes and restrictions associated with the pandemic, as well as progress in the development of remote forms of competitions, training and various seminars and conventions. Requirements for the remote format of competitions have been developed and presented in some sports, such as judo (Kata form), karate, cheerleading and others, however, the successful holding of such competitions requires methodological support for the training process, modern methods for training judges, as well as improved approaches to video recording, and criteria and indicators for assessing various types of athletes' fitness (Generalov, 2023). The analysis of scientific and methodological literature served as the basis for searching for modern approaches to improving the methodological foundations of holding karate competitions in a remote format, which include: preparation and holding of online competitions, approaches to evaluating performances at competitions, approaches to objective recording of athletes' performances at competitions.

All of the above served as the basis for setting the goal of the study, which consists of theoretical justification for the development of methodological recommendations for holding karate competitions in a remote format. To achieve this goal, it is necessary

[1] https://orcid.org/0000-0002-8720-7447
[2] https://orcid.org/0000-0001-6824-2530
[3] https://orcid.org/0000-0002-7954-2341
[4] https://orcid.org/0000-0001-8407-1700
[5] https://orcid.org/0009-0003-4067-9097

to solve the following tasks: analyze existing approaches to conducting and evaluating athletes' performances at karate competitions in the usual "live" format; study the key differences between the two types of performances that affect the objectivity of athletes' assessment if they are not taken into account in the judging process; develop recommendations for judges participating in judging such competitions to obtain the most objective and transparent assessment, and also give recommendations to athletes on how to prepare for a performance in order to obtain the best possible result for their level.

2 METHODOLOGY AND METHODS

The theoretical and methodological basis for the development of methodological foundations for holding karate competitions in a remote format was formed by the fundamental works on pedagogy by Galperin P.Ya., Sh.A. Amonashvili, Yu.K. Babansky; concepts of informatization of education and work on the application of information technologies in the field of physical education and sports: P.K. Petrov, V.Yu. Volkov, L.A. Khasin; martial arts masters: Shoshin Nagamine, Masatoshi Nakayama, Hirokazu Kanazawa and others; comparison, synthesis and generalization.

3 RESULTS OF THE STUDY

In the last few years, public life around the world has changed somewhat. This has affected many areas of people's lives and sport is no exception. Any changes, and especially a reduction in the training and competition schedule, negatively affect the physical fitness of athletes (Bystritskaya, Burkhanova, Ivanova, Stafeyeva, Zhemchug, 2018; Gitin, 2011). Therefore, during the pandemic and the restrictions associated with it, it was necessary to reconsider the possibilities of the training process and adapt to new conditions. In this regard, the remote format provides significant assistance. Over time, ideas emerged for conducting distance training and technical seminars linking athletes from different cities, and later, different countries (Danilova, 2022). At first, this was done in order not to lose the usual communication and as psychological support. Later it developed into mutually beneficial cooperation and new learning opportunities. Naturally, the next step was the emergence of ideas about not only training in an online format, but also the idea of holding competitions. Moreover, it is interesting that such ideas arose absolutely separately in different countries and different federations. But the meaning remained the same - psychological support for athletes, the desire to maintain the necessary physical and competitive shape regardless of the changed living conditions and maintenance, as well as the emergence of new communications within not only one country, but also at the international level.

Over time (in different countries at different times), the pandemic came to naught, restrictions were lifted, but the new practice has already shown its viability and relevance in everyday life. Online training and technical seminars are still being held, bringing together athletes and coaches from different cities and countries (thereby helping, among other things, to save time and money due to the lack of need to travel distances). Judicial seminars in an online format are becoming common, bringing together a large number of young judges who want to improve their professional qualifications but do not have the opportunity to stop their regular work activities for a long time (Masatosi, 2019).

As for the remote format of competitions: a large number of them were held by different federations and countries, both locally and internationally. And after the restrictions were lifted, one interesting fact was discovered - for some sports, for certain categories, such a format may not only be in demand, but also developed in ordinary life, not constrained by restrictions on movement. Moreover, the remote format provides opportunities in areas where they did not exist before.

In January 2023, a draft law was submitted to the State Duma of the Russian Federation, enshrining in law the definition of a "sports event using remote technologies" and the responsibilities of the organizer of such events. It is assumed that all competitions that are currently held online, including eSports, will be able to become official, that is, they will be regulated by law and can be included in the unified calendar plan of the Ministry of Sports of the Russian Federation. Thus, regulatory framework for holding competitions in an online format is currently being developed, which will contribute to the intensive development of this type of competitions and the theoretical and methodological justification of the training process (Generalov, 2023).

As an example of competitive activity in a remote format, we considered karate in our study. Although, the provisions under consideration can be organically introduced into some other sports that include formal performances, such as: kickboxing solo drills, Solo and Duet performances in fencing, Kata kobudo in Eastern martial arts, Duo-system in jiu-jitsu and some other sports that are not related to martial arts.

To achieve this goal, the existing approaches to conducting and assessing athletes' performances at karate competitions in the usual "live" format were analyzed, and the key differences between the two types of performances - online and "live", which can significantly affect the objectivity of athletes' assessment during the judging process were identified.

Since this format is a relatively new way of sports communication and, as a rule, is based on rather disparate events held by different federations in different parts of our planet, there is no universal methodology for preparing athletes for this type of competition, and for preparing qualified judges that would take into account the specifics of assessing such performances in order to obtain the most objective results of the competitions both between competing athletes and in relation to “live” performances. There are also no requirements for technical support of the competitions, either in terms of providing materials for assessment or ensuring transparency of judging (Mihal'chi, 2022). This study is an attempt to draw attention to the problems of holding online competitions of various federations in order to achieve objective, high-quality and full-fledged (in terms of sports competitions) holding of sports events in a remote format, taking into account and generalizing the experience of participation in such competitions, as well as in their judging. (Prokof'ev, Aleksandrov, Avstrievskih, SHemeneva, 2021).

With a great variety of karate styles and, accordingly, federations that unite them, both sports, which are official types, and traditional ones, not registered as a sport in Russia, but included in international federations and holding competitions at various levels, it is nevertheless possible to identify general criteria for assessing formal performances - kata. They were described quite thoroughly in such sources as: "The Essence of Okinawan Karate-Do" by Shoshin Nagamine, "Karate-Do: My Way of Life" by Gichin Funakoshi, "Best Karate" by Masatoshi Nakayama, "Karate-Do Kyohan: The Master Text" by Gichin Funakoshi, "Karate: The Complete Kata" by Hirokazu Kanazawa (Gitin, 2011; Gichin, 1973; Masatosi, 2019; SHoshin, 2011; Hirokadzu, 2013). These publications are very authoritative sources in the world of karate. On their basis, principles and criteria for assessing kata in competitive activities were developed. On their basis, international and Russian sports federations have developed common criteria for assessing kata in competitive practice and introduced them into the relevant Competition Rules of sports federations. It must be said that despite all the diversity and seemingly external differences in styles, trends, assessment scales, methods and recommendations for assessment, decision-making procedures and the general assessment criteria are generally the same and are based on historical sources.

Analysis and generalization of the assessment systems of various federations, presented in the Karate Competition Rules of the international federation SKIF, which currently includes more than 140 countries of the world, allowed us to identify the main criterion for performing the technique of the exercise. This criterion implies that Kata must be performed competently and must demonstrate a clear understanding of the traditional principles it contains. When assessing the performance of a participant or team, the judge will use the following indicators:

realistic demonstration of the meaning of Kata;

understanding the technique in Kata - the trajectory of blocks and punches embedded in the meaning;

good timing, rhythm, speed, balance and power focus;

proper use of breathing to assist physical effort during demonstration;

correct focus of attention and concentration;

correct stance with proper tension in the legs and feet on the ground;

correct tension in the abdomen and hips, without bouncing when moving;

correct form of execution of the declared kata, which is a demonstration of the corresponding style of Karate-do.

It can be said that these assessment criteria are identical and common requirements for judges for all styles, directions and federations of karate, and are included in all Karate Competition Rules. The assessment of kata demonstrations in online competitions is based on these same criteria. Judges must rely entirely on these criteria when making decisions. These provisions are the central content component of any judicial seminar in the training of judges, and seminars for the online competition format are no exception.

The online format imposes its own specifics on the assessment process. This is primarily due to two factors:

the performance is assessed from only one angle, some elements of the demonstration fall outside the judge's field of vision, while others, on the contrary, capture all the attention;

the assessment process is significantly influenced by factors unrelated to the athlete's performance demonstration itself, such as the quality of the performance recording, the lighting of the space, the camera angle, and the angle (frontal background) of the Kata chosen for demonstration.

4 RESULTS AND DISCUSSION

As a result of the analysis of the available methodological literature and our own practical experience of participating in karate competitions in a remote format, we have formulated recommendations for judges judging such competitions in order to obtain the most objective and transparent assessment. Recommendations have also been formulated for athletes on how to prepare for a performance in order to achieve the best possible result for their level.

An important aspect of athletes' preparation is the choice of a performance program. The most important thing here is that the judges will asses the performance from only one angle - the front view. Taking this fact into account, one should carefully consider the choice of the performance program:

for formal performances (Karate Katas, Kobudo Katas, Taekwondo Poomsae, Wushu Taolu, etc.) the athlete should choose those forms that are most visible from the front;

for free performance, when the program is drawn up directly for each athlete (freestyle with and without weapons, solo kickboxing drills, solo exercises, art fencing group) - the athlete should build their program in such a way that their back is as little as possible relative to the front line, and they should be in the center of the filming area for more than 2/3 of the performance. This is directly related to the difficulty of perceiving a performance that does not meet these criteria, and may negatively affect the assessment;

special attention should be paid to the elements of increased complexity when including them in a program or choosing (for formal performances) a program with their presence. To do this, it is necessary to strengthen the training process with general physical and special physical training, choosing exercises that will most contribute to the development of specific qualities necessary for performing certain elements of the performance;

Also, in the process of preparing for competitions in a remote format, it is advisable to conduct a control video recording 2-3 times during the entire preparatory pre-competition period for independent assessment of the visual effect of the performance and subsequent correction of the training process.

Analysis and generalization of the assessment systems of various federations, presented in the Karate Competition Rules, allowed us to formulate recommendations for the preparation of judges when conducting competitions in an online format.

As with athletes, it should be noted that the preparation of judges is also associated with their normal process of preparation for the implementation of their professional activities: constant improvement of their qualifications, attendance of training seminars of various levels, passing theoretical and practical tests and exams, regular judging at competitions of various levels in various judging positions. And of course, judging competitions in an online format has its own specific features that judges should pay attention to in order for the results of the competition to be as transparent and objective as possible.

For the preparation of judges, the most appropriate training method is to conduct introductory judicial seminars immediately before the competition. The issues discussed at these seminars can be divided into three groups:

1) issues related to the general principles of judicial activity, decision-making criteria, etc.;

2) the specifics of assessing a recorded performance: moments that should not be paid attention to and, conversely, moments on the video that reduce the score. This may be due, for example, to non-compliance with the Competition Regulations - going beyond the shooting area, unacceptable camera angle, non-compliance with the requirements for the athlete's uniform, etc. In some cases, this may lead to the athlete's disqualification, while in others, it may result in a lower score. Such points must be discussed in advance at the orientation seminar. The main thing in solving such issues is to prevent a violation of the principle of equality of all athletes in a given competition in order to obtain the most objective result.

3) technical issue of implementation of judicial activities. It is related to the format in which the competitions are held - live broadcast of performances in real time, for example, via YouTube, a preliminary assessment of the sent videos with their subsequent broadcast and personal protocols open to the public, or the absence of broadcast during remote assessment of performances.

An important point in the preparation of judges (when broadcasting performances and assessing them in real time) is their training in working with the platform on which the assessment will take place and the application in which the judges will communicate with each other. Naturally, organizing competitions in such a format in itself makes such competitions and judging as transparent and objective as possible.

In general, we would like to note that a positive aspect for competitions of this format for the organizations holding them would be the creation of a permanent panel of judges. This will significantly improve the quality of judging and, accordingly, will help attract more and more participants to the competition.

One of the important issues when holding online competitions is the means of recording the performance. Here we have identified two sides of the problem:

1. General requirements for recording that are included in the competition regulations by the organizers:

technical characteristics of the video recording: video size, horizontal video only, lighting, etc.;

requirements for the performance itself:

perspective and viewing angle

whether the camera is static or can be moved

is it necessary to shoot in one take or is it possible to "glue" the frames together

permissibility of using music, lighting, and other special effects

requirements for the athlete's uniform and footwear

requirements for the shooting location

requirements for the form of performance itself (permitted kata, permitted weapons, permitted elements)

the number of videos required for the competition. This may be due to the number of laps, rounds, and tours provided by the competition organizers.

All these criteria are intended to create equal conditions for all participants in the competition, contributing to an objective, fair and transparent result of the competitive process, which, in turn, will create a positive reputation for the competition itself and will contribute to an increase in the number of participants.

The second side of the problem is to increase the competitiveness of the athlete by working with video recording capabilities, naturally within the framework of the recording requirements of the competition regulations. This can be expressed, for example, in such indicators as:

the height at which the camera is mounted,

lighting

place of performance (if options are acceptable)

sound and lighting design - within the framework of the regulations

video quality, etc.

5 CONCLUSIONS

Thus, the presented material on the justification of the need to improve remote forms of holding karate competitions allowed us to draw the following conclusions. Online competitions have many positive aspects and open up new opportunities for competitive activities. Improving approaches to training athletes, preparing judges and online recording for performances in a remote format will allow athletes to participate in such tournaments more effectively, and recommendations for judges on the implementation of their activities will allow for an objective assessment of athletes' performances in a remote format to identify the strongest, regardless of the competition mode. Our recommendations for athletes on preparing for performances in a remote format will allow them to participate in such tournaments more effectively, and recommendations for judges on the implementation of their activities will allow for an objective assessment of athletes' performances in a remote format to identify the strongest, regardless of the competition mode.

REFERENCE

Bystritskaya, E. V., Burkhanova, I.Y., Ivanova, S. S., Stafeyeva, A.V., Zhemchug, Y.S., 2018. Models of master’s degree theoretical research in Russia and the USA.Astra Salvensis, Supplement 2/2018: Proceedings of the ―IV International Forum on Teacher Education‖. Pages: 115-124

Generalov, V.V., 2023. Komp'yuternyj i fidzhital sport v Rossii: administrativno-pravovoe regulirovanie i perspektivy. *Vestnik Ural'skogo yuridicheskogo instituta MVD Rossii.* №3(39). S. 5-7

Gitin, F., 2011. Karate-do: moj zhiznennyj put'.

Gichin, F., 1973. Karate-Do Kihon: osnovnoj tekst.

Danilova, E.E., 2022. Osobennosti motivacionnoj sfery sovremennyh rossijskih shkol'nikov: soderzhanie, vozrastnaya dinamika, rol' obrazovatel'noj sredy.*Vestnik Mininskogo universiteta*. T.10. № 1 (22).

Masatosi, N., 2019. Luchshee karate.

Mihal'chi, E.V., 2022. Izuchenie vzaimosvyazej adaptivnosti k fizicheskim usloviyam sredy s drugimi psihologicheskimi kachestvami lichnosti. *Vestnik Mininskogo universiteta.* T.10. № 2 (22).

Prokof'ev, I.E., Aleksandrov, A.N., Avstrievskih, N.V., SHemeneva, S.V., 2021. Osobennosti organizacii studencheskih onlajn-sorevnovanij po futbolu v

usloviyah pandemii COVID-19. *Uchenye zapiski universiteta imeni P.F. Lesgafta.* № 2 (192). S. 253-256.
Perevoshchikova, E.N., Stafeeva, A.V., Frolova, S.V., CHepurnova, T.A., Elizarova, E.YU., 2023. Postroenie sistemy nezavisimoj ocenki obrazovatel'nyh rezul'tatov budushchih pedagogov. *Teoriya i praktika fizicheskoj kul'tury*. №6.
Polozhenie k Vserossijskim onlajn sorevnovaniyam po Vostochnomu boevomu edinoborstvu «Voskhodyashchaya zvezda kobudo». 2021.
Polozhenie k OTW. Mal'ta, dekabr', 2021 g.
Pravila vida sporta dzyudo (utv. prikazom Minsporta Rossii ot 06.02.2020 N 80) (red. ot 20.01.2023)
Videomaterialy sudejskih ustanovochnyh seminarov. Organizator K.Galea, Mal'ta, iyun'-iyul' 2020.
SHoshin, N., 2011. Sut' okinavskogo karate-do". 234 s.
Hirokadzu, K., 2013. Karate: Polnoe kata. Kodansha Interneshnl.
https://alivebe.com/
https://didaktor.ru
https://hr-elearning.ru
https://gofederation.ru

Probability and Information Entropy in the Analysis of Reliability of Technical Systems

A. S. Dulesov[1] [1], D. Y. Karandeev[1] [2], A. A. Konovalov[1] [3], D. B. Bayyr[1] [4], N. V. Dulesova[2] [5]
[1] *Katanov Khakass State University, 92, Lenina ave., Abakan, 655017, Russia*
[2] *Khakas Technical Institute of Siberian Federal University, 15, Komarova ave., Abakan, 655017, Russia*

Keywords: probability measure, information entropy, reliability analysis.

Abstract: The paper outlines the issues of reliability analysis of complex technical systems. The justification of the need to perform reliability analysis of complex technical systems, the structure of which is a network, is given. We propose to apply for this purpose, in addition to probabilistic characteristics, information entropy calculated based on the K. Shannon model. A classical assessment of a random event in reliability analysis as a possible outcome (test result) is given. Following the theories of probability and information, the classical measures of probability and their relationship to the measure of uncertainty of information (entropy) are considered. The role of the private entropy obtained as a result of the tests and its participation in the classical Shannon model are indicated. A distinctive feature of this model is the differentiation of entropy into components related to two incompatible events with the probability of failure-free operation and the probability of failure. This avoids mixing entropies in the additive event accounting process. According to the classical theorems of addition and multiplication of probabilities, as well as consideration of compatible, incompatible and overlapping events, mathematical expressions of entropy are presented. They allow us to assess the level of information uncertainty in the task of reliability analysis for subsequent comparison and selection of system structures.

1 INTRODUCTION

The development of information technology provides for the implementation of analysis not only on the basis of the application of information measures, but also on the possibility of using information theory. In it, the key place is occupied by the issues of measuring information and its uncertainty when considering problems about the state and choice of systems.

Any technical system, especially a complex one (Bar-Yam, 2002; Kudzh, 2014), involves the creation of a model that, in the modeling process, due to the presence of uncertainty, doesn't fully reflect the variety of relationships between the elements of the system and the environment.

A complex technical system is classified to as an information technology system endowed, in particular, with the property of reliability. This property involves the study of approaches to the analysis of the relationship between subsystems (elements), the violation and restoration of which changes the behavior and state of the entire system.

At the same time, it is important to understand how the system interacts with the external environment (Monakhov, Savinykh, Tsvetkov, 2005). Therefore, it should be considered as open, for which interaction is considered through information and energy.

In the process of studying the state and behavior of complex systems, structural analysis (Butko, 2017) and structural modeling (Tsvetkov, 2017) are in demand. Taking into account the system analysis,

[1] https://orcid.org/0000-0001-6371-0171
[2] https://orcid.org/0000-0001-6202-5228
[3] https://orcid.org/0009-0001-2685-1503
[4] https://orcid.org/0009-0000-6904-7286
[5] https://orcid.org/0000-0001-8445-2095

structural reliability analysis is an integral part of it. These studies relate to the rejection of a number of system characteristics and the transition to the implementation of selective analysis. These studies concern the abandonment of a number of system characteristics and the transition to selective analysis. Thus, the system has to be replaced by an idealized theoretical abstract object (Tsvetkov, 2017). In fact, such a concept as "complexity" doesn’t provide for consideration of all the properties of the system, so we propose a way to simplify, understanding that one should not expect to get a one hundred percent result.

Reliability analysis concerns not only a complex technical system, but also a complex network. This network has a simpler structure of connections between the elements. Each element is endowed with the function of converting and transferring energy, as well as resources. The network structurally characterizes the state of the object. The transition of an object from one state to another depends on the external random influence of nature and purposeful human control.

Since the network is a simpler object in comparison with a complex system, it is therefore often depicted as a graph (Borisenko, Lakhno, Chepovsky, 2010). Despite the fact that the representation of a complex system and a complex network are not equivalent, they have common features. These include elements or blocks that have both external and internal connections. Considering the network structure as a graph, each branch of it is an element attached to some vertex. The whole set of formed vertices of the graph is characterized by a high density of internal connections and a low density of external connections, which is typical for closed systems. However, the graph representation of a network has the property of grouping networks. This allows you to move from a simple nodal representation of the network to a complex one, that is, in the form of blocks. Each of the blocks is an association of elements according to functional characteristics, representing small physical systems with a common input and output, which facilitates the analysis of structural reliability. Therefore, by presenting the network as a graph, the task of analyzing reliability is facilitated without losing the properties of the system.

2 THE CLASSICAL DETERMINATION OF PROBABILITY AND ENTROPY

Let’s further consider the relationship between the probability of events and information entropy in the analysis of the reliability of technical systems. In this process, we will take into account the author's scientific results presented in (Dulesov, Khrustalev, Dulesova, 2016; Dulesov, Eremeeva, Karandeev, Dulesova, 2018; Dulesov, Karandeev, Eremeeva, Khrustalev, Dulesova, 2019).

Testing (experience, experiment) is distinguished among the basic concepts from the theory of probability and reliability. It refers to the fulfillment of a number of conditions to determine the achieved level of reliability. Tests, for example, include control of equipment operating modes, exposure to loads on the test object, etc. Testing can also be attributed to the operation of the facility, where operating conditions, unintended impacts, environmental influences, etc. are considered as loads.

A random event (a possible event or just an event) is understood as any fact or factor that may or may not occur during testing. For example, during laboratory testing, equipment may break down, and during operation, various kinds of failures and accidents may occur. A random event in the reliability analysis is considered as a possible outcome, the result of the test. Considering the state of the system, the issues of randomness are related to the need to improve process control systems aimed at consolidating efforts to combat the elements (nature, unintended and intentional (dangerous) human actions, etc.).

From the point of view of identifying cause-and-effect relationships between objects, event A occurs because the cause is the appearance of the preceding event B. These events can be considered incompatible, the occurrence of one of them excludes the appearance of the other in the same test. For example, if an object fails during the testing process, then it cannot be considered as working. Events A and B are considered joint if they can occur together in the same trial. Two incompatible (opposite) events – when one of them must necessarily happen. The event opposite to event A is denoted as $\overline{A}$.

Let's start considering the classical probability and the measure of information uncertainty. At the same time, we will follow the theories of probability and information.

In the practice of reliability analysis, it is important to be able to compare events according to the degree of possibility of their occurrence. For example, during the testing process, the technical system should be much more efficient than in a state of failure. At the same time, it should be characterized by a certain level of information. Therefore, to compare events, informed decisions on the application of probability and information measures are required. The probability of a random event is a numerical measure of the degree of objective possibility of an event occurring. In addition, information entropy is taken into account – measure of the uncertainty of the system, measuring the degree of unpredictability of the occurrence of a probabilistic event, as well as a measure of information, meaning (according to the Shannon approach) the degree of knowledge about the possible state of the object. In addition to the above, we highlight the concept of a state, which denotes a set of stable values of variable parameters that characterize an object from the occurrence of an event to its transition to another event. The state is characterized by describing the variable properties of an object.

Most information technology systems are endowed with statistical data on their states. Then it becomes possible to determine the probability of an event and the amount of information in the analysis process. To do this, you can use the relative frequencies (frequencies) of event *A*:

$$W(A) = M / N \tag{1}$$

where *N* is the total number of experiments, *M* is the number of experiments in which event *A*.

In this case, the amount of information obtained is calculated in bits as:

$$h = -\log 2\ W(A) \tag{2}$$

The value of *h* is called partial entropy. For example, it is a measure of the uncertainty of random events that occur during tests (experiments) conducted in factory laboratories. Since the number of experiments is quite large and if the experiments are performed under the same conditions, (then according to the conditions of Lyapunov's theorem on the normality of the distribution of random variables with an unlimited increase in their number). We can testify to the following: when performing tests, the relative frequency W(A)) changes little, fluctuating around a certain constant number $p^*(A)$. This fulfills the condition: $p^*(A)=W(A)$. Therefore, $p^*(A)$ can be considered a statistical probability of the event in question.

Under these conditions, the application of the information entropy of K. Shannon (11), calculated by the expression:

$$H(X) = -\sum_i^m p_i(x) \log p_i(x) \tag{3}$$

subject to consideration of independent events:

$$\sum_{i=1}^m p_i(x) = 1 \tag{4}$$

where the base of the logarithm is arbitrary.

The mathematical expression of Shannon (3) is valid both for calculating information I and for entropy H. Entropy is endowed with some properties, which can be found in (12). One of them is: entropy is additive, that is, the total entropy consists of the entropies of events i:

$$H(X) = H(X_1) + H(X_2) + \ldots + H(X_i) + \ldots + H(X_n) \tag{5}$$

The application of (3) in reliability analysis has its own specifics. Complex technical systems have a high (close to one) probability of trouble-free operation. It means that the failure of the object doesn't occur within the specified operating time or a specified time interval. The value of $p^*(A)$ is the probability of failure-free operation obtained as a result of testing and it, together with the failure rate, characterizes the reliability of the object. In turn, the private entropy, measured in bits, according to (2):

$$h = -\log_2 p^*(A) \tag{6}$$

It will be close to zero, meaning that entropy as a factor of information uncertainty means the following: during the testing process, the information received (entropy) indicates a small number of events leading the test object to failures. The search for undesirable events (leading to failures) doesn't require a lot of additional information and time.

Considering the events as incompatible, from the point of view of reliability, the probability of failure-free operation p(t) and the probability of failure q(t) are distinguished (in most situations, coinciding with the probability of restoring an operable state). Then the function (3) will have the following form:

$$H = H(p) + H(q) = -\sum_i^n p_i(t) \log p_i - \sum_j^m q_j(t) \log q_j \tag{7}$$

subject to consideration of independent events:

$$\sum_{i=1}^n p_i(t) + \sum_{j=1}^m q_j(t) = 1 \tag{8}$$

Here n is the number of events related to the probability of failure-free operation $p_i(t)$, m is the probability of failure $q_j(t)$. Having proposed these expressions, we note the following: they are valid for reliability analysis, since random events relate to two qualitatively different indicators of object reliability (operation and failure). Expressions (3) and (4) will be valid without taking into account the qualitative separation of events.

Let's turn to the consideration of geometric probability and entropy. Since the number of outcomes in the analysis of the reliability of systems is limited, the geometric probability and entropy can be interpreted as follows.

Let's highlight the time interval for the entire period of operation (testing) of the object – the MN segment. This segment has its own length and is characteristic of only one state of the object. Suppose that a segment CD ≤ MN randomly falls on this segment, then this will be an event that covers part of the original segment with its length and its own state. At the same time, we don’t take into account which specific section of MN the event will appear on. Then the probability of occurrence of event A on any part of the segment MN can be calculated using the formula:

$$p(A) = \frac{t_{CD}}{T_{MN}} \tag{9}$$

where tCD is the length of the segment CD related to a random event, TMN is the length of the segment MN.

Information entropy, as a measure of uncertainty (unpredictability) of the occurrence of event A on the considered segment MN:

$$h(A) = \log p\,(A) \tag{10}$$

From expression (10) it can be seen that with increasing length of the segment CD, followed by coincidence with MN, $\lim_{p(A)\to 1} h\,(A) = 0$. The partial entropy of h(A)=0 means that there is no uncertainty when the event fully covers the segment MN. For very small segments CD, the partial entropy has a large amount of uncertainty and it becomes difficult to determine the location of the CD segment on MN.

By analogy, the task can be completed when an area g ≤ G falls on flat area G, then the probability of such an event A is determined by the expression:

$$p(A) = \frac{s_g}{S_G} \tag{11}$$

where s is the area of part g of the region G, and S is the area of the entire region G.

Information entropy, as a measure of uncertainty (unpredictability), is characterized by the event A about the presence of area s on area S. Calculation of h(A) is performed by expression (10).

Example. Let there be a piece on the chessboard. We don’t know which platform (cell) s it is located on. It is necessary to find a figure. The entire area of the board S consists of 64 platforms s. The probability that the figure is on the square (according to (11)) will be 1/64. By expression (10) information entropy h(A)=log2(1/64) = 6. After completing the action: dividing the board in half, the probability of finding a piece on the remaining half will be 1/32, h(A)=5. This action allowed us to remove the uncertainty of the shape search by 1 bit. Each further division in half allows you to remove the uncertainty by 1 bit until the search is completed.

3 A SET-THEORETIC INTERPRETATION OF THE BASIC CONCEPTS OF ENTROPY

Monitoring of tests (equipment failures during operation of a technical system), as a factor in the use of digital technologies, includes consideration of the set of all mutually exclusive outcomes, that is, the space of elementary events related to the elements of the system.

Let’s introduce operations on events that are equivalent to operations on the corresponding sets. We will consider the events from the perspective of reliability analysis, taking into account the work (Dulesov, Kondrat, 2014; Dulesov, Kondrat, 2014; Karandeev, Dulesov, Bazhenov, Karandeeva, Dulesova, 2022).

Since the probabilities of events are directly related to entropy, indirect methods are used to determine it, not direct methods (represented, for example, by expressions (3) and (7)). They allow us to determine the probabilities and entropy of other events related to them based on the already known probabilities and entropy of some events. At the same time, the main theorems of probability theory are taken into account. The mathematical expressions presented below are consistent with the probability theorems and mathematical calculations of A. Khinchin (16), as well as the geometric interpretation of the main actions on events using Venn diagrams.

The product of two events A and B (denoted AB or $A \bigcap B$) is an event consisting of those outcomes that are included in both A and B. Such an event AB provides for the simultaneous occurrence of events A and B. As an example, we can note the simultaneous presence of operable and non-operable states and their combinations only for two or more elements of the system.

According to the property of independence of events and the multiplication theorem, the calculation of probability has the form:

$$p(AB)=p(A)\cdot p(B) \quad (12)$$

The product of two events is the result of obtaining a joint entropy, the average amount of information for a pair of joint events A and B:

$$H(AB) = p(B)\cdot H(A) + p(A)\cdot H(B) \quad (13)$$

where H(A) = p(A)·log p(A) и H(B) = p(B)·log p(B) – the entropy of events A and B.

The sum of two events A and B (denoted A+B or $A \bigcup B$) is an event consisting of all outcomes: a operable and non-operable state, included in either A or B. In other words, A+B is understood as the following event: either event A or event B. The appearance of these events simultaneously (operable and non-operable) is not possible for the system element in question.

The probability of two incompatible events is:

$$p(A+B) = p(A) + p(B) \quad (14)$$

and the entropy for two incompatible events is calculated by the formula:

$$H(A+B) = H(A) + H(B) = – p(A) \log p(A) – p(B) \log p(B) \quad (15)$$

According to the probability addition theorem, the probability p(A+B) of the sum of events A and B for two elements is:

$$H(A+B) = H(A) + H(B) – H(AB) = p(B)\cdot H(A) + p(A)\cdot H(B) \quad (16)$$

The sum of the probabilities of opposite events is 1:

$$p(A) + q(A) = 1 \quad (17)$$

and the entropy of these events is calculated by the formula (7).

The difference between two events A and B (denoted A–B or A\B) is an event consisting of the outcomes included in A, but not included in B. The meaning of this difference of events is that event A occurs, but event B doesn’t occur. In this case, we mean the conditional probability p(B\A) = pA (B) of event B, provided that event A has occurred. Similarly, p(A\B) = pB (A) can be written.

Accordingly, conditional entropy is the amount of information about event A, provided that its own information is subtracted from it in the event of an event with probability p(B):

$$H(A\backslash B) = H(A) – p(B)\cdot H(A) \quad (18)$$

$$H(B\backslash A) = H(B) – p(A)\cdot H(B) \quad (19)$$

Based on the multiplication theorem, the probability of the product of two events is equal to the product of the probability of event A by the conditional probability B, provided that the first event occurred:

$$p(AB) = p(A) \cdot p_A (B) \quad (20)$$

and vice versa:

$$p(BA) = p(B) \cdot p_B (A) \quad (21)$$

Then the entropy of the joint events A and B can be calculated using the formulas:

$$H(AB) = p(A)\cdot H(B) \quad (22)$$

$$H(BA) = p(B)\cdot H(A) \quad (23)$$

Expressions (22) and (23) in total correspond to expression (13).

The presented set-theoretic interpretation of the basic concepts of entropy is limited, since statistical entropy concerns the consideration of discrete and continuous random variables and their numerical characteristics.

4 CONCLUSION

Considering the role of probability and entropy measures, the possibilities of their application in the task of monitoring and analyzing reliability are indicated by the needs for the use of digital technologies for the development of technical systems. Calculating not only probability according to statistical data, but also entropy is the result of choosing network structures that meet high reliability requirements. The presented theoretical calculations and mathematical expressions relate not only to the implementation of the initial stage of the solution search, but also to the reference point in the application of statistical estimates.

REFERENCES

Bar-Yam, Y., 2002. *General Features of Complex Systems. Encyclopedia of Life Support Systems*. London, UK: EOLSS UNESCO Publishers, Oxford.

Kudzh, S.A., 2014. The multidimensional nature of the consideration of complex systems. In *Prospects of science and education*, 1, 38-43.

Monakhov, S.V., Savinykh, V.P., Tsvetkov, V.Ya., 2005. *Methodology of analysis and design of complex information systems*. Moscow, Russia: Prosveshchenie.

Butko, E.Ya., 2017. A systematic approach in the formation of the structure. In *Slavic Forum*, 2(16), 25 - 31.

Tsvetkov, V.Ya., 2017. *Structural modeling: monograph*. Moscow, Russia: MAKS Press.

Tsvetkov, V.Ya., 2017. Complex technical systems. In *Educational resources and technologies*, 3(20), 86 - 92.

Borisenko, V.V., Lakhno, A.P., Chepovsky, A.M., 2010. Special representation of graphs and visualization of semantic networks. In *Fundamental and Applied Mathematics*, 8(16), 27 – 35.

Dulesov, A.S., Khrustalev, V.I., Dulesova, N.V., 2016. Quantification of information in the closed structure of a technical system. In *2nd International Conference on Industrial Engineering, Applications and Manufacturing*. ICIEAM.

Dulesov, A.S., Eremeeva, O.S., Karandeev, D.Yu., Dulesova, N.V., 2018. Approaches to information measurement of the structure state of technical systems. In *International Multi-Conference on Industrial Engineering and Modern Technologies*. FarEastCon.

Dulesov, A.S., Karandeev, D.J., Eremeeva, O.S., Khrustalev, V.I., Dulesova, N.V., 2019. The logarithmic basis to measure the amount of information related to the assessment of reliability of elements of the technical system. In *IOP Conference Series: Materials Science and Engineering. International Workshop "Advanced Technologies in Material Science, Mechanical and Automation Engineering – MIP: Engineering – 2019"*. Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations.

Shannon, C.E., 1949. Communication Theory of Secrecy. In *Systems Bell System Tech. Journal*. 28(4), 656 – 715.

Prokhorov, Y.V., 2022. Entropy in information theory. In *BigRussianEncyclopedia*.

Dulesov, A.S., Kondrat, N.N., 2014 The measure of uncertainty of information and its properties in relation to the assessment of the random behavior of a technical object. In *Journal "Scientific Review"*, 7(1), 258 - 264.

Dulesov, A.S., Kondrat, N.N., 2014. The amount of information at the overlap and intersection of elementary events. In *Journal "Scientific Review»,* 12(1), 146 - 150.

Karandeev, D.J., Dulesov, A.S., Bazhenov, R.I., Karandeeva, I.J., Dulesova, N.V., 2022. Entropy determination in the problem of the analyzing an electrical network state under the condition of independence of functioning of its elements. In *Journal of Physics: Conference Series*. IV International Conference on Applied Physics, Information Technologies and Engineering.

Khinchin, A.Ya., 1953. The concept of entropy in probability theory. In *Successes of mathematical sciences*, 8:3(55), 3 – 20.

Enhancing OLAP Query Performance Using NVIDIA GPU Shared Memory

Ilsaf N. Galavetdinov[a], Damir M. Bagymanov[b], Elena S. Belashova[c]
and Elmira Sh. Kremleva[d]
Institute of Computer Technologies and Information Security, Kazan National Research Technical University named after A. N. Tupolev – KAI, Kazan, Russia
ilsaf26052002@gmail.com, bagymanovdm@gmail.com, bel_lena@mail.ru, e-smile29.04@mail.ru

Keywords: GPU Shared Memory, OLAP Systems, Data Encoding, Conflict Resolution, Memory Management, Query Optimization.

Abstract: This article investigates the application of NVIDIA GPU shared memory for enhancing query performance in Online Analytical Processing (OLAP) systems. It delves into the unique capabilities of GPU architectures, specifically focusing on how shared memory can be optimized to accelerate analytical database queries. The discussion encompasses the use of integer-based encoding for organizing dimension tables and aggregated structures as simple arrays, which aligns with the GPU's memory banks to optimize data access and minimize overhead. Key strategies outlined include the dynamic resolution of memory bank conflicts through intelligent data reallocation and the management of multiple data copies within the GPU's limited shared memory. This is particularly significant in handling data-intensive operations common in OLAP systems, where efficiency and speed are paramount. The article also explores methods to mitigate potential bank and warp conflicts by strategically placing and replicating data, thus ensuring optimal parallelism and throughput. Furthermore, we analyse the impact of data distribution patterns, including the handling of skewed data distributions, on memory access and query performance. By examining how data skew affects serialization and access efficiencies, the study provides insights into the optimal management of shared memory resources to enhance query response times and overall system performance. In conclusion, the article highlights the transformative potential of GPU shared memory in processing large-scale data queries within OLAP systems, proposing several techniques to exploit the parallel processing capabilities of GPUs effectively. These optimizations not only reduce query latencies but also scale up the analytical capabilities of databases to meet the challenges of modern data environments.

1 INTRODUCTION

The modern digital landscape is characterized by an exponential growth of data, which continually challenges existing computational frameworks to keep pace with increasing demands for speed and efficiency. Graphics Processing Units (GPUs), with their inherent parallel processing capabilities and superior memory bandwidth, have emerged as a potent solution to this challenge. These capabilities make GPUs ideally suited for handling large volumes of data, thus providing a compelling hardware acceleration option for more effective system performance. By leveraging the high throughput of GPU memory, businesses can harness real-time data analytics and complex data warehousing applications, which are essential for driving decisions and strategies in today's fast-paced market environments. Additionally, GPUs offer an advantage in terms of energy efficiency compared to traditional CPUs, making them an attractive option for cloud computing infrastructures where power consumption and thermal management are critical considerations.

[a] https://orcid.org/0009-0002-1199-2589
[b] https://orcid.org/0009-0004-9497-8778
[c] https://orcid.org/0000-0003-4662-185X
[d] https://orcid.org/0000-0003-0858-0575

The utilization of GPUs for general-purpose computing has been extensively explored, with many studies underscoring their benefits across various computational tasks. Specifically, in the domain of Database Management Systems (DBMS), significant strides have been made in adapting GPU architectures for database operations. Key studies in this area include work by R. Fang et al. (2007), which explored the architectural suitability of GPUs for database processing, and P. Bakkum and K. Skadron (2010), who investigated the performance gains from GPU-accelerated database systems. Further, G. Diamos et al. (2013) demonstrated novel approaches to utilize GPU resources for improving the execution of SQL queries.

In terms of specific database operations, B. He et al. (2008) showed how GPUs could be used to accelerate complex join algorithms, which are fundamental for relational database processing. T. Kaldewey et al. (2012) developed a GPU-based hash join algorithm that efficiently utilized PCIe bandwidth to maximize data throughput. Earlier works, such as that by N.K. Govindaraju et al. (2004), have shown that GPUs can significantly speed up database operations like conjunction selections and aggregations, which are pivotal for analytical querying in older GPU architectures with different memory setups.

Despite these advances, the application of GPUs in database processing is still a nascent area ripe with opportunities for groundbreaking research, especially as newer generations of GPUs offer even greater compute and memory capabilities.

This research aims to formulate foundational principles for executing critical analytical database functions such as filtering and string-matching using GPU technology. The study will delve into various data domains to identify and optimize the key performance bottlenecks associated with these functions. By systematically exploring and exploiting the parallelism and high throughput capabilities of GPUs, this work seeks to redefine the benchmarks for speed and efficiency in analytical database operations. The overarching goal is to develop scalable, GPU-accelerated techniques that can support the complex and voluminous data analysis needs of modern enterprises, ultimately facilitating faster insights and enhanced data-driven decision-making processes.

2 DOMAIN ANALYSIS AND THE APPLICABILITY OF USING A GPU COPROCESSOR IN DBMS TASKS

The immense computational power of modern graphics processing units has opened new avenues for solving Database Management System tasks in conjunction with central processing units (CPUs). Despite this, many DBMS tasks remain memory-bound and do not benefit from the more powerful coprocessor, particularly due to the bottleneck presented by PCIe interfaces. Furthermore, not every task is suitable for execution on a GPU. Data-intensive tasks such as string processing generally do not see speed improvements due to data transfer bottlenecks. However, when the workload is substantial enough to fully utilize the GPU's parallel architecture, the investment in initializing the GPU can be justified.

Based on existing research and experimental findings, conclusions have been drawn on how DBMS performance can be enhanced using GPUs. Four distinct categories of DBMS tasks have been identified where performance gains can significantly impact the entire system and reduce response time for queries:

1) Application logic integration: most DBMS offer the capability to integrate application logic through stored procedures, allowing the DBMS to execute logic written in languages other than SQL, such as C++ or Java. These languages may provide easier or more efficient means in certain scenarios. Thus, the question arises: how can the coprocessor be utilized to leverage tasks in this first category?

2) Query optimization: users and applications typically interact with the database using SQL, a declarative language that does not specify how a query should be executed. Therefore, the DBMS must first construct an execution plan (EP) that informs the execution engine which operations to perform and in what order. The performance heavily relies on this plan, making query optimization a critical task for building and optimizing the EP.

3) Storage management: another crucial performance factor is the accessibility of stored data. Storage optimization generally aims at three goals: reducing the volume of memory used, speeding up read operations, and facilitating fast data modifications. However, optimizing for all three is not always possible. For instance, indexes can expedite data retrieval and searching but require memory for storage and need adjustments upon data

modifications. Compression reduces memory consumption but makes modifying compressed data more challenging. Typically, DBMS divides data so that frequently modified data is stored differently from read-only data. Rarely accessed data is archived, and the system automatically moves data based on usage, load, and system requirements. The faster this service can be performed, the more frequently it can be utilized. Furthermore, offloading parts of this service to a coprocessor can free up CPU resources for other operations.

4) Query execution: the final and perhaps most critical category is the execution of the EP itself. Typical database operations, such as joins, selections, and aggregations, have varying characteristics, and not every operation is suited for GPU execution. Moreover, various methods exist for transferring data from one operation to another.

Understanding the specific capabilities and limitations of GPUs in the context of DBMS tasks is essential. While GPUs offer significant advantages in terms of computational power and energy efficiency, their effectiveness in DBMS depends on the nature of the tasks and the ability to manage data transfer efficiently. This section underscores the potential and challenges of integrating GPU technology into the realm of database management, highlighting areas where GPUs can most effectively be deployed to enhance DBMS performance.

3 INTEGRATION OF GPUS FOR STATIC TASKS IN DBMS

Central Processing Units are versatile and universally programmable, tasked with managing a variety of operations from image processing to the execution of complex scientific calculations. This versatility, while beneficial for general-purpose computing, means CPUs are not optimized for highly specialized tasks. In contrast, Graphics Processing Units are tailored for specific operations, particularly those that benefit from parallel processing capabilities, such as graphic rendering. However, GPUs are not ideally suited for non-SIMD (Single Instruction, Multiple Data) operations, such as complex string manipulations or certain database tasks that require dynamic data handling.

The integration of GPUs into a Database Management System framework is not aimed at completely replacing CPUs but rather at complementing them by offloading specific, well-defined tasks. This approach can relieve some of the processing load on CPUs, allowing them to handle tasks that are more suited to their generalist capabilities. GPUs, with their ability to handle multiple operations simultaneously, can efficiently process tasks that are independent of the core database management functions.

Offloading tasks to GPUs can significantly enhance performance, but it is crucial to identify which tasks are appropriate for such processing. These tasks typically involve operations where the computational load is substantial enough that the GPU's parallel processing capabilities can be fully utilized, and where the data transfer bottlenecks are minimal. It is important to note that not all tasks will benefit from being transferred to a GPU; the nature of the task and the architecture of the DBMS must be conducive to parallel processing.

To determine whether a DBMS task is suitable for GPU acceleration, several criteria must be considered:

1) Existence of a parallelizable algorithm: the task must have an associated algorithm that can be executed in parallel. This is the fundamental requirement for any operation offloaded to a GPU, as GPUs excel in handling multiple operations simultaneously.

2) Suitability for SIMD execution: the task should be amenable to execution using the SIMD model, which is a core strength of GPU architectures. This involves operations that can be broken down into smaller, similar tasks processed in parallel.

3) Comparison of processing and transfer times: the decision to offload a task to a GPU should consider the time it takes to process the data on the CPU versus the time to transfer the data to and from the GPU. Offloading is justified when the GPU can process the data faster than the CPU, despite the data transfer time.

4) Minimization of additional data transfers: effective GPU utilization requires minimizing unnecessary data transfers, which can negate the benefits of accelerated processing. Tasks that can be completed on the GPU without frequent data exchanges with the main system memory are ideal candidates.

5) Overlap of data transfer and computation: if the data transfer to the GPU and the GPU's processing can occur simultaneously, it can lead to significant reductions in total processing time. This overlapping can optimize the usage of resources and reduce idle times.

Experimental results have repeatedly shown that the performance of algorithms on GPUs can be difficult to predict due to the complex interplay of data transfer speeds, algorithm design, and GPU architecture. However, with the right kind of task and careful planning of data flow and algorithm structure, GPUs can offer substantial performance enhancements in a DBMS environment.

The strategic integration of GPUs to handle static tasks within a DBMS can lead to significant performance improvements, particularly for data-intensive operations that align with the GPU's parallel processing capabilities. By carefully selecting tasks based on the outlined criteria, DBMS can harness the power of GPU technology to optimize performance and enhance overall efficiency in processing large datasets. This integration not only accelerates specific database operations but also frees up CPU resources for other critical tasks, thereby improving the responsiveness and throughput of the entire database system.

4 ANALYTICAL OLAP SYSTEMS

Online Analytical Processing systems represent a transformative approach to handling and analyzing vast amounts of data. Unlike traditional relational databases, OLAP systems utilize a multidimensional data model, transitioning from the concepts of relationships and entities to those of dimensions and data cubes. This shift allows for a more accessible and intuitive data retrieval mechanism for analysts, freeing them from many of the limitations of SQL through a different approach to report creation and data analysis.

At the core of an OLAP system is the data cube, which consists of multiple dimensions, each representing a different aspect of the data. A dimension can be viewed as a data category that has been pre-summarized across a range of attributes, making the analysis faster and more user-friendly. Each data cube within an OLAP system is an organized collection of data cells arranged in these dimensions. Cells represent data points defined by their position within the dimensional structure – each uniquely identified by its dimension values, known as labels.

Dimensions are essentially categories of information. For example:

- Temporal dimensions: include time intervals such as days, months, quarters, and years.
- Geographic dimensions: cover spatial hierarchies such as cities, regions, countries, and continents.
- Product dimensions: might include categories like type, category, brand, and manufacturer.

Each dimension contributes to a comprehensive view of the dataset, allowing analysts to drill down or roll up to analyse data at varying levels of granularity.

The structure of an OLAP system typically revolves around two main types of tables:

1) Fact table: this is the central table in a star schema configuration of an OLAP database. The fact table contains the quantitative metrics or measures of the business process, such as sales revenue, quantity sold, or inventory levels. Measures stored in the fact table are influenced by the corresponding dimensions.

2) Dimension tables: these tables are linked to the fact table and decode the dimension keys contained within it. For example, a 'Products' dimension table in a retail business database might list product names, manufacturers, categories, and other attributes. Dimension tables support the data cube structure by allowing the creation of hierarchies within each dimension.

Dimension tables not only decode dimension keys but also organize data into hierarchical structures that represent natural relationships within the dimensions. This hierarchical structuring is crucial for enabling efficient, intuitive navigation and analysis, supporting operations such as slicing, dicing, drilling down, and rolling up.

In OLAP systems, dimension tables are typically denormalized. This means that information is intentionally duplicated across the database to avoid complex joins, thus speeding up query response times. Although denormalization may lead to increased disk space usage, it substantially reduces the computational overhead associated with data retrieval, which is critical in scenarios requiring rapid analytical feedback.

The unique structure of OLAP databases, particularly the use of denormalized dimension tables and a central fact table, is designed to optimize data retrieval. This setup minimizes the number of joins required during query execution, thus enhancing performance. By carefully structuring data in alignment with anticipated query patterns, OLAP systems can offer swift and efficient answers to complex analytical questions.

OLAP systems provide powerful tools for handling complex analytical queries through a multidimensional approach to data organization. By redefining how data is structured and accessed, OLAP enables faster, more intuitive, and more flexible data analysis than traditional relational databases. The use of dimensions, data cubes, and specialized schemas like star and snowflake designs, supports efficient data analysis processes, making

OLAP an essential element in modern data-driven decision-making frameworks.

5 PRINCIPLES OF UTILIZING NVIDIA GPU SHARED MEMORY IN ANALYTICAL DATABASE QUERIES

The architecture of NVIDIA GPUs, with their shared memory capabilities, offers a powerful platform for enhancing the performance of analytical database queries, particularly within Online Analytical Processing systems. This section explores sophisticated encoding methods and conflict resolution techniques essential for leveraging GPU shared memory effectively in database environments.

OLAP systems frequently employ integer-based encoding for foreign key and grouping columns, which begin sequentially from zero. This encoding facilitates the organization of dimension tables and aggregated structures as simple arrays, rather than complex hash tables. The benefit of such array-based organization on NVIDIA GPUs, specifically on models like the C2070, is the direct correlation between array indices and memory banks due to the GPUs' cyclical allocation of memory banks every four bytes. This structure not only simplifies data access but also maximizes bank-level parallelism by aligning data access patterns with the physical memory architecture.

To illustrate, consider a foreign key column 'd' with integer values ranging from 0 to c-1, where c represents the cardinality of the reference table. In such a setup, each value in 'd' corresponds directly to an index in the array, and hence to a specific memory bank. For a GPU with a warp size of 32, like the NVIDIA C2070, a 'warp' of threads processes data in chunks of 32 elements. When values such as 3 and 35 occur within the same warp, they result in a bank conflict due to their modulo 32 equivalence, which maps them to the same memory bank.

A sophisticated approach to resolve such conflicts involves creating alternate "versions" of conflicting elements at different indices that do not conflict under the modulo operation. For example, relocating the element at index 35 to index 3207 ensures that values 3 and 3207 are processed by different memory banks, thus eliminating the bank conflict within the warp. This method of dynamic reallocation within the dataset not only resolves immediate conflicts but also accommodates future accesses by creating alternative pathways for data retrieval.

In scenarios with unrestricted task environments, the potential number of copies for each data element could be limitless. However, practical constraints of shared memory capacity necessitate a more controlled approach. Typically, creating up to 32 copies of each data element – one for each bank – could theoretically eliminate all bank conflicts. Yet, such an approach is often impractical due to memory limitations. Instead, a strategy might be implemented where an average of five copies per element is maintained, ensuring that the overall memory usage does not exceed five times the original dataset size.

When performing aggregation operations that involve writes to shared memory, managing value conflicts becomes crucial, especially when the same value appears multiple times within a warp or across neighboring warps. To address this, additional copies of the conflicting values are created, and their placement is strategically managed to avoid further conflicts. This might involve extending conflict analysis beyond individual warps to consider potential conflicts in a "window" of neighboring warps, assessing the impact of simultaneous updates on shared memory resources.

The distribution of data, particularly in columns with skewed distributions (Zipfian distributions ranging from $\alpha = 0$ for uniform to $\alpha = 2$ for highly skewed), significantly affects memory access patterns and conflict probabilities. Analyzing such distributions helps in planning the number of copies needed and optimizing the serialization of read/write operations. By predicting the skewness and potential hotspots of data access, the system can better manage memory allocation and access patterns, enhancing overall query performance.

Effective utilization of shared memory on NVIDIA GPUs in OLAP queries requires not only an understanding of the GPU architecture and memory management principles but also a dynamic approach to data encoding, conflict resolution, and copy management. By strategically managing data placement and access, analytical databases can leverage the parallel processing power of GPUs to achieve significant performance improvements in query processing, thereby reducing latency and increasing throughput in data-intensive environments.

Let's represent in UML the interaction between users, system and hardware in the context of using CUDA:

```
   User -> Application: Submit query
   Application -> CPU: Parse and
prepare query
```

```
   CPU -> GPU: Allocate memory and
transfer data
   GPU -> CUDA Core: Launch CUDA kernel
   CUDA Core -> CUDA Core: Execute
parallel processing
   CUDA Core -> GPU: Complete
processing
   GPU -> CPU: Transfer results back
   CPU -> Application: Compile results
   Application -> User: Display results
```

6 CONCLUSION

The integration of NVIDIA GPU shared memory in the processing of analytical database queries, particularly within the context of OLAP systems, presents a substantial opportunity to enhance the performance and efficiency of data operations. This article has explored the theoretical and practical aspects of utilizing GPU shared memory, emphasizing encoding methods, conflict resolution strategies, and the optimization of data structures to harness the full potential of GPU architectures.

By employing integer-based encoding for key columns, databases can organize data into simple arrays aligned with the GPU's memory bank structure, thus optimizing access patterns and reducing overhead. This alignment is crucial for maximizing the throughput and parallelism inherent in GPUs, which are especially beneficial in handling large volumes of data typical of OLAP systems.

The strategy of dynamic conflict resolution through the intelligent placement of data and the creation of alternate data paths within the GPU's shared memory addresses the challenges of memory bank conflicts. Such conflicts, if left unmanaged, can significantly degrade performance. Our discussion included methods for dynamically reallocating data to avoid conflicts within warps and across neighboring warps, thereby ensuring smoother and faster data processing.

Moreover, the management of data copies within the shared memory – balancing between the need to minimize memory usage and the need to avoid bank conflicts – emphasizes the necessity of a strategic approach to memory allocation. This balance is critical in environments with limited memory resources but high demands for data throughput and query responsiveness.

Finally, the consideration of data skew and the statistical analysis of access patterns provide crucial insights into how data should be distributed across GPU memory banks. Understanding these patterns allows for more effective predictions of hotspots and potential bottlenecks, guiding the optimization of data structures for better performance.

In conclusion, the effective utilization of GPU shared memory in OLAP queries can lead to significant performance gains. By addressing the challenges of data distribution, conflict resolution, and memory management with innovative strategies, databases can leverage the computational power of GPUs to achieve faster query processing and more efficient data analysis, thereby meeting the increasing demands of modern data-intensive applications.

REFERENCES

Burris, J. W., 2017. Test-Driven Development for Parallel Applications. In *2017 Second International Conference on Information Systems Engineering (ICISE)*, pp. 27-31.

Yogesh, T., Vimala, P., 2020. Test-Driven Development of Automotive Software Functionality. In *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)*, pp. 1162-1165.

Fontela, C., Garrido, A., 2013. Connection between Safe Refactorings and Acceptance Test Driven Development. *IEEE Latin America Transactions* 11(5): 1238-1244.

Guerra, E., 2014. Designing a Framework with Test-Driven Development: A Journey. *IEEE Software* 31(1): 9-14.

Amrit, C., Meijberg, Y., 2018. Effectiveness of Test-Driven Development and Continuous Integration: A Case Study. *IT Professional* 20(1): 27-35.

Gibadullin, R. F., Vershinin, I. S., Volkova, M. M., 2020. Software development for placing tiles in two-dimensional space. In *2020 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)*, pp. 1-7.

Moe, M. M., Oo, K. K., 2020. Evaluation of Quality, Productivity, and Defect by applying Test-Driven Development to perform Unit Tests. In *2020 IEEE 9th Global Conference on Consumer Electronics (GCCE)*, pp. 435-436.

Dookhun, A. S., Nagowah, L., 2019. Assessing The Effectiveness Of Test-Driven Development and Behavior-Driven Development in an Industry Setting. In *2019 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)*, pp. 365-370.

Viktorov, I., Gibadullin, R., 2023. The principles of building a machine-learning-based service for converting sequential code into parallel code. *E3S Web of Conferences* 431: 05012.

Kozlov, E, Gibadullin, R, 2023. Prerequisites for developing the computer vision system for drowning detection. *E3S Web of Conferences* 474: 02031.

Gorodova, J., Pachina, N., Tkachenko, S., Pachin, G., 2021. Digital Literacy in the Aspect of Continuing Teacher's Education. In *2021 1st International Conference on*

Technology Enhanced Learning in Higher Education (TELE), pp. 220-223.
Yoqubjonov, J., Gibadullin, R., Nuriev, M., 2023. Advanced robotic process automation for enterprise efficiency. *E3S Web of Conferences* 431: 07011.
Kondratiev, V., 2020. Fundamental Changes in Mathematics Education in the Context of Digital Transformation. In *2020 Ivannikov Ispras Open Conference (ISPRAS)*, pp. 75-77.
Shakirzyanov, M., Gibadullin, R., Nuriyev, M., 2023. Prerequisites for the development of the system of automatic comparison of video and audio tracks by the speaker's articulation. *E3S Web of Conferences* 419: 02029.
Chituc, C. -M., 2022. An Analysis of Technical Challenges for Education 4.0 and Digital Education Ecosystems. In *2022 IEEE German Education Conference (GeCon)*, pp. 1-5.
Gibadullin, R. F., Perukhin, M. Y., Mullayanov, B. I., 2020. Optimization of water supply by the method with model predictive. In *2020 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)*, pp. 1-6.

Conceptual basis of healthcare system development

Igor' Borisovich Kovalenko[1] [1], Mariya Vladimirovna Lugovskaya[2] [2],
Maksim Sergeevich Kapranov[3,4] [3]
[1]Belgorod National Research University, Head of Chair of innovation medical technologies, PhD, Belgorod
[2]Belgorod National Research University, associate professor of Chair of Management and Marketing, PhD, Belgorod city
[3]Belgorod National Research University, assistant of Chair of innovation medical technologies, Belgorod
[4]Moscow Regional Clinical Research Institute named after M.F. Vladimirskiy, researcher of endovascular department, Moscow
kovalenko_i@bsu.edu.ru, lugovskaya@bsu.edu.ru, kapranov@bsu.edu.ru

Keywords: Healthcare system, high-tech medical care, medical education, university clinic, healthcare, system, modernization.

Abstract: The article describes the use of the program-target method in developing a program for modernizing the healthcare system. A number of effective measures have been proposed to reorganize the financing system of healthcare organizations in the region in order to stimulate their development, and ultimately improve the health of the population. A system of organizational control of a medical organization has been developed, which involves the introduction of a model of a quality management system and general management in medical organizations. The system determines and controls the established order of work, which the medical organization, based on its goals, can describe in the form of a diagram that clearly demonstrates the shortcomings of the organization's activities, monitors structural interactions and demonstrates directions for development in order to take specific measures to eliminate identified problems. This will ensure effective management and quality results for the medical organization.

1 INTRODUCTION

Today there is a period of complex development in the field of medicine in the country, as this is associated with the presence of several forms of management at once: the prevailing importance of private medicine; the constancy of public medicine and the presence of a new organization form: a public-private partnership. But despite the active development of this area, it is necessary and mandatory, in our opinion, to implement a systematic process approach to the management of medical organizations. It will allow, with available resources, to continuously improve the quality and safety of medical services; to solve assigned tasks effectively, minimizing possible mistakes and deviations from planned results. And it is the development of mechanisms for interaction between divisions of medical organizations that will allow to form control over the effectiveness of work.

Existing management models in healthcare, regardless of the forms of their management, are focused on the process of providing medical care, but without a system of organizational control of medical organizations (OCMO), as well as without taking into account many interrelated processes and activities of medical organizations. But it should be noted that the priority task in the healthcare system remains to increase the availability of medical care and patient satisfaction with the work of medical staff (Korobkova, 2020).

2 RESEARCH METHODOLOGY

This study on the formation of organizational control in medical organizations is formed with the aim of

1 https://orcid.org/0000-0000-0000-0000
2 https://orcid.org/0000-0002-6584-3100
3 https://orcid.org/0000-0002-2382-8682

improving the quality control and management system in medical organizations, assessing medical, financial, personnel and social efficiency. Thereby ensuring the proper functioning of medical organizations, taking into account the study of each aspect (medical, financial, personnel, social), determining the actual level of compliance, searching for problems and forming the necessary conceptual component for proper development, taking into account all the identified disadvantages of the organization's activities, through automation and the installation of organizational controls.

Each study will provide effective (measurable) indicators, which will allow for a detailed descriptive analysis of four basic aspects of medical organization activities.

1. Medical effectiveness:

- planning the volume of work in healthcare organizations;

- planning the level of satisfaction with the quality of services.

2. Financial efficiency:

- planning of medical care resources;

-evaluation of the efficiency of using medical organization resources;

- planning performance indicators for medical personnel;

- determination of the level of planned costs.

3. Personnel efficiency:

- planning the number of staff positions;

- planning the development of medical stuff.

4. Social efficiency:

- population satisfaction planning;

- personnel satisfaction planning.

Medical and economic standards (MES) for the provision of medical care in hospitals and outpatient clinics in the region continue to be implemented and improved. The criteria for assessing the final results of the work of medical workers and healthcare organizations are being improved (Makarov, 2005).

A necessary condition for improving the management of the healthcare system is the diagnosis of this process. Representing one of the types of social technologies, it is able to give an adequate idea of the situation developing in each specific period of time, identify problems, and provide empirical material for forecasting.

The specificity of sociological diagnostic methods and, accordingly, the features of the system of indicators used in this case make it possible to identify, mainly, the nature of the perception of proposed methods of structuring and exchanging opinions of its participants, to determine the level of their competence in this area, the degree of readiness for change, and typical behavioral practices used when forming a healthcare management system (Novozhilov, 2012). It is these aspects that are key to understanding the need for structuring healthcare, since the state and prospects for the development of this idea in a medical organization depend to a decisive extent on the readiness and competence of personnel.

To date, regarding each of the above areas of the effectiveness of a medical organization, studies have been conducted based on sociological surveys of employees of medical organizations and administrative personnel.

We have identified the following as important indicators characterizing the dispositions of participants in the process of forming a healthcare management system:

1) level of awareness of possible restructuring the healthcare management system;

2) level of competence in the field of formation and use of knowledge;

3) assessment of the process of formation and structuring of the healthcare management system;

4) assessment of the conditions for the formation and structuring of the healthcare management system;

5) perception of barriers that arise in the process of managing the healthcare system.

The study was conducted using a questionnaire survey among three groups of respondents (administrative staff of medical organizations, employees and experts). The sample population of medical organization workers consisted of 200 respondents, who were: doctors, department heads, senior nurses; managers and employees of administrative structures - 83 persons. At the same time, a formal survey of experts was conducted. The sample population consisted of 30 respondents, who were government officials and scientists.

During the research, the main attention was paid to the analysis and assessment of two parameters.

The first parameter is the specificity of respondents' dispositions regarding the formation of a management system for medical organizations and their further mass use. They were assessed by analyzing awareness of the phenomenon "Basic aspects of medical organization activities" the process of data collection and its analysis, dissemination and use. The second parameter is the degree of coincidence of identified dispositions among those who manage medical organizations and those who are directly involved in the dissemination and collection of information regarding the basic aspects of the activities of this very organization. The need to assess this parameter is explained by the fact that the process of managing a medical organization involves people with different views, different values and goals.

3 RESEARCH RESULTS

Let's consider each of the parameters we have highlighted in more detail.

1. Level of awareness of possible restructuring of the healthcare management system. This indicator includes two main elements: firstly, knowledge a

bout the medical organization, its goals, objectives, mission, structure, and functioning mechanism, without which it is difficult for employees to understand the problems associated with the functioning of the organization; secondly, an idea of the phenomenon itself, "Basic aspects of medical organization activities", its content, and role in the development of the organization.

The results of the study confirmed a fairly obvious, relatively high level of awareness among employees about medical organizations and their internal aspects of functioning. So, to the question, "how complete is your knowledge about the functioning of a medical organization?" 20.46% noted that they were "full"; 67.25% – "mostly complete"; 9.33% – "more likely to be full than not"; 2.20% – "insufficiently complete".

Analyzing the obtained distribution of answers, we can conclude that the majority of employees of the medical organizations we surveyed are not confident in the completeness of their knowledge about the structure, goals, mission, and functioning mechanism of the organization. This is primarily evidenced by the uncertainty in the respondents' answers and the choice of such "borderline" answer options as "partially", "more likely complete than not", etc.

The incompleteness of knowledge about medical organizations is complemented by the fact that only a minority of respondents consider them to be fully accessible. About half of the respondents (namely 48.13%) noted that knowledge about a medical organization is "partially" available to them, and only 25.49% – "fully", 6.15% consider the availability of knowledge about a medical organization to be insufficient, and another 15.82% of respondents noted that they would like to receive more such knowledge. This gives grounds for the conclusion that internal communications in medical organizations are ineffective.

The lack of an effective system for conveying to employees knowledge about the processes occurring in medical organizations can be considered one of the negative consequences of the neo-managerialist approach to the management of healthcare organizations, within which an employee of a medical organization is just a hired (technical) employee, and his main task is " work on indicators" (Okhlopkova, 2015).

Meanwhile, personnel development is a condition that contributes to strengthening interaction, consistency, and coordination of the activities of subjects and/or structural units of a medical organization, without the development of which it is extremely difficult to form an effective healthcare system management system.

2. *The level of competence in the field of formation and use of knowledge* is determined by the presence of clear ideas about the content and capabilities of technologies used in this area and the skills to use them.

The survey revealed that only 25.49% of employees of medical organizations fully use knowledge regarding the "Basic aspects of medical organization activities" in their practice; 48.13% of respondents – partially; 21.97% - not enough (while 15.82% answered that they would like to use this knowledge more); the rest found it difficult to answer or did not answer this question at all.

In this regard, another rather obvious contradiction arises. It manifests itself in the fact that the practice of production, dissemination, and use of internal knowledge is initially focused specifically on stimulating the innovative activities of a medical organization and its development. On the other hand, the implementation of this type of activity is associated with numerous difficulties. The involvement of various groups of workers in the innovation process remains insignificant. Thus, a survey of employees showed that the almost absolute majority of respondents agree that participation in the implementation of innovations is manifested mainly without independent activity: 49% of respondents believed that employees of a medical organization are involved in active innovation activities to a minimal extent and that the majority of them work according to old standards, 36% are confident that employee involvement in innovative processes is at an average level. Only 15% of respondents said employee engagement was above average.

Such an imbalance can be fully explained by the fact that knowledge about the basic principles of the functioning of a medical organization is, first of all, knowledge that is in demand when developing, making, and implementing management decisions. This is knowledge that ensures the effectiveness of administrative and bureaucratic procedures. Employees, as a rule, rarely participate in them.

This, in particular, demonstrates the unpreparedness of a medical organization to function in conditions of continuous change. Indicative here are: exclusion of employees from the development and decision-making processes; inertia of the organizational system of a medical organization associated with its unreasonable construction, excessive branching of the staff structure, duplication of certain functions by structural units to the detriment of others, irrational use of resources and lack of conditions for operational management, coordination, interrelationships and interaction of system elements; insufficient professional training of managers and personnel in the field of forecasting, design of systems and processes, unpreparedness to work in constantly changing conditions.

3. *Assessment of the process of formation and structuring the healthcare management system.*

In particular, the lack of clear ideas about the phenomenon “Basic aspects of medical organization activities” significantly complicates their assessment, even for those who are generally familiar with the process of their formation (remember, there are 28.13% of them). To the question “What is your attitude towards the formation of a management system for healthcare organizations?” Most of the informed employees found it difficult to answer (50.44%), 22.99% answered “positive”, another 18.72% – “rather positive than negative”, 3.08% – “rather negative than positive” " and 1.76% - "negative". Moreover, among those who chose the “negative” option, 82.89% were unable to identify the main reasons for this.

The uncertainty in the respondents' answers is quite understandable. Without a proper understanding of the content of “**Basic aspects of medical organization activities**,” which the study revealed, it is impossible to objectively assess the process of functioning and development of a medical organization. In the absence of such a vision, any actions related to the production, dissemination, and use of knowledge acquire a fragmented, unsystematic character. Knowledge is systematized and disseminated only by individual employees, not always receiving the approval and support of management and their colleagues.

Thus, considering the specifics of assessing the real process of production, dissemination, and use of knowledge, we can say: at present, it is practically not institutionalized and is carried out spontaneously. It almost does not include employees who have a very vague understanding of the phenomenon “Basic aspects of medical organization activities”. This, on the one hand, creates significant difficulties for the formation of a management system; on the other hand, it makes it possible to carry out this activity “from scratch” without spending significant efforts on transforming previously established but ineffective institutions.

4. *Assessment of the conditions for the formation and structuring of the healthcare management system;*

Regulation of the process of production, dissemination, and use of knowledge consists in determining the principles and rules for working with a package of knowledge, the goals pursued, mechanisms, and evaluation indicators.

In particular, with regard to the principles of forming a management system for a medical organization, 24.22% of the surveyed administrative employees believe that they are defined quite clearly, 53.36% noted that they are mostly defined, 11.66% that the goals are not defined. 37.67% are convinced of a clear definition of the goals of the emerging information system for updating educational services; 49.78% believe that they are mostly defined, 5.38% - not defined. Regarding the results of indicators for assessing the functioning of the system, 24.66% believe that they are formulated quite clearly; 42.60% – they are mostly defined and not defined.

Assessing the state of the organizational mechanisms for managing a medical organization, 19.73% of respondents noted that they were defined quite clearly, 51.12% - mostly, 17.94% - not defined.

When assessing the degree to which problems in managing a medical organization were resolved, we used a scale that provided not only polar but also intermediate answer options (Podberezkin, 2019). Its use makes it possible to determine indices (weighted average coefficients) for each of the research positions - in this case, for the elements of forming a management system for a medical organization. The maximum possible index value is “+1” (complete, unambiguous definition), the minimum possible is “-1” (complete, unambiguous uncertainty), i.e. the index clearly demonstrates whether the situation is positive or critical (Pavlov, 2019).

Regarding the analyzed elements, the indices were:

− goals of the emerging information system for updating the management of a medical organization – 0.618;

− principles of forming a management system for a medical organization – 0.509;

− mechanism for managing a medical organization – 0.452;

− assessment of the results of implementing system indicators – 0.459.

Thus, based on the data obtained, it can be argued that currently, in a medical organization, the most difficult thing is to determine the organizational mechanism for managing corporate knowledge and assess this process. The complexity of solving these problems is obvious and is determined by several circumstances:

- firstly, the insufficient optimality of building the management system of medical organizations, which, on the one hand, has changed noticeably in recent years, on the other hand, the changes have not significantly increased the degree of flexibility of the administrative system, nor have they given it significant additional possibilities for increasing the cognitive potential of healthcare organizations;

- secondly, the conflict between the internal and external systems for assessing the functioning of medical organizations was clearly identified, which was more or less consistently resolved by reformatting the internal to external parameters, which are not always adequate to the tasks being solved. This ultimately led to the demotivation of many employees, their disorientation regarding the real guidelines of their professional activities. The inconsistency of formal evaluation criteria and their inorganicity with the substantive side of professional activity were clearly reflected in ideas about the degree of institutionalization of the management of medical organizations;

- thirdly, both the problems of forming a mechanism for managing the medical organization and the problems of criteria for their evaluation remained aside from mainstream developments. Largely because the justification of the proposed formal models looked like an apologetic for unpopular decisions, and alternative models were not considered by the administration.

This method, developed by Rensis Likert, assumes that the respondent expresses his agreement or disagreement with each judgment from the proposed set on a rating scale, and his place on the final attitude scale is determined by the sum of the ratings of each individual judgment.

Thus, an index with a positive value indicates a numerical superiority of consonants over dissenters, an index close to zero indicates the equality of these groups, and a negative one indicates the predominance of dissenters.

5. Perception of barriers that arise in the process of managing the health care system.

In the process of managing a medical organization, managers are and will continue to face barriers of a sociogenic nature that significantly complicate the creation of a management system. Barriers are based on unresolved or unsatisfactorily resolved problems.

Firstly, these are problems that characterize the quality of the system’s construction, or the lack thereof, forming a “low-quality barrier.” Thus, employees ranked the following among the most significant among them: lack of knowledge and awareness (43.64%); the impossibility of coordinating the management process (28.95%) and the inability to convey the values and vision of the information received to a wide audience (28.95%). A fairly large proportion of respondents noted the problem of dispersion both in sources and time of acquisition - 39.04%. 15.79% of respondents – unverified; 8.77% - impossibility of their immediate use.

Secondly, problems associated with technologies of development, distribution, and use, which determine the “technological barrier”. These respondents included:

− problem of knowledge generation. It is solved quite effectively only in the opinion of 43.86% of employees and 41.44% of administrative workers;

− the problem of ensuring the process of developing new ideas. Only 25.44% of employees and 23.77% of administrative workers believe that it is resolved quite effectively in medical organizations;

− the problem of introducing new methods (only 25.44% of employees and 24.66% of administrative workers report its effective solution);

− the problem of commercialization of results, which is solved quite effectively according to 22.15% of employees and 18.39% of administrative employees.

Thirdly, organizational problems and, accordingly, the “organizational barrier”. The majority of administrative workers surveyed (56.95%) consider employee interest and involvement to be the most difficult task when building a medical organization management system; 45.29% name monitoring the progress of the process as such a task; 26.46% – effectiveness assessment; determination of target orientation -27.35%; resource provision – 37.67%

4 CONCLUSIONS

Based on the data obtained, we can state quite confidently: often management staff pay attention almost exclusively to the formal side of the issue, which is determined by their status and the conditions in which they are forced to make organizational decisions. These conditions are characterized by significant restrictions on independence and strict external control, which is predominantly formal in nature.

Experts were asked to evaluate the conditions for creating a development scheme for medical organizations using the OCMO system in most medical organizations. The resulting estimates look like this:

− financial conditions for creation, according to experts, are quite effective, therefore 46.67% of respondents are considered to be ineffective, and for 10% they are ineffective;

− personnel conditions are effective, according to 63.33% of respondents, while only 20% consider them ineffective;

− 80% of experts consider organizational conditions to be effective, and 10% believe the opposite;

− temporary and material and technical conditions – effective, so considered 36.67%, ineffective temporary conditions – 20%, material and technical – 40%;

− Conditions for effectiveness are given, as 70% of experts believe, but these conditions are ineffective for 13.33% of respondents.

The increased optimism of experts, in our opinion, is explained by the fact that most of them accepted the uncritical assessment of medical realities that is currently dominant among external experts, which can be seen in a number of scientific publications. The possible presence of an overly optimistic assessment may indicate insufficient knowledge of the situation, or more precisely, a lack of information that could fully characterize the level of mastery of production technologies, distribution, and use of the OCMO formation system inherent in the entire staff and administrators. The actual state of affairs usually looks much more complicated than it seems to an outside observer, even if he is positioned as an expert in the medical field. And in this regard, the problem of the quality of external expert activity in this area is being updated. However, it is beyond the scope of this study.

Thus, the data obtained allow us to assert: if the process of regulating management is nevertheless, to one degree or another, implemented in the medical organization, then the situation with the formation of organizational structures that carry out this activity is much more complicated.

Prior to the introduction of the development scheme for medical organizations using the OCMO system, we identified a number of problems indicating imperfections in the healthcare system.

Among which we note the following:

1. Shortage of staffing in healthcare organizations;

2. Lack of qualified personnel to fulfill newly posed tasks for the development prospects of the healthcare system (about 52% of healthcare workers have not improved their qualifications over the past 5 years);

3. Outdated doctor education system;

4. Poorly developed legal aspect of protecting the activities of a doctor;

5. Lack of a system of motivation for employees of the healthcare system, or its poor development;

6. The integrative function in the health care system is poorly developed, more administrative activities lead to neglect of other aspects, such as economic or behavioral;

7. Lack of a unified system for exchanging information between organizations (with the exception of telemedicine and other technological methods);

8. Weak material and technical base of most municipal medical organizations.

That is why we propose to introduce the OCMO system as a tool for effective management and ensuring high-quality results of the activities from medical organizations. The system determines and controls the established order of work, which the medical organizations based on its goals, can describe in the form of a diagram that clearly demonstrates the shortcomings of the organization's activities, monitor structural interactions, and demonstrate directions for development in order to take specific measures to eliminate identified problems.

The OCMO system is a model of quality management system and general management adapted for a medical organization.

Medical organizations have a fairly developed organizational structure, with a large number of departments performing many functions. But at present, none of them can solve the entire range of problems associated with functioning. At best, it only accumulates, and does not fully index them for further use (Bourdieu, 1986).

Connections between structures whose competencies at least potentially include participation in the management of medical organizations are not optimal. Each of them solves its own specific problems, often without connection with the work of other departments. In the course of our research, almost every third administrator (30.92%) noted the absence of a single space for the transfer of knowledge in medical organizations. Combined with the bureaucratization of this process, this circumstance creates significant problems for the organization as a whole, for its structural divisions, and individual actors.

Thus, it can be argued that the organizational conditions for managing the medical organization are currently significantly deformed. The deformation is of a bureaucratic nature and is a consequence of excessive formalization of medical activities, rather paradoxically complemented by the unjustified disunity of participants.

REFERENCES

Korobkova, O.K., 2020. Directions for improving the management of medical services in the healthcare system at the regional and municipal levels. [Article in Russian] *J Teoriya i praktika upravleniya.* № 4. p 31-35.

Makarov, V.L., 2005. Social technologies: problems and prospects of the lower level. [Article in Russian]. *J Ekonomika regiona.* № 3. p 5-15.

Novozhilov, M.V., 2012. Features of corporate system management. [Article in Russian]. *J Audit I finansoviy analiz.* №2.

Okhlopkova, N.A., 2015. Managing business communications in a 21st century organization. [Article in Russian] *J Materialy IV Mezhdunarodnoi studencheskoi nauchno-practicheskoi konfrencii – Cheboksary: TSNS "Interaktiv Plus".* p126-127.

Podberezkin, A.I., 2019. Health care reform strategy. [Handbook in Russian] Book Nasledie. 344 p.

Pavlov, K.V., 2019. Modernization of healthcare in the region: directions, forms and methods. [Article in Russian]. *J Regionalnaya ekonomika: teoriya i practica.* № 2. p 55- 63.

Bourdieu, P., 1986. The forms of capital. Handbook of Theory and Research for the sociology of education / ed. J. Richardson . – New York, P. 241-258.

Hammer, M., Champy, J., 1993. Reengineering the corporation: a manifesto for business revolution. New York : Harper Business , 187 p.

Reschke, H., 1984. Projectmanagement: konzeptionelle Grundlagen. 2. Aufl. – München : Ges . für Projektmanagement INTERNET Deutschland, 72 S.

Zaitman, G., Duncan, R., Holbek, J., 1973. Innovations and organizations. New York : Wiley . 212 p.

The Main Scenarios for the Development of Nuclear Power Industry: Opportunities and Risks

Soldatova Natalia Fyodorovna[1] [1], Kolesnikova Olga Viktorovna[2] [2],
Suvorova Elena Viktorovna[2] [3]
[1]*Financial University under the Government of the Russian Federation, Leningradsky Prospekt, 49, Moscow, Russia*
[2]*National Research University "Moscow Power Engineering Institute", Krasnokazarmennaya, 14A, Moscow, Russia*
NFSoldatova@fa.ru, KolesnikovaOV@mpei.ru, esuvorova@bk.ru

Keywords: nuclear power industry, nuclear power industry development scenario, sustainable development, lean production, economic efficiency, ecological system, digital ecosystems in the industry.

Abstract: The proposed article is aimed at discussing the need to choose the optimal long-term scenario for the development of Russian nuclear power industry, to reveal its content, directions, expected risks and consequences of implementation. The authors take the position of strengthening the state's responsibility for choosing innovation priorities in the country's energy sector. It is impossible to foresee the directions of Russia's socio-economic development without substantiating the ways of transformation of nuclear power industry – the basis for the formation of sustainable development of society under the conditions of sanctions pressure. Russian industry experts identify five basic scenarios for the development of nuclear power industry: from an innovative scenario to a digital model in the format of digitalization of the industry. The scenario of a complete abandonment of nuclear energy is not being considered by Russian specialists. Each of the discussed scenarios has its limitations and carries certain risks, but the growing energy needs of the Russian economy cannot be satisfied by the current model of nuclear power industry development, which requires a significant increase in economic, social and environmental efficiency.

1 INTRODUCTION

The energy crisis that has affected the global economy, combined with the need to control the climate agenda, dictates the need to develop an optimal source of energy: affordable, reliable and environmentally friendly – nuclear power. Despite the slowdown in the development of nuclear power industry in the world over the past ten years, a number of countries have decided to accelerate the development of nuclear power industry by increasing its share in the fuel and energy balance.

The growth of nuclear capacity is increasing several times every year. This trend is especially observed in countries such as China and India. Countries such as Vietnam, Indonesia, Malaysia and others are showing great interest in developing their own nuclear industry. The preference for energy resource leaders is gradually changing. Until 2020, the leadership in electricity production belonged to developed countries of the world, such as the USA and France. But the trend is changing and China is coming out on top in energy production. The possible distribution of nuclear power will be as follows: the United States will take 2nd place, and France will take 3rd place. Russia may also see a decline to 5th place with an increase in nuclear power production by 43% by 2040. Due to the rapid growth of nuclear power production, South Korea will occupy the 4th place. Japan will take 6th place if it goes through the relevant certification procedures to meet the new safety regulations. India is also actively working on these issues, achieving significant success. India's nuclear energy production will increase fivefold and it could take 7th place by 2040.

[1] https://orcid.org/0000-0002-8732-4547
[2] https://orcid.org/ 0000-0002-8552-799X
[3] https://orcid.org/0000-0002-7151-272X

2 RELEVANCE AND PROSPECTS

The growth rate of nuclear energy in the world is constantly increasing. If before 2014 there were 5 nuclear reactor launches per year, then in subsequent years there has been a significant increase in the commissioning of new nuclear power plants. Thus, during the period from 2015 to 2018, an average of ten reactors were launched. In 2019, it is planned to launch 14 new reactors. Countries such as Belarus and the UAE are joining the ranks of nuclear nations, as in the next two years, the commissioning of 30 new reactors with a capacity of up to 33 GW is planned. All this was provided for by the Harmony plan proposed by the WNA, which assumed a significant increase in nuclear energy, and its share will reach 25% in the world by 2050.

The hypothesis of the study is based on the assumption that the optimal choice of a long-term scenario for the development of nuclear power industry can form the basis for high rates of economic and social development and sustainable growth of the Russian economy.

The research methodology is based on a systematic approach that includes a synthesis of academic and industry science and methods such as the method of comparisons and groupings, the logical method, as well as cluster analysis. The authors used the information base presented on the official websites of the Federal State Statistics Service and international information platforms.

3 NUCLEAR SAFETY CONCEPTS

Regarding security in the energy industry, a concept that first appeared in the 1970s is inextricably linked to the restriction of oil embargoes. The concept of “energy security” itself has different approaches in different countries. However, in many countries of the world, the safety of nuclear energy is tied to three main goals:

Ensuring high quality and cost-effective energy supply,

Promoting the efficient use of energy

Environmental protection aimed at sustainable ecological development.

All target strategies of the Russian Federation within the framework of nuclear power industry development relate to strengthening cooperation and coordination of stakeholders to ensure reliability and security in the field of electricity supplies.

For example, in Malaysia, electricity generation capacity is provided by gas (10,494.4 MW), coal (8,066 MW), hydro power (2,149.1 MW) - data for 2015 (Demetriu, 2013). The electricity sector is strictly regulated and the national grid is operated by Tenaga Nasional Berhad (TNB) in Peninsular Malaysia, while the other two grids are operated by Sabah Electricity Sdn Bhd (SESB) and Sarawak Energy Berhad (SEB) in Sabah and Sarawak, respectively (Demetriu, 2013).

Assessment of macroeconomic effects from the implementation of nuclear energy projects

All nuclear energy projects can be assessed from different perspectives:

Efficiency assessment for the supplying countries

Assessment of benefits for the purchasing (recipient) countries

The supplying country receives an increase in external demand for products and an increase in external demand for related products of industries.

The second assessment gives advantages to the recipient country, which consists in an increase in demand for the products of the fund-forming industries and does not require initial investments, since the financing of projects in the nuclear energy sector is either at the expense of external funds or at the expense of the supplying company.

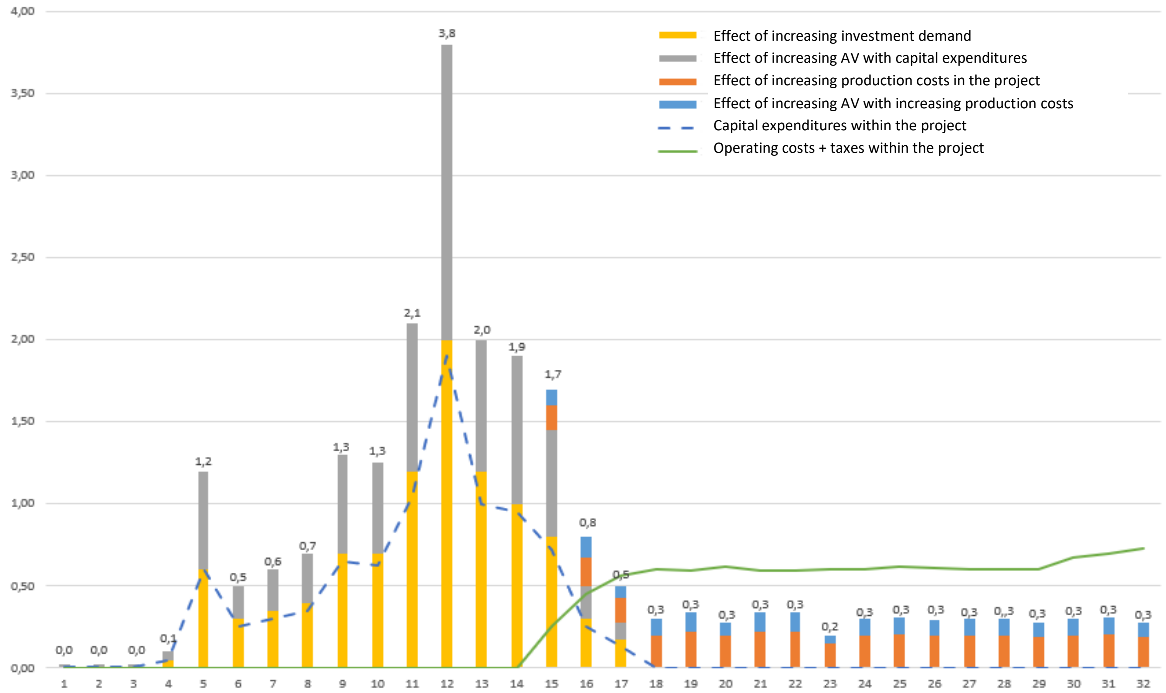


Figure 1: Estimates of the multiplicative effects on production for the supplying country by year (in constant prices in 2013, billion US dollars). Source: calculations by the Institute of Economic Forecasting of the Russian Academy of Sciences.

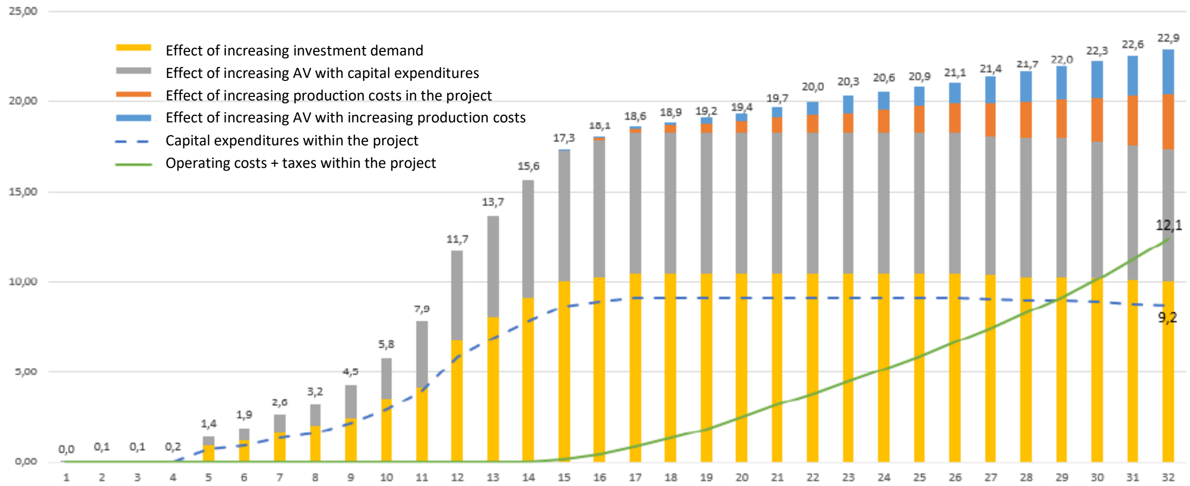


Figure 2: Estimates of the effects on production for the supplying country as a cumulative total (in constant prices in 2013, billion US dollars) Source: calculations by the Institute of Economic Forecasting of the Russian Academy of Sciences.

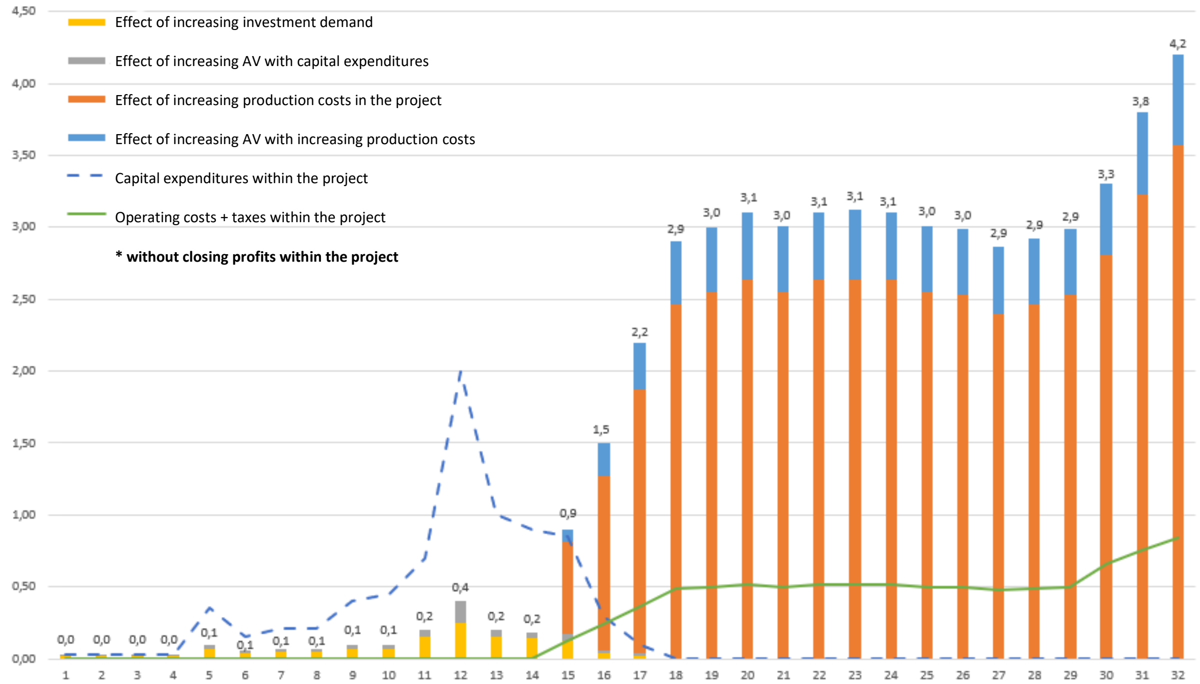


Figure 3: Estimates of the multiplicative effects on production for the recipient country by year (in constant prices in 2013, billion US dollars).

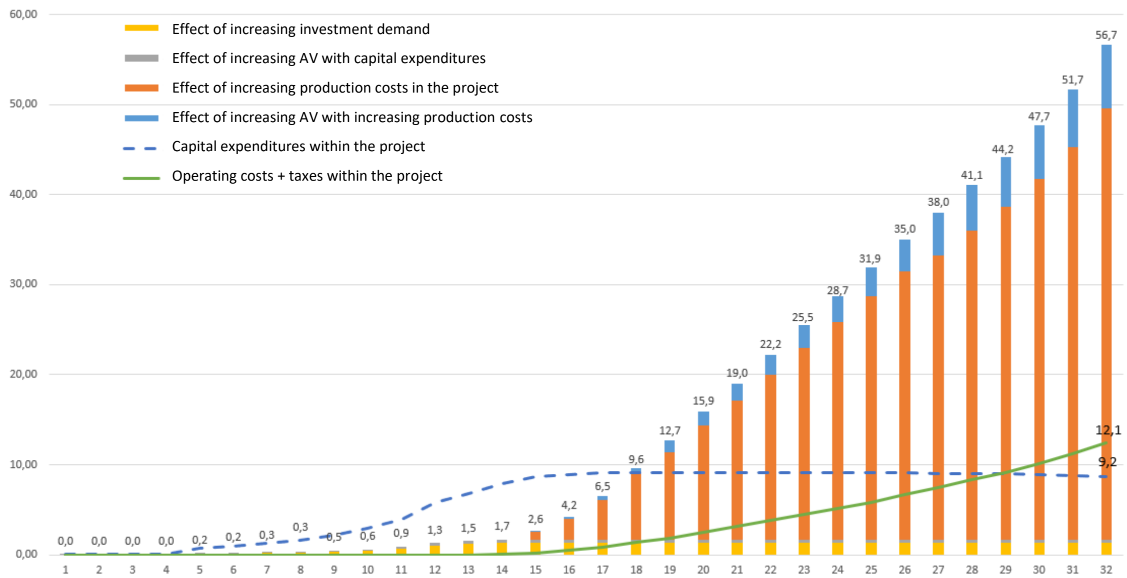


Figure 4: Estimates of the effects on production for the recipient country as a cumulative total (in constant prices in 2013, billion US dollars). Source: calculations by the Institute of Economic Forecasting of the Russian Academy of Sciences.

The main scenarios for the development of nuclear power industry, based on a systematic approach, in key areas.

So the first direction can be identified as the management of the development of nuclear power industry within the country.

The main condition for the growth of economic indicators in Russia is the development of the nuclear industry, which includes four large scientific and industrial complexes: first of all, this is nuclear engineering, then the nuclear fuel cycle and the nuclear environment complex and, most importantly, R&D (namely, industry research institutes). Considering the operation of stations within the country, the following can be distinguished: 10 nuclear power plants operate 35 power units: 13 power units with channel-type reactors (10 power units with RBMK-1000 type reactors and 3 power units with EGP-6 type reactors); 20 power units with VVER type reactors (of which 13 VVER-1000 power units, 5 VVER-440 power units of various modifications and 2 VVER-1200 power units); 2 power units with fast neutron reactors (BN-600 and BN-800). The capacity of all power units is 29 GW. The introduction of new production capacities in the Russian Federation in 2018 made it possible to show record electricity generation. Thus, all Russian nuclear power plants have produced 204,6273 billion kWh (in 2017, 202,868 billion kWh).

Currently, the nuclear industry in Russia employs over 250 thousand people and includes over 400 enterprises and organizations. This industry employs highly qualified personnel who service nuclear power plants and implement their scientific developments in the field of designing nuclear reactors and disposing of spent nuclear fuel.

The temporary shortage of nuclear power plant generating capacities immediately affects the pace of development of the Russian economy. The commissioning of Novovoronezh NPP-2 and Rostov NPP will provide additional impetus for the further development of these subjects of the Russian Federation. There is also a rather promising project to launch a floating nuclear thermal power station in the northern territories of our country.

The second direction is the creation of a management model in the international market in the near future.

Nuclear energy is currently the basis for achieving sustainable development of the entire energy sector. As previously mentioned, the demand for electricity worldwide, and especially in developing countries, will increase by 30% by 2035. Accordingly, global investments in natural coal-fired power plants will decrease. When planning the construction of nuclear facilities within the framework of the implementation of the IAEA nuclear energy programs, representatives of the Rosatom State Corporation and the World Nuclear Organization should share their thoughts on the main directions for the development of nuclear infrastructure (NI). To organize, support and implement the national nuclear energy program, it is necessary to create a large-scale nuclear infrastructure that includes a large number of key instruments of influence. These include: minimization of administrative, financial, technical, regulatory and other risks. The implementation of this project will require huge efforts for all stakeholders (customer country, supplying country). Rosatom, in turn, offers its foreign partners corresponding packages for the creation and improvement of a national nuclear infrastructure program.

By 2030, the nuclear programs of Russia, India and China will play an important role in the implementation of Plan 303. It is recommended that small modular reactors and low-accident fuel types be introduced into practice more widely. Here it is important to note the existing global emission problems and constantly make every effort to cope with them.

By 2040, a decline in existing energy sources is expected and up to 200 GW of nuclear power plants should be decommissioned. However, various options are being considered to reduce this loss to 2.6 GW. But this will require significant efforts to extend the service life of existing reactors to 30 years. The IEA recommended that national governments lower unnecessary barriers to wider use of nuclear energy

The existing Harmony project proposes increasing the level of nuclear generation to 25% by 2050. This, in turn, is only possible with the commissioning of 1000 GW of new nuclear generating capacity. For this purpose, the World Nuclear Association has identified three areas of action – creating acceptable conditions in the electricity markets, a reliable safety system and improving regulatory processes. The Rosatom Production System (RPS) includes a set of measures for the culture of lean production processes, capable of providing competitive advantages at the global level. The RPS encourages employees of institutions and enterprises to develop a culture of communication with clients, promptly resolve emerging problems, pay close attention to the wishes of clients, end consumers, consumer workshops, try not to produce defective products, eliminate excess stocks, etc.

The third direction is safe and lean production management.

Currently, Russia is the only country that owns a functioning BN–600 fast neutron reactor, which was put into operation at the Beloyarsk NPP; a new BN-800 reactor is under construction; new reactors are planned to be commissioned – this explains the interest of the Americans in cooperation with Rosatom. (Zhukov, Kopytin, Popadko, 2022) The spent fuel of modern nuclear power plants is plutonium and uranium 238, which in the future can perfectly serve as fuel for reactors, which contributes to bringing nuclear energy to a higher level.

The fourth direction is the management of processes for maintaining the ecological system

But there are negative examples that carry the threat of shutting down nuclear power units due to a number of unresolved economic reasons. For example, the United States is holding back the development of nuclear power industry by promoting relatively cheap shale gas on the market. Since 2013, 4,674 MW of nuclear generating capacity has been shut down in the United States for this reason, and another 11,000 MW are at risk of closure. But based on the results for last year, the American nuclear power industry has had excellent results in terms of safety. They worked with a CUF of about 90% and provided the country with 2/3 of “carbon-free energy”. About half of U.S. nuclear power plants operate in regulated markets with fixed government rates.

The situation is more favourable in China, where cooperation with the French company EDF will allow the construction of two EPR-1600 units using the same fuel. This will be the first operational EPR nuclear power unit in the world. CGN is actively involved in the implementation of new projects in the UK, holding a 20% stake in the power unit construction project. It should be noted that the UK's exit from the EU will not affect the prospects for the development of nuclear power industry in the country. Thus, over the past 2018, CGN has signed more than 30 contracts with companies in the UK and the EU for a total amount of about 60 million pounds.

The following primary and essential tasks were set:

- limiting the increase in average global temperatures to "well below 2 degrees",
- cessation of greenhouse gas emissions,
- increasing access to energy in all regions of the world.

There are disputes about the safety of these power plants. A number of specific examples of serious accidents at nuclear power plants are given: accidents at power plants in Chernobyl, Three Mile Island and Fukushima, which led to very significant consequences for people's lives and had a negative impact on the environment. But despite this, nuclear energy is currently the only alternative to hydrocarbon sources, which makes it practically an unlimited reserve source for all mankind (Tay, 2019). Therefore, the long-term prospects for nuclear energy are positive. Taking into account both the low environmental impact of nuclear power plants and the limitation of hydrocarbon raw materials. As evidence of this, we can cite the example of the construction of 61 nuclear power units worldwide, and another 147 similar units are currently at the design stage.

Unfortunately, these legislative requirements are not always and everywhere met and observed. Thus, in 2018, CO2 emissions increased by 1.4% compared to 2016. Only 4 nuclear power plants were able to switch to environmentally friendly energy, the rest have only made some progress in improving the technologies used

The fifth direction is the management of unified chains within the framework of the digitalization of the industry

In 2018 alone, the Government of the Russian Federation allocated 505 million rubles for the development, launch and targeted support in the field of “end-to-end” technologies (quantum technologies, artificial intelligence). Recently, digitalization has become one of the priority areas of state policy of the country and Rosatom in particular. It can be understood as a system for improving the efficiency of internal processes through the wider use of digital technologies. There is active development of own digital products, own advanced technologies for key sectors of the domestic economy, and automation of control systems. In recent decades, companies within Rosatom have been introducing digital products and technologies of their own development into their production and management processes. Modern approaches to managing processes and people require state-owned enterprises involved in the construction of nuclear power plants to provide an increasingly wide range of services: creating digital twins of facilities and other high-tech solutions. The most notable projects are being carried out at the Federal Nuclear Center in Saratov under the sign of the engineering division of Rosatom. All projects are implemented based on the general concept of development of the Russian Federation within the framework of digitalization of the country. This allows for access to new markets and the launch of new products through the use of advanced digital software products and technologies. This introduction into the energy sector allows for a reduction in production costs.

In the minutes of the meeting of the Board of Directors of Atomenergoprom JSC, it is reported that in order to digitalize the Russian nuclear industry, Rosatom State Corporation plans to create the Tsifrum company within its structure. Since December 2018, Rosatom has been carrying out “digital” uranium mining. All production processes are controlled from the main control center. Rosatom State Corporation, together with scientists from the National Research Nuclear University MEPhI, has created an innovative intelligent technology that allows for the leaching of underground uranium. The implementation of this project makes it possible to significantly increase labor productivity, and at the same time, the economic efficiency of mining.

Atomenergoprom JSC (Nuclear Power Industry Complex) is a powerful integrated company that unites civil assets of the nuclear industry. In the nuclear energy sector, Atomenergoprom provides a full production cycle from uranium mining to the construction of nuclear power plants and their commissioning.

A single information platform created using Multi-D technology is one of the strategic components aimed at meeting construction deadlines and reducing the cost of nuclear power plants, achieving a competitive LCOE.

4 RESULTS AND DISCUSSION

There are several scenarios for the development of nuclear power industry. All scenarios are interconnected in terms of indicators and resources used in nuclear power industry. The indicators include LCOE and CO2 emissions, the resources include the total amount of water consumed due to electricity generation.

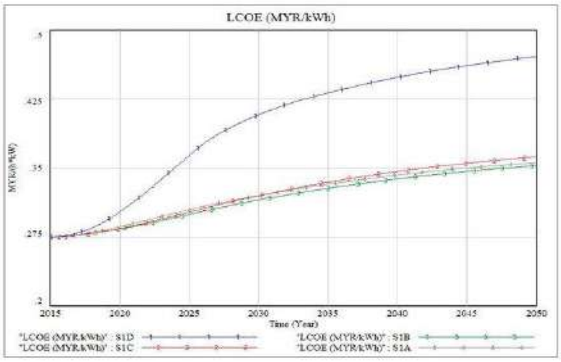


Figure 5: S1 - Levelised Cost of Energy (LCOE) (Demetriu, 2013).

The LCOE will be between S1B and S1C by 2050. Figure 5 shows that for S1B, S1C and S1D the LCOE will increase gradually, following an S-shaped curve, from approximately MYR 0.27 kWh to MYR 0.35 in 2050. S1 scenario - LCOE for solar power will be higher than for hydroelectric power. The significant difference in LCOE increase is due to the expansion of bioenergy, marine and wind energy.

Scenario S2 is presented in Fig. 6, where the LCOE behavior for scenario S2 is shown. Maintaining RE penetration at 5% without using nuclear energy would increase the LCOE to 0.35 MYR/kWh (S2A) and 0.53 MYR/kWh (S2B), respectively. S2B is significantly higher because diesel has a high LCOE. On the other hand, LCOE will be maintained at 0.27 MYR/kWh if nuclear penetration occurs as shown by S2C (10%) and S2D (20%). This is consistent with the fact that nuclear energy is significantly cheaper compared to other types of energy.

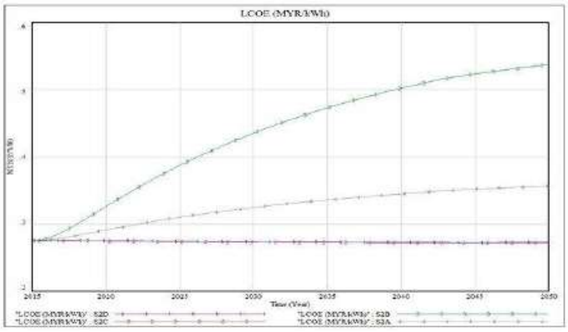


Figure 6: S2 - LCOE (Demetriu, 2013).

For the second scenario, the projected CO_2 emission figures are 112,000–114,000 $KtCO_2e$/year. Nuclear power emits much less into the environment than in the first scenario.

Considering the LCOE level, CO_2 emissions and water use in energy production, nuclear power is recommended worldwide.

Misnon et al. (Misnon, Hu, Rahman, YAsir, 2017) suggested that organizations and the public in many countries are generally willing to accept nuclear energy projects, but not everyone is aware of the benefits of this industry. However, there are risks of accidents such as Chernobyl, Fukushima, which increases the time frame and leads to some protests about nuclear energy (Misnon, Hu, Rahman, YAsir, 2017).

5 CONCLUSIONS

There are currently 436 nuclear power units in the world. Their total capacity is 369,818 MW. Countries with low AC use are noted. As an example, we can cite France, where 74% of electricity is generated by nuclear power plants, in South Korea - 35.48%, in Belgium - 51%, and 29.21% in Japan. The record holder for low use of AC is the United States, where the total capacity of power plants is 101,240 MW (about 20% of the total amount of electricity generated in the country).

A broad and detailed analysis of the prospects of energy markets is carried out, with mandatory consideration of demographic, technological, economic, political, climatic and other factors. There was a slight increase in the share of nuclear energy in electricity consumption from 10.5% in 2015. Up to 11.0-11.4% in 2040. These indicators may be different for developed and developing countries.

Scientists from many countries predict a decrease in the share of nuclear power plants in electricity production in OECD countries by 0.3% by 2040, that is, to the level of 17.7%. However, the share of nuclear power outside the OECD could rise significantly to 7.9%, or 3.4% by 2040.

The European continent, due to various political decisions taken, may significantly reduce its nuclear capacity (by 20%) by 2040. These are France, Germany, Belgium, Spain, Sweden, Great Britain, Switzerland. In North America, over the same period under review, under favorable circumstances, the volume of nuclear capacity will increase by 3%, and under unfavorable circumstances, it will decrease by 0.2 and 1.8%, respectively. Countries such as Poland, Lithuania, and Turkey are aiming to increase nuclear generation. However, the current trends will not give the expected effect. Electricity production at nuclear power plants will be carried out, which will lead to a reduction of 15% in a favorable scenario and 27% in an unfavorable scenario.

The Russian government plans to increase the share of nuclear energy from 20% to 25% in the country's energy balance by 2045. Achieving this indicator indicates the commitment to maintaining carbon neutrality, as outlined in the low-carbon development strategy of the Russian Federation. Rosatom is actively engaged in the most promising areas of nuclear energy development, which allows Russia to remain a key growth point for nuclear generation. Despite the high capital intensity of NPP construction, the significant cost of conservation of first-generation nuclear power plants, the extremely high efficiency of NPPs (up to 86%) indicates the prospects for the further development of nuclear power industry in the country.

Given the influence of a huge number of factors on the economy of the country and regions, it is impossible to definitely predict the future direction of nuclear energy development in the long term, but it is possible to compare model scenarios of development, conditionally identifying five groups of scenarios.

The first direction is a growing one, which is based on the use of innovative technologies to achieve the priority goals of the Russian Nuclear Energy Sector. The second direction is focused on the development of international nuclear energy: today, Rosatom is building 58 facilities in 18 countries around the world (regions of East and South Asia, the Middle East, Africa). OPEC experts predict that by 2045 the share of nuclear energy in the energy balance will grow to 6.6% (compared to 5.3% in 2022). The third development scenario is based on the thesis that nuclear energy has been legally recognized by a number of countries as environmentally friendly, and the Russian Federation and the People's Republic of China consider nuclear generation as a "green" project. The fourth group of scenarios is based on the development of nuclear energy - IV generation reactors with a closed nuclear fuel cycle. Russia is already a world leader in low-power reactor technology. And the fifth group of scenarios suggests the introduction of unified supply chains as development priorities in the implementation of the national digitalization project of the industry. It is obvious that nuclear energy is aimed at achieving environmental goals, supporting efforts to combat climate change and ensuring national energy security.

REFERENCES

Aziatskie energeticheskie scenarii 2030 / red. S.V. ZHukov. M.: Magistr, 2012. 336 s. [Asian Energy Scenarios 2030. Ed. S.V. Zhukov. M.: Magistr, 2012. 336 p. (In Russ.)]

P. Bobylyov vystupil na sessii komiteta po ustojchivoj energetike OON. 2019. Ministerstvo energetiki RF. URL: https://minenergo.gov.ru/node/16013 (data obrashcheniya 13.04.2020)

Vodorodnaya ekonomika. Energeticheskij byulleten'. Vypusk №73, iyun' 2019. https://ac.gov.ru/files/publication/a/22855.pdf (data obrashcheniya 13.04.2020)

Demetriu, D., 2013. Zemletryasenie v YAponii, yadernoe bedstvie na cunami i Fukusima: obzor 2011 goda. Dostupno na sajte: http://www.telegraph.co.uk/news/worldnews/asia/japan/8953574/Japan-earthquake-tsunami-and-Fukushima-nuclear-disaster-2011-review.html (dostupno 2 marta 2017 g.).

Zhukov, S.V., Kopytin, I.A., Popad'ko, A.M., 2022. Predely integracii novyh vozobnovlyaemyh istochnikov energii v elektroenergetike stran Evrosoyuza: ekonomicheskie aspekty. Kontury global'nyh transformacij: politika, ekonomika, pravo. T. 15. № 1. S. 203-223.

Itogi raboty optovogo rynka elektroenergii i moshchnosti s 22.11.2019 po 28.11.2019. Associaciya ZHdaneev O., Zuev S. Razvitie VIE i formirovanie novoj energopolitiki Rossii. 2020 / Energeticheskaya politika. Obshchestvenno-delovoj nauchnyj zhurnal. URL:

https://energypolicy.ru/?p=3234 (data obrashcheniya 10.04.2020)
Makroekonomicheskie effekty razvitiya atomnoj energetiki (metodologiya i prakticheskie ocenki): nauchnyj doklad. M.: Izdatel'skij dom «Mezhdunarodnye otnosheniya», 2018. – 70, [1] s.
Misnon, F.A., Hu, Y.S., Rahman, I.A., YAsir, M.S., 2017. Obshchestvennoe vospriyatie Malajzii v voprosah yadernoj energetiki. AIP Conf. Proc. 1799 , 020006. [Google Scholar]
Mezhdunarodnoe energeticheskoe agentstvo korrektiruet prognoz razvitiya atomnoj energetiki v mire. YAndeks Novosti ot 27 maya 2018
Obzor pravovogo regulirovaniya vozobnovlyaemyh istochnikov energii v Rossii. 2019. «Danilov i Partnery» URL: http://danilovpartners.com/ru/publikacii/obzor-pravovogo-egulirovanijavozobnovljaemyh-istochnikov- jenergii- v-rossii/ (data obrashcheniya 10.04.2020)
Perspektivy atomnoj energetiki v mire i Rossii. Rost yadernoj energetiki v mire nahoditsya na 25-letnem maksimume. YAndeks Novosti 24 aprelya 2018
Reznikova, O.B., Sinicyn, M.V., Gahokidze, I.Z., 2022. Dolgovremennye scenarii razvitiya mirovoj elektroenergetiki:osnovnye tendencii i neopredelennosti. *Kontury global'nyh transformacij: politika, ekonomika, pravo.* 2022. T. 15. № 2. S. 33-48.
Sinicyn, M.V., 2021. Kitaj kak global'nyj drajver elektrifikacii dorozhnogo transporta: riski dlya rynka nefti. EKO. № 9. C. 53-68.
Energeticheskaya komissiya. Poluostrov Malajziya Obzor otrasli elektrosnabzheniya 2016 goda ; Komissiya po energetike: Putradzhajya, Malajziya, 2016; p. 73.
Energoeffektivnost' i razvitie vozobnovlyaemyh istochnikov – osnovnye trebovaniya k energetike ustojchivogo razvitiya. RIO Novosti ot 18 aprelya 2019.
Zhukov, S.V., Kopytin, I.A., Popadko, A.M., 2022. The Limits of New Renewable Energy Sources Integration in Electricity Sector in the EU Countries: Economic Aspects. *Outlines of global transformations: politics, economics, law*. Vol. 15. No. 1. Pp. 203-223. (In Russ.)]
BP Statistical Review of World Energy – all data. 1965-2021. URL: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html
European Commission. COM (2021) 564 final 2021/0214 (COD) Proposal for a Regulation of the European Parliament and of the Council establishing a carbon border adjustment mechanism (Text with EEA relevance). 14.07.2021. URL: https://eur-lex.europa.eu/resource.html?uri=cellar:a95a4441-e558-11eb-a1a5-01aa75ed71a1.0001.02/DOC_1&format=PDF
European Commission. COM (2021) 564 final Annexes 1 to 5 to the Regulation of the European Parliament and of the Council establishing a carbon border adjustment mechanism. 14.07.2021. URL: https://eur-lex.europa.eu/resource.html?uri=cellar:a95a4441-e558-11eb-a1a5-01aa75ed71a1.0001.02/DOC_2&format=PDF
Five Year Plan for forests and grassland protection released. 2021. August 19. URL: https://chinadialogue.net/en/digest/five-year-plan-for-forests-and-grassland-protection-released/
Idel, R., 2022. Levelized Full System Costs of Electricity. February 2022. URL: https://ssrn.com/abstract=4028640 http://dx.doi.org/10.2139/ssrn.4028640 29 P.
Inflation Reduction Act (IRA) Summary. Energy and Climate Provisions. Bipartisan Policy Center. 2022. URL: https://bipartisanpolicy.org/blog/inflation-reduction-act-summary-energy-climate-provisions/
Lovins, A.B., 2022. US nuclear power: Status, prospects, and climate implications. *The Electricity Journal.* May. Vol. 35. Is. 4. Pp. 107-122.
McKerracher, C., 2022. The World's Electric Vehicle Fleet Will Soon Surpass 20 Million. 8.04.2022 g. URL:https://www.bloomberg.com/news/articles/2022-04-08/plug-in-ev-fleet-will-soon-hit-a-20-million-milestone?srnd=green
O'Boyle, M., Esposito, D., Solomon, M., 2019. Implementing the Inflation Reduction Act: a Roadmap for State Electricity
Policy. Energy Innovation Policy and Technology LLC. 2022. October. URL: https://energyinnovation.org/publication/implementing-the-inflation-reduction-act-a-roadmap-for-state-electricity-policy/
Renewable Capacity Statistics 2020. The International Renewable Energy Agency (IRENA) // URL: https://www.irena.org/publications/2020/Mar/Renewable-Capacity-Statistics-2020 (data obrashcheniya 12.04.2020)
Tay, A., 2019. By the numbers: China's net-zero ambitions // Nature. URL: https://www.nature.com/articles/d41586-022-00802-3.
U.S. Energy Information Administration. Short-Term Energy Outlook. 2023. January 10. URL: https://www.eia.gov/outlooks/steo/
https://www.atomic-energy.ru/articles/2022/12/13/131170?ysclid=lupo33uqeu803784461
https://www.iaea.org/sites/default/files/gc/gc50com5or-3_rus.pdf
https://www.atomic-energy.ru/interviews/2020/03/13/102201?ysclid=luio2wa8gh533994706
https://www.iaea.org/sites/default/files/gc/gc50com5or-3_rus.pdf
https://ru.valdaiclub.com/a/highlights/na-puti-k-evraziyskomu-atomnomu-konsortsiumu/

Economic Efficiency of City External Lighting Systems: Methodological Research Toolkit

Dmitri Kondratiev[1][a], Anatoli Osipov[1][b], Petr Akmarov[2][c], Elena Nekrasova[1][d] and Olga Abasheva[1][e]

[1]*Department of Management and Law, Udmurt State Agrarian University, Izhevsk, Russia*

[2]*Department of Economic Cybernetics and Information Technologies, Udmurt State Agrarian University, Izhevsk, Russia*

{kondratievdmitri, anatoliosipov1955, izhgsha_ur, nekrasova-elena-v, abasheva175}@mail.ru

Keywords: Outdoor (external) lighting, economic efficiency, research toolkit, city.

Abstract: The article reveals the methodological tools for research and assessment of the economic efficiency of the functioning and development of outdoor lighting systems in cities. The purpose of the research in the work is to substantiate approaches and methods for assessing efficiency, establishing types and groups of efficiency criteria, as well as developing a system of performance indicators for outdoor lighting systems. Taking into account the nature and purpose of the research object, the authors propose to make a comprehensive assessment of its effectiveness based on three groups of criteria through indicators of socio-economic, technical-economic and financial efficiency. In order to ensure comparability of efficiency indicators assessment of heterogeneous outdoor lighting systems, the work substantiates the new concept of "conditional luminaire". The methodological research tools proposed in the work can be used by owners in making decisions on the expansion, reconstruction, and modernization of outdoor lighting systems.

1 INTRODUCTION AND METHODOLOGY

Depending on the nature of vital activity objects and the spheres of their possible socially significant application, which predetermine the types of results and benefits they create, it is necessary to distinguish between the corresponding types of efficiency acceptable to them, which have a practical need to evaluate them. The types of efficiency, taking into account the nature-determined features of the forms and expressions of results and benefits created by various objects, respectively include economic (commercial), general economic, social, budgetary, investment, technical, environmental and other types of efficiency [1, 2]. It should be noted that any socially significant object usually carries several types of efficiency and is always endowed with economic efficiency, because economics is the basis for the functioning and development of any human community and everything that has value for people is certainly an economic good that has an economic significance and, accordingly, economic efficiency.

The city's outdoor lighting system belongs at least to the list of socially, technically, environmentally, budgetarily, politically, commercially, financially and general economically (the last three are types of economic results) significant objects [3-7]. Therefore, all of the listed types of efficiency are applicable to it, among which the most important and primary are the social, technical and economic components. The first - due to the main purpose of the facility - involves ensuring favorable conditions for the life and activities of the population, including business workers and employees of public administration bodies, the second - due to the nature of the management object - ensuring reliability, safety, energy efficiency, continuity and sustainability of the functions performed, the third -

[a] https://orcid.org/0000-0001-8480-6199
[b] https://orcid.org/0000-0001-9657-5893
[c] https://orcid.org/0000-0002-1361-033X
[d] https://orcid.org/0000-0003-4613-383X
[e] https://orcid.org/0000-0003-4905-1039

due to the presence of utility as an economic good, - ensuring maximization of the ratio of benefits and costs of its functioning and development. Therefore, taking into account the priority of these components, in this work the main emphasis is on the study of the content and justification of the key criteria for assessing the socio-economic, technical-economic, as well as financial-economic efficiency of external lighting systems of municipalities. At the same time, the assessment of the social and technical components in this work is carried out through the prism of approaches and categories of economic efficiency.

All approaches to assessing economic efficiency should be divided into simply economic, based on the study of costs and results, accounting, associated with the study of income and expenses, and financial, associated with the assessment of receipts and payments, - totally may be three groups of categories and their corresponding indicators, acceptable in relation to a specific object of research and assessment [8]. In our case, the first and third approaches are important.

The first approach in relation to an outdoor lighting system allows one to study and evaluate the economic parameters of a functioning facility, allowing one to judge its economic condition (the degree of individual elements suitability and the system as a whole), economic potential (the degree of elements use), economic returns (economic results from individual elements - effect in the form of savings or an increase in total benefit or utility), economic risks (losses in value terms caused by imbalances in the parameters of the object's economy, leading to the object as a whole not meeting the requirements of its external environment or disturbing its internal balance as a balanced system), etc. As a result of applying this approach, it is important to understand the economics of the system from the inside and establish its viability and consistency within the framework of existing and possible operating concepts.

The third approach is based on the cash flows assessment determined by budget limits and obligations arising in connection with contracts (agreements) for the maintenance, repair and operation of an external lighting system as a single object that creates a minimum set of economic results (socio-economic in our case), approved by the customer and satisfying the needs of direct consumers (primarily the population, as well as other categories - business, government agencies, etc.). In the context of this approach, the emphasis is on assessing the compliance of the payments volume (in our case, unless the contractor violates the contract terms, we are dealing primarily with a unidirectional cash flow) with the volume and quality of the socio-economic good (service) provided in a comparable monetary value, that is, taking into account the factors of the money time value theory. The economic content of the functioning processes of the external lighting system (hereinafter referred to as the System), the state of its elements, the use of potential, etc., if this does not directly violate the special terms of the contract, is entirely within the jurisdiction and responsibility of the contractor, that is, how he organizes the work on service provider, whether he uses energy-efficient technologies, whether he makes investments in modernization, etc., except in cases specifically stipulated by the contract or under additional agreements - all this does not in any way affect the assessment of the System efficiency level. In simple terms, the less money the customer (municipal entity) pays for a service of a certain volume and required quality, the more effective the model (concept) of the outdoor lighting system.

Considering the fact that the target result of the System functioning (as, in general, any other socially significant object) is to satisfy the specific consumer needs, and the consumer of the System work results in our case is the population, including employees of organizations and public authorities, then the choice of the most cost-effective option for the future state and functioning of the outdoor lighting system should be based primarily on considerations of socio-economic efficiency. Understanding that the System by its nature is a technical object that ensures the achievement of the target goods result, then when choosing a solution in conditions of identical socio-economic efficiency of the System development options, the criteria of technical-economic efficiency come into the background. And given the structure of costs in the System, energy efficiency criteria come first. In third place in importance may be the criteria and indicators of ordinary economic, commercial and financial efficiency.

2 RESEARCH RESULTS AND DISCUSSION

As criteria for the socio-economic efficiency of the Systems, two groups of indicators (two criteria) can be used: 1) the number (volume) of social results available (or created) by the external lighting system per resident (per unit territory area, per unit length of roads, sidewalks, per unit of transport or pedestrian flow, etc.) on average for a certain period of time (static method), for example, per year, or in the dynamics of time calendar periods (dynamic method), for example, monthly; 2) cost (volume of financial payments) of available (created) social good per inhabitant (also, possibly, by other divisors, as well as in statics or dynamics). As an additional criterion of socio-economic efficiency, the criterion of cost (financial burden) per unit of social good provided can be used [9-11]. Both quantitative and qualitative indicators can be considered as social goods (results) indicators. The latter can be assessed in points, percentage of the target audience satisfaction, by indirect indicators, for example, traffic safety, as a social good, can be assessed by the percentage reduction in accidents, crimes, the number of harm cases to health (from falls, collisions) or days of disability. The main social goods (results), in our opinion, in modern populated areas are the number of light points and the volume of luminous flux. Qualitative indicators should be specially developed and assessed for specific territories (sections) of the city (village, other populated area), such as roads, parks, squares, etc. [12-14].

The criteria of socio-economic efficiency must be followed when expanding outdoor lighting systems, as well as bringing their condition to the minimum regulatory requirements for the provision of the population and the territories where they are located in terms of the illuminated places number (area), by the level and quality of illumination, therefore these criteria are the main ones.

Let's consider an example of a comparative assessment of the socio-economic efficiency of the lighting system in the Izhevsk city and a potential outdoor lighting project for one of the new city microdistricts (table 1).

The data in table 1 shows that the level of socio-economic efficiency of the project under consideration is significantly inferior in efficiency to the City System. In particular, the annual current costs by the project per one resident of the microdistrict are more than 4 times higher than such costs in the city. The number of light points according to the project and, obviously, the luminous flux volume per resident are also several times higher than the provision of city citizens. An additional criterion is the annual current costs for one light point - it is not the main one, but it also indicates the inefficiency of the project.

Taking into account the above, priority should be given to solutions to expand the System to a size that provides the required coverage of territories (sections) of a populated area with a minimum number of light points and illumination level, creating conditions for fairly comfortable and safe movement in the conditions of a populated area at night, by roads and pedestrian routes of citizens in the territory municipality. Therefore, preference should be given to projects for installing additional light points in the most densely populated, most pedestrian-, passenger- and transport-loaded, least light-provided microdistricts (territories, sections) of a settlement. For this purpose, in the conditions of a municipality or individual settlements, in our opinion, minimum standards for the provision of light points can be established per resident of the territory (district, microdistrict, zone, etc.) and per unit area of the territory, as well as cost standards lighting also per inhabitant and per unit area, which can also be ranked according to the importance of the territory.

Table 1: Comparative assessment of the socio-economic efficiency of the city’s outdoor lighting system and a potential outdoor lighting project for one of its new neighborhoods.

Indicator name	Project indicator value	Indicator value for the city
Full initial (replacement) luminaires cost, million rubles	55	292
Annual current costs, million rubles:		
- maintenance costs	2,2	35
- electricity costs	7,4	118
- depreciation costs	5,5	29
Total	15,1	182
- including current annual costs excluding depreciation	9,6	153
Light points number, pcs.	3000	37583
Annual current costs for 1 light point, rub./piece	5033	4840
Maintenance and electricity costs for 1 light point, rub./piece	3200	4071
Number of inhabitants, thousand people	12000	623000
Annual current costs per 1 inhabitant, rub./person	1258	292
Maintenance and electricity costs per 1 inhabitant, rub./person.	800	246
Light points number per 1 thousand inhabitants, pcs./thousand people	250	60
Effective light points number for the project (maximum), pcs.	724	-
Effective light points number for the project (minimum), pcs.	696	-

The technical-economic criteria used to evaluate the System can also be represented by two groups of indicators: 1) indicators of the functionality of the System and 2) indicators of the cost of the System. At the same time, you need to understand that the technical-economic criteria of the System largely determine both the values of individual indicators and the level of socio-economic efficiency of the System as a whole, and affect other types of efficiency - environmental, aesthetic, political, general economic, commercial, etc. One of the most important problems in the technical-economic assessment of existing Systems is the heterogeneity of their main elements - primarily the types of luminaires used [15].

As part of future research, in order to ensure uniformity and comparability of assessments of the functionality and cost of the System technical component, we propose to introduce the concept of a "conditional luminaire". A conditional luminaire is a luminaire rated at 100 W (thus consuming 100 Wh), emitting 15,000 lumens and having an effective average life of 10 years (or approximately 50,000 hours). The conditional luminaire generally corresponds to the key effective average technical parameters of modern LED luminaires of the mid-price segment used in outdoor lighting systems of municipalities. In this case, a luminaire (light point) should be understood as a light source in combination - the luminaire itself with a lamp. Thus, using the category "conditional luminaire", each System luminaire and the System as a whole can be converted into conditional luminaires - by dividing the luminous flux of each luminaire by a luminous flux of 15,000 lumens.

Table 2: Comparative assessment fragment of the technical-economic efficiency of options for an external city lighting system with gas-discharge (mercury) and LED lamps.

Indicator name	Replacement luminaires				Replaceable luminaires			
Luminaire type	LED			Total	gas-discharge		mercury	Total
Luminaire brand	Groza 80	Groza 100	Groza 150		YCS 100	YCS 150	MCS 250	
Luminaires number, pcs.	4217	10943	229	15389	4217	10943	229	15389
Average price including VAT, rub.	9900	15900	20700	14327	3690	5850	2700	5211
Luminous flux, lumen	12000	16500	22400	-	9000	15000	13000	-
Initial cost of lamps, million rubles	41,7	174,0	4,7	220,5	15,6	64,0	0,6	80,2
Total luminous flux, million lumens	50,6	180,6	5,1	236,3	38,0	164,1	3,0	205,1
Total power, kW	337	1094	34	1466	422	1642	57	2120
Electricity consumption, MW*hour/year	933	3026	95	4054	1166	4539	158	5863
Annual electricity costs, thousand rubles/year	8022	26021	817	34860	10028	39032	1361	50421
Conditional luminaires number in one luminaire, con. lm./pcs.	0,80	1,10	1,49	-	0,60	1,00	0,87	-
Conditional luminaires total number, con. lm.	3374	12037	342	15753	2530	10943	198	13672
Annual electricity consumption by one conditional luminaire, kW*h/con. lm.	276,5	251,4	277,7	257,3	460,8	414,8	797,6	428,8
Annual electricity costs per one conditional luminaire, rub./con. lm.	2378	2162	2389	2213	3963	3567	6859	3688
Conditional luminaire average price, rub./con. lm.	12375	14455	13862	13996	6150	5850	3115	5866
Average price of lamps for lighting fixtures, rub./piece	0	0	0	0	1020	950	1100	971
Average lamp life, years	0	0	0	0	3,9	3,9	3,9	3,9
Annual costs for replacing lamps, thousand rubles	0	0	0	0	1033	2680	56	3769
Annual amount of lamp depreciation, thousand rubles	0	0	0	0	1109	2680	65	3854
Annual amount of lighting fixtures depreciation, thousand rubles	4036	16821	458	21315	1556	6402	96	8053
Reduced annual current costs total, thousand rubles	12058	42842	1275	56175	13725	50794	1578	66097
Reduced annual current costs per one conditional luminaire, rub./con. lm.	3574	3559	3729	3566	5425	4642	7951	4835

Subsequently, we can reduce all the indicators of functionality and cost of existing light points of different types known to us to a common denominator - a conditional luminaire, and judge their functionality, energy efficiency, and maintenance costs in one single comparable estimate. But, with one caveat, that a conditional luminaire as a universal unit is not suitable for assessing the technical-economic efficiency of unique luminaire (those having a special aesthetic or ergonomic application, color spectrum, etc.).

Technical-economic efficiency criteria should be applied when making decisions on modernization, restoration, and reconstruction of Systems.

Let's consider an example of a comparative assessment fragment of the technical-economic efficiency of System options with traditional gas-discharge and modern LED lamps of the middle price segment (table 2).

The data in table 2 indicate that obsolete gas-discharge (and especially mercury) lamps are significantly inferior to their LED counterparts in terms of technical-economic characteristics.

It is believed that the criteria of ordinary economic (commercial, financial) efficiency are usually not applicable to assessing the effectiveness of social objects, which include the System. However, it is known that commercial efficiency is defined as the difference between the results (income, receipts) obtained and the costs (expenses, payments) incurred to obtain them [16-18]. At the same time, one of the types of economic results (income, receipts) can be the "savings" on costs (expenses, payments), which is applicable for any objects (projects) of assessment, both commercial and social, environmental and others. In order to obtain the savings (reduction of costs, expenses, payments) in one or another part of the System, it is necessary to incur costs (expenses, payments) to improve the condition of the elements of this System part or the processes occurring in it. In our case, the possibility of savings in the outdoor lighting system may be associated with a reduction in electricity costs for lighting, labor costs, machines and mechanisms for maintenance, reduction in electricity losses, reduction in restoration costs, etc. Typically, the possibility of savings is determined by investments in modernization, automation, robotization, digitalization, expenses in improving discipline and labor organization, expenses in improving control, standardization, regulation, planning, etc. Savings in each specific case require the development (or at least clarification) of a methodology for its measurement and evaluation.

For example, savings may represent the expected economic outcome of gas-discharge to LED lighting upgrade projects and associated improvements to the System during its subsequent operation. The benefit (in this case, financial-economic effect) will come down to savings in budget costs and minimization of budget payments to the municipality during the service life of the System improvements caused by the lighting fixture modernization projects. Savings within the framework of these projects can be expressed primarily by a reduction in the amount of costs for electricity consumed by the System and a reduction in the amount of costs for servicing lamps in terms of the cost of replacing gas-discharge lamps. In addition, it may also be necessary to estimate the savings or cost overruns (plus or minus) in the costs of major repairs of fixtures, as well as additional income (receipts) from recycling or costs (payments) for recycling old fixtures [19-21].

Table 3: Financial-economic efficiency of replacing gas-discharge YCS 150 with LED luminaires Groza 100, million rubles.

Indicator name	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Investments	-174									
Saving on electricity	13	13	13	13	13	13	13	13	13	13
Savings on lamp replacement	5,4	5,4	5,4	5,4	5,4	5,4	5,4	5,4	5,4	5,4
Saving on repairs	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7
Total savings	20,1	20,1	20,1	20,1	20,1	20,1	20,1	20,1	20,1	20,1
Receipts from gas-discharge luminaires sales	6,4	-	-	-	-	-	-	-	-	-
Net cash flow	-147,5	20,1	20,1	20,1	20,1	20,1	20,1	20,1	20,1	20,1
Cumulative net cash flow	-147,5	-127,4	-107,3	-87,2	-67,1	-47	-26,9	-6,8	13,3	33,4
Cash flow (at a rate of 6%)	-148	19	18	17	16	15	14	13	13	12
Cumulative cash flow (at a rate of 6%)	-148	-129	-111	-94	-78	-63	-49	-35	-23	-11
Luminaires wear (service life 10.3 years)	17	17	17	17	17	17	17	17	17	17
Luminaires residual value	157	140	123	106	90	73	56	39	22	5

The costs (payments) aimed at obtaining these savings and which need to be estimated represent capital investments (investments) in replacing gas-discharge lamps with LED lamps, which include the purchase price (including acquisition and delivery costs) and the cost of their installation. The financial-economic effect from the modernization and subsequent operation of lighting systems can be expected to be obtained only in the long term. It represents the difference between the total savings achieved over the life of new luminaires and the one-time investment in upgrading them. The system as a social object can create other types of economic (financial) results, which requires the implementation of appropriate projects (events).

Let us give an example of assessing the financial-economic efficiency of a project fragment for upgrading gas-discharge to LED luminaires (table 3). Initial data are presented in table 2.

The data in table 3 indicates that the financial-economic efficiency of the lighting fixtures modernization project is quite attractive for the System we are considering as an object classified as social. Without taking into account the time factor, the investment profit on the project will be 33.4 million rubles in 10 years, and the payback period is 8.3 years. When discounted at a rate of 6% per annum, the project during the service life of the improvements (10 years) generates losses of 11 million rubles, that is, it almost pays for itself, which nevertheless indicates its low investment attractiveness for private investors.

3 CONCLUSIONS

The methodological approaches, methods, criteria and indicators for studying and assessing the economic efficiency of outdoor lighting systems proposed in the work allow us to comprehensively judge the advantages and disadvantages of the System as a whole and its individual elements, identify and rank social, technical and financial-economic problems of its functioning, as well as develop and justify projects for its improvement and development strategies.

REFERENCES

Rudenok, V.A., Kondrateva, N.P., Mazunina, N.I., Tikhonova, O.S., 2022. The effect of synergism in seed treatment with electron-donor solution and uv irradiation. *IOP Conference Series: Earth and Environmental Science.* Vol. 949. P. 012110.

Kondratiev, D.V., Ostaev, G.Y., Khosiev, B.N., Tegetaeva, O.R., Basieva, L.V., 2023. The efficiency assessment methodic of expenses budget financing on the chemicals acquisition by agricultural producers. *Lecture Notes in Networks and Systems.* Vol. 622. pp. 683-695.

Kondratyev, D.V., Ostaev, G.Y., Khosiev, B.N., Mukhina, I.A., Markovina, E.V, 2023. Synergy in firm governance for increasing competitiveness of agro-industrial enterprises. In Unlocking digital transformation of agricultural enterprises. Technology Advances, Digital Ecosystems, and Innovative Firm Governance. Innovation, technology, and knowledge management. Springer, Cham. pp. 265-273.

Kondratiev, D.V., Osipov, A.K., Gainutdinova, E.A., Abasheva, O.V., Ostaev, G.Ya., 2022. Criteria and indicators of synergistic efficiency of food industry enterprise management. *IOP Conference Series: Earth and Environmental Science*. Vol. 949. P. 012080.

Ostaev, G., Kondratyev, D., Kravchenko, N., Nekrasova, E., 2020. Crisis identification and development of crisis management algorithm in the agricultural sector. *Amazonia Investiga*. Vol. 9. No. 29. pp. 316-326.

Ostaev, G.Ya., Kondratiev, D.V., Klychova, G.S., Nigmatullina, N.N., Klychova, A.S., 2022. Corporate management of financial potential. *Bulletin of the Kazan State Agrarian University*. Vol. 17. No. 1 (65). pp. 129-134 (In Russian).

Rudchenko, Y.A., Rudchenko, G.R., 2019. Methodological approach to analyzing the economic efficiency of introducing modern light sources. *Economics. Business. Finance*. No. 6. pp. 25-30 (In Russian).

Ostaev, G., Kondratyev, D., Nechaev, B., Romanova, A., 2020. Foresight research in management accounting: scenario forecasting and a comprehensive system of expert assessment methods in agricultural holdings. *Amazonia Investiga*. Vol. 9. No. 29. pp. 188-203.

Kondratiev, D.V., Ostaev, G.Ya., Klychova, G.S., Kurakova, Ch.M., 2021. Development of property management in municipalities. Izhevsk, Shelest. pp. 180 (In Russian).

Kondratiev, D.V., Ostaev, G.Ya., Klychova, G.S., Valiev, A.R., Ziganshin, B.G., 2021. Stochastic analysis and optimal management of incentives for personnel of a commercial organization. *Bulletin of the Kazan State Agrarian University*. Vol. 16. No. 2 (62). pp. 116-123 (In Russian).

Loshkarev, I.Y., Shirobokova, T.A., 2019. Methods for assessing the parameters of led-based lighting in livestock houses. *Journal of Physics: Conference Series.* Vol. 1333. P. 062013.

Bakirov, S.M., Shirobokova, T.A., 2023. Justification of the parameters of the artificial LED lighting system for livestock premises. *Agroengineering*. Vol. 25. No. 6. pp. 61-66 (In Russian).

Rustemli, S., Demir, Yu., 2021. Comparative analysis of lighting installations used in road illumination. *Light & Engineering.* Vol. 29. No. 6. pp. 86-94.

Shirobokova, T.A., Shuvalova, L.A., Novoselov, I.M., Pokoev, P.N., 2022. Prospects for the use of led lighting devices in poultry farming. *AIP Conference Proceedings*. Vol. 2661. P. 060016.

Kozlovskaya, V.B., Kalechits, V.N., 2014. Energy-efficient light sources in the external lighting system. *Energy and management*. No. 2. pp. 8-13 (In Russian).

Lobão, J.A., Devezas, T., Catalão, J.P.S., 2014. Decision support in the investment analysis on efficient and sustainable street lighting. *IFIP Advances in Information and Communication Technology*. Vol. 423. pp. 345-352.

Ostaev, G.Ya., Kondratiev, D.V., Kotlyachkov, O.V., Konina, E.A., Suetin, S.N., Istomina L.A., 2019. Improving the methods and approaches of analysis and management accounting in agriculture. *Amazonia Investiga*. Vol. 8. No. 20. pp. 135-143.

Valiullin, K.R., 2020. The system of indicators of street lighting systems energy efficiency. *IOP Conference Series*. Vol. 791. P. 012048.

Ovchukova, S.A., Kondratieva, N.P., Kovalenko, O.Y., 2021. Energy saving in lighting technologies of agricultural production. *Light & Engineering*. Vol. 29. No. 2. pp. 21-25.

Wang, B., Liu, X., Yang, Y., 2018. Energy efficiency retrofitting of lighting in university libraries based on illumination suitability analysis. *Light & Engineering.* Vol. 26. No. 3. pp. 132-139.

Moral-Carcedo, J., Pérez-García, J., 2021. Measuring aggregate electricity savings from the diffusion of more efficient lighting technologies. *Energy Efficiency*. Vol. 14. No 7.

Methodological Approaches to Assessment of Entrepreneurial Ability

Dilfuza Matyakubova[1] [1], Azizbek Yakubov[3] [2], Saburov Javohir[3] [3], Khurshid Zaripov[1] [4], Faxriddin Bekchanov[2] [5]

[1] *"Urgench state university", 220100, Khamid Olimjon, Urgench, Uzbekistan*

[2] *"Mamun university", 220900, Qibla Tozabog, Khiva, Uzbekistan*

[3] *Urgench Ranch Technology University, Khonqa Street, 26, 220100, Urgench, Uzbekistan*

dilfuza.m@urdu.uz, yaqubov-azizbek@list.ru, soburov2912@gmail.com, xurshidbek.zokirovich@gmail.com, b.faxriddin.yi@gmail.com

Keywords: entrepreneurial ability, assessment, methodological approach, entrepreneurship

Abstract: Assessing entrepreneurial ability is fundamental for understanding and predicting success in business ventures. This paper explores methodological approaches to assessing entrepreneurial ability, with a particular focus on utilizing surveys as a tool for self-assessment. A survey consisting of 20 questions was administered to a sample of aspiring entrepreneurs, aiming to capture various dimensions of entrepreneurial skills, traits, and behaviors. Based on the survey results, a comprehensive assessment of individuals' perceived abilities in business endeavors was calculated. The paper discusses the design and implementation of the survey instrument, including the selection of questions and the rationale behind their inclusion. It also examines the process of data collection and analysis, highlighting key findings and insights derived from the survey responses. Furthermore, the paper discusses the strengths and limitations of using self-assessment surveys in evaluating entrepreneurial ability, including considerations related to validity, reliability, and potential biases. By leveraging survey data, this study contributes to the ongoing discourse on methodological approaches to entrepreneurial assessment, providing valuable insights into the self-perceived competencies of aspiring entrepreneurs. The findings offer implications for entrepreneurship education, training, and talent development initiatives aimed at fostering the growth and success of future business leaders.

1 INTRODUCTION

Entrepreneurship, often hailed as the engine of economic growth and innovation, has garnered significant attention from scholars, policymakers, and practitioners alike. At the heart of entrepreneurial endeavors lies the entrepreneurial ability—the set of skills, traits, and behaviors that enable individuals to identify, pursue, and capitalize on opportunities in the marketplace (Oosterbeek et.al 2009). Understanding and assessing entrepreneurial ability are crucial endeavors, as they hold the key to unlocking insights into the factors driving entrepreneurial success and failure. Assessing entrepreneurial ability is a complex and multifaceted task, requiring the integration of various methodological approaches to capture the nuances of entrepreneurial behavior (Pittaway and Edwards 2012). From psychometric assessments and behavioral observation to case studies and simulation exercises, researchers and practitioners employ diverse tools and techniques to evaluate individuals' entrepreneurial aptitude. Among these approaches, self-assessment surveys emerge as a valuable method for gauging individuals' perceptions of their own entrepreneurial capabilities (Souitaris et.al 2007).

In this paper, we delve into methodological approaches to assessing entrepreneurial ability, with a particular emphasis on the utilization of surveys for self-assessment purposes (Jones and Iredale 2010). The central aim is to explore the design,

[1] https://orcid.org/0000-0002-7059-2510
[2] https://orcid.org/0000-0003-2195-6784
[3] https://orcid.org/ 0009-0004-8949-2685
[4] https://orcid. org/0000-0003-2372-192X
[5] https://orcid.org/0009-0001-5699-3916

implementation, and implications of a self-assessment survey administered to a sample of aspiring entrepreneurs. By examining individuals' self-perceived abilities in various aspects of business endeavor, we seek to shed light on the complexities of entrepreneurial skill development and self-awareness (Reynolds et.al 2005).

The paper is structured as follows: first, we provide an overview of the theoretical foundations underpinning entrepreneurial ability and the importance of its assessment in entrepreneurial research and practice. Next, we discuss methodological considerations in entrepreneurial assessment, highlighting the strengths and limitations of different approaches. We then introduce the design and implementation of the self-assessment survey, detailing the selection of survey questions and the rationale behind their inclusion. Subsequently, we present the findings derived from the survey data analysis, offering insights into individuals' self-perceived entrepreneurial abilities. Finally, we discuss the implications of the findings for entrepreneurship education, training, and talent development initiatives.

2 METHODOLOGY

We used experimental studies to involve manipulating variables to observe their effects on entrepreneurial behavior or performance and conduct experiments to examine the impact of different types of feedback or incentives on individuals' decision-making in entrepreneurial contexts. Network analysis was used as a technique in order to study the social networks of entrepreneurs and their impact on business success. By analyzing the structure and dynamics of entrepreneurial networks, key influencers, information flow patterns, and resource exchange mechanisms have been identified. Survey was designed and used to collect important data for analyzing and grouping also making recommendations.

3 RESULTS AND DISCUSSION

Assessing entrepreneurial competency presents a fundamental challenge, given the absence of sufficiently precise and practical methodologies for measuring its quality indicators from a scholarly perspective. Therefore, developing the methodology for assessing entrepreneurial competency occupies a central position. In order to develop the methodology for assessing entrepreneurial competency, the following five approaches were studied by economists (Fig 1).

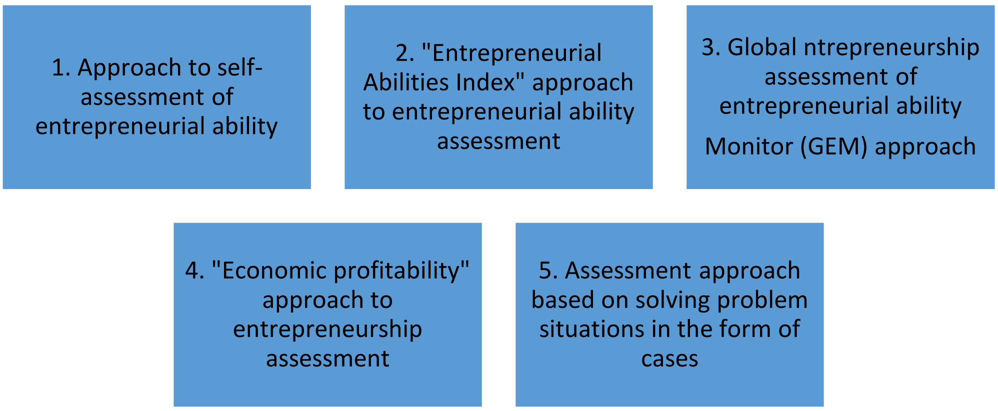


Figure 1: Methodology of assessment of entrepreneurial ability approaches.

1. Approach to self-assessment of entrepreneurial ability. Self-assessment of entrepreneurial competence is crucial for individuals engaging in small business and private entrepreneurship to possess a certain level of entrepreneurial knowledge. Diagnosing an individual's entrepreneurial competence before embarking on a new venture can be instrumental. Based on diagnostic results, clear recommendations can be provided for the enhancement of their entrepreneurial capabilities (Johannisson 2010).

Self-assessment of entrepreneurial competence can be conducted through two main avenues - offline and online testing methods. The diagnostic methodology for assessing individuals' entrepreneurial competencies comprises four stages:

1. Utilizing test questions for self-assessment of entrepreneurial competence.
2. Expression of respondents' personal attitudes towards the test questions assessing entrepreneurial competence.
3. Calculation of the total score obtained from the completed questionnaire.
4. Determination of the level of entrepreneurial competence development based on the aggregation of scores.

The diagnostic assessment of individuals' entrepreneurial competencies is conducted through providing responses to the following 20 questions. The test, titled "Entrepreneurial Aptitude," prepared by T. Matveeva, consists of the following clear questions aimed at determining entrepreneurial capability. These questions are about taking risks, international communication, motivation, experience, investments and others.

Each question in this diagnostic assessment is answered with either "yes" or "no." Each positive response earns 1 point. The total sum of points corresponds to the entrepreneurial competence level of the individuals based on the following assessment scale:

- 17-21 points: Entrepreneurial competence at the "developed" level.
- 13-16 points: Entrepreneurial competence at the "proficient" level.
- 0-12 points: Entrepreneurial competence at the "weak" level.

Table 1 information indicates that among 250 eligible youth surveyed, 26% possess all necessary qualities to become entrepreneurs, and after completing their higher education, they may start their own businesses. However, for the majority, 70% of them, reaching the level of competence required for success in entrepreneurship is not that straightforward. Nevertheless, if they engage in developing their entrepreneurial skills, becoming successful entrepreneurs becomes feasible. It's noteworthy that the remaining 10 individuals (4%) expressed no doubt in their ability to become successful entrepreneurs (Morselli 2019).

Table 1: Self-assessment of entrepreneurial abilities of young people results.

№	State of entrepreneurial ability (according to points accumulated as a result of "yes" or "no" answers)	Qualitative levels of entrepreneurial ability of respondents	The number of respondents specific to the qualitative level of entrepreneurial ability	Their share in the total participation, in %
1	0-12 points	Weak	10	4
2	13-16 points	Competent	175	70
3	17-21 points	Developed	65	26
	Total	-	250	100

The disadvantages of this method, in our opinion, are as follows:

1. Test results may not be clear enough due to disregarding the "maybe" option between "yes" and "no" responses to the questions (Moberg 2014).
2. Utilizing opportunities from the entrepreneurship infrastructure in the test questions was overlooked. For instance, when asked, "Do you have the ability to attract investments from friends and acquaintances for your business venture?" without considering options like "or have you sought loans from banks and utilized government subsidies?", the test could have been more comprehensive.
3. Subjective factors may not accurately reflect the real state of entrepreneurial competence because each respondent provides their own individual responses to the questions without a mechanism for quality control.
4. While the test may allow for a general diagnostic assessment of individuals' entrepreneurial abilities in the context of starting a specific business or initiating their own work, it may not provide the opportunity to determine the level of their "entrepreneurial skill."

2. "Entrepreneurship ability index" approach. Entrepreneurial competency assessment from a quality perspective was conducted by the Central Economic and Mathematical Institute (CEMI) of the Russian Academy of Sciences through examination. S.V. Terebova and P.S. Pleshakov proposed the "Entrepreneurial Competencies Index" for evaluating the entrepreneurial competency of individuals (Neck 2011). This index suggests calculating the integral index, which considers the importance of each characteristic by assigning weights based on the significance of qualities exhibited by eligible youth in

a 70-point system (0 points - not important at all; 4 points - extremely important).

Each question was assessed on a Likert scale with a 4-point system as follows:

- Extremely important (4 points).
- Very important (3 points).
- Moderately important (2 points).
- Not important at all (1 point).

In the monitoring results, the numerical ratings of the components of work potential were obtained in the form of "from zero to one", indicating the actual scores on the scale. The "Entrepreneurial Competencies Index" calculated using this method reflects the real assessment of entrepreneurial competency levels, as demonstrated by the example of the Khorezm region of Uzbekistan (Table 2).

Table 2: The quality characteristics of labor competency in the Khorezm region of Uzbekistan.

Quality	Index value in 1997	Index value in 2008	Rating level	Trend line
1. Communication ability	0,733	0,747	3	parallel to the time axis
2. Physical health	0,682	0,729	4	increasing
3. Mental health	0,699	0,756	2	increasing
4. Smart potential	0,630	0,621	7	falling
5. Moral level	0,775	0,769	1	falling
6. The need for success	0,612	0,660	6	increasing
7. Creative potential	0,593	0,571	8	falling
8. Cultural level	0,609	0,684	5	increasing

According to the monitoring data in Table 2, it is evident that during the years 1997-2008, there was a consistent trend towards a stable state of mental, social, and emotional well-being among the population, reflected by the highest values of labor quality indicators. The lowest value was attributed to the productivity competency index. Alongside this, there is a tendency for an increase in physical and mental health, civic engagement, and the need for success. The downward trend is rational and productive, particularly pertaining to the population's mental well-being (O'connor 2013).

3. Global Entrepreneurship Monitor approach (GEM). The Global Entrepreneurship Monitor (GEM) is a scientific research project aimed at providing information on the state of entrepreneurship activity and the macroeconomic (national level) conditions for promoting entrepreneurship development. The GEM project was initiated in 1997 by leading scholars from the United Kingdom, the United States, Finland, and Ireland. Institutionally, the project is supported by two major institutions in the field of entrepreneurship research - Babson College in the USA and London Business School in the United Kingdom. In 1999, the first annual scientific report was published by the participants of the project, with 10 countries involved; in 2000, it increased to 20 countries, and by 2007, 42 countries participated. Currently, GEM is considered the largest research project in the field of entrepreneurship in terms of the number of countries covered. The main goal of this project is to conduct a comparative analysis of the levels of entrepreneurship activity among countries. This involves assessing the "entrepreneurial activity," defined in the project as "the creation and management of new businesses," within the conceptual model of GEM, which is described with the following key indicators:

-potential entrepreneurs - individuals who are willing and capable of starting and managing a business, utilizing their opportunities, knowledge, and experience to organize business activities.

-early-stage entrepreneurs, including:

- Nascent entrepreneurs - individuals who have taken active steps toward starting a business during the past year, have full ownership in their businesses, but have not yet paid salaries or other types of remuneration for three months or more.

- Owners of new business - individuals who own and manage a newly created business and have been operating for more than three months but less than 42 months and have received income.

-successful entrepreneur or successful business owner-manager - an entrepreneur or manager of a business that has been actively operating for more than 42 months and has shown a significant level of income over time.

4. "Economic profitability" approach. Uzbek scientist, professor N.Q.Murodova believes that it is appropriate to determine the quality of the activities of small business entities, their state and level of economic profitability by quantitative measurement. This refers to the "economic benefit of enterprises" the ability to satisfy various needs at the expense of the income that the enterprise receives in return for the realization of its production and entrepreneurial potential is understood. It is recommended to calculate the level of entrepreneurial activity using the following formula:

EA=AI-(FC/AI-VC)*100% (1)

EA-level of entrepreneurial activity of the enterprise;

AI-annual income of the enterprise;

FC-fixed costs of the enterprise;

VC-variable costs of the enterprise.

Through this methodology, as a result of determining the level of economic profitability of small business activities, their activity is evaluated. In this case, the scientist divides the income of business enterprises according to the following economic profitability:

• economically helpless activity (state of poverty);

• profitability at the level of interest of the owner of the enterprise, i.e. mature economic activity (private profitability);

• profitability in the interests of the enterprise owner and hired workers,

i.e. economically developed activity (collective benefit);

• social benefit, i.e. prospective activity (social benefit);

• non-profit making, i.e. carried out by means of illegal entrepreneurship.

In accordance with the cases of economic usefulness classified above, the quality levels of business entities and the specific quality mark representing them are also recommended.

Table 3: Levels of profitability and quality of small business activity.

Rate of profitability of small business activity percentage)	Economic profitability of small business activity cases	Quality levels of small business activity:	Quality marks of enterprises
0-25	Unstable lust	Economically weak business activity	-
26-50	Self-interest	Economically mature activity	Bronze
51-75	Collective benefit	Economically developed activity	Silver
76-100	Social benefit	A promising activity	Gold

As can be seen from Table 3, there are specific classifications of each achieved quality level of the performance of small business entities, which are evaluated by the relevant criteria. "Economic usefulness" of entrepreneurship assessment positive aspects of the approach are to determine the level of business rating of business enterprises and to divide them into different groups, and accordingly to create an opportunity to develop a system of specific measures (Kuziboev et.al 2024).

5. Assessment approach based on solving problem situations in the form of cases. Russian scientist E.K. Klimov developed an evaluation method based on solving problem situations in the form of a case for the purpose of researching entrepreneurial activity. E.K. Klimov recommends evaluating the indicator "Psychological readiness for entrepreneurial activity" using the following 7 criteria:

- entrepreneurial motives;
- business goals;
- initiative;
- strategic thinking;
- resistance to stress;
- entrepreneurial intention;
- business resources.

It is believed that it is appropriate to determine the above-mentioned criteria for determining the readiness for entrepreneurship by means of a survey based on the "Situational Questionnaire". This questionnaire is based on information about 19 problem situations and 4 respondents. Problem situations consist of business problem questions and four possible solutions. The problem situation has the following form. "An entrepreneur wants to invest in the purchase of an enterprise. What factors do you think he should take into account to evaluate the profitability of the enterprise?"

Answer options:

a) the profit of the last year;

b) the average annual profit of the last five years;

c) determined based on the amount of profit of previous years

the average annual forecast profit for the next five years;

g) the average annual forecast profit over the next five years, determined on the basis of the confidence that the buyer's management skills will contribute to a sharp increase in profit.

4 CONCLUSION

In conclusion, this paper has explored methodological approaches to assessing entrepreneurial ability, with a particular emphasis on the utilization of self-assessment surveys. Entrepreneurial ability, characterized by a combination of skills, traits, and behaviors, plays a pivotal role in shaping individuals' success in business endeavors. The assessment of entrepreneurial ability is a multifaceted task, requiring the integration of diverse methodologies to capture the complexities of entrepreneurial behavior. Through the implementation of a self-assessment survey consisting of 20 questions, this study has provided valuable insights into individuals' self-perceived entrepreneurial abilities. The survey data analysis revealed patterns and trends in how aspiring entrepreneurs perceive their strengths and weaknesses across various dimensions of entrepreneurial endeavor. By examining factors such as risk-taking propensity, creativity, resilience, and leadership skills, the survey shed light on the diverse skill set required for entrepreneurial success.

The findings of this study have important implications for entrepreneurship education, training, and talent development initiatives. By understanding their own strengths and weaknesses as perceived through self-assessment, aspiring entrepreneurs can tailor their learning and development efforts to enhance their entrepreneurial capabilities. Furthermore, educators and practitioners can use the insights derived from self-assessment surveys to design targeted interventions aimed at fostering the growth and success of future business leaders.

In conclusion, methodological approaches to assessing entrepreneurial ability, including self-assessment surveys, contribute to our understanding of the factors driving entrepreneurial success and failure. By leveraging diverse methodologies, researchers and practitioners can gain comprehensive insights into the complex dynamics of entrepreneurship and inform strategies for supporting aspiring entrepreneurs on their journey towards business success.

5 REFERENCES.

Oosterbeek, H., Van Praag, C.M., IJsselstein, A., 2009. The impact of entrepreneurship education on entrepreneurship skills and motivation. *European Economic Review,* 54, 442-454.

Pittaway, L., Edwards, C., 2012. Assessment: examining practice in entrepreneurship education. Education + Training, 54(8), 778-800

Souitaris, V., Zerbinati, S., Al-Laham, A., 2007. Do entrepreneurship programmes raise entrepreneurial intention of science and engineering students? The effect of learning, inspiration and resources. *Journal of Business Venturing,* 22, 566–591.

Jones, B., Iredale, N., 2010. Enterprise education as pedagogy. *Education + Training,* 52(1), 7-19

Reynolds P., Autio E., 2005. Global Entrepreneurship Monitor: Data collection, design and implementation 1998–2003. Small Business Economics 24 (3): 205–231.

Johannisson, B., 2010. The agony of the Swedish school when confronted by entrepreneurship. In Skogen, K & Sjövoll, *J. (eds.) Creativity and Innovation:* Preconditions to entrepreneurial action, Tapir Academic Press.

Morselli, D., 2019. The Assessment of Entrepreneurial Education. In: The Change Laboratory for Teacher Training in Entrepreneurship Education. SpringerBriefs in Education. Springer, Cham.

Moberg, K., 2014. Assessing the Impact of Entrepreneurship Education: From ABC to PhD, PhD Series, No. 19.2014, ISBN 9788793155398, Copenhagen Business School (CBS), Frederiksberg.

Neck, H.M., Greene, P.G., 2011. Entrepreneurship education: Known worlds and new frontiers. *Journal of Small Business Management,* 49(1), 55-70.

O'connor, A., 2013. A conceptual framework for entrepreneurship education policy: Meeting government and economic purposes. *Journal of Business Venturing,* 28(4), 546-563.

Kuziboev, B., Ibadullaev, E., Saidmamatov, O., Rajabov, A., Marty, P., Ruzmetov, S., Sherov, A., 2023. The Role of Renewable Energy and Human Capital in Reducing Environmental Degradation in Europe and Central Asia: Panel Quantile Regression and GMM Approach. Energies 2023, 16, 7627.

Metrological Supply of the Repair and Testing of the Nose of the Aircraft (Radom)

Djumamurotov B.A.[1] [1], Aytbaev Temur Abatbaevich[2] [2] and Rakhimova Nigina Murod qizi[3] [3]
[1]*Doctoral student at Tashkent State Technical University, Universitetskaya , Tashkent, Uzbekistan*
[2]*Trainee teacher at Karakalpak state university, Nukus, Uzbekistan*
[3]*Joint Belarusian-Uzbek Interdisciplinary institute of applied technical qualifications in Tashkent, Uzbekistan*
bexzodjumamuratov3@gmail.com, 3994505t@mail.ru, rahimova_ng93@mail.ru

Key words: Radom, SVCh, radio frequency (RCH) intensity, aviation engines, radio-transparent material, components, composite materials, equipment, seashell.

Abstract: In this article, after the repair of the front part of the aircraft (radom), how much transparency of the composite material was restored or lost in this part, how much change there was in the restored material, that is, it allows to determine the quality of the nose part will give. in this, a device is created by measuring how much transparency our radio apparatus has reduced in the range of 9-12 GHz, and with the help of these devices, it is the main tool in determining the quality of the nose part of the aircraft and determining the result after the test. When you go on a foreign trip by plane for travel and work, you will not notice the impact of the external environment on the outside of the plane.

1 INTRODUCTION

Air travel is one of the important factors in the development of the world economy. The opening of new routes and routes will increase the intensity of air travel. This, in turn, causes air traffic congestion and air traffic management becomes a complex process. Uzbekistan Airways Technics is a division of JSC that provides aviation engines, components, equipment, as well as aircraft maintenance and has a hundred years of work experience in the field of repair.

A common failure in aircraft is bird strikes on the outer parts of the aircraft, especially in farm areas where the plane crosses over grain storage areas, i.e. overhead areas, in general, bird strike damage (Kudrin, Selivanova, 2016; Tribovane, Caldeirinha, 2022).

Such damage causes various malfunctions in aircraft.

In particular, the part of the plane that often fails is the nose part, which is called radom. Due to the high speed of the aircraft, the shock caused by the impact of the birds causes serious damage to the obtekatel, in this case, the impact energy is proportional to the square of the relative speed. According to experts, if a plane collides with a "seagull" at a speed of 320 km per hour, then the impact force is about 3200 kg per square centimeter.

$$[F]_{tex} = 1kg \cong kg \times 9.8\, m/s^2 \cong 9.8N; \qquad (1)$$

$$[F]_{SI} = 1N;$$

$$[F]_{SGS} = 1dina = 10^{-1}N;$$

$$[F]_{tex} = 1kg \cong 3200 \times 9.8\, m/s^2 \cong 31360N;$$

However, in the nose, there are radars, which are the "eyes" of the aircraft. So this muzzle part is not just a normal shell, it has to be a shell with special radiolucency properties, so we can't just replace the obtecatel with any material we want.

It is certainly possible to restore it by specially certified factories and enterprises.

The convenient geographical location of the airline, adjacent to the territory of "Tashkent

[1] https://orcid.org/0009-0000-1283-3892
[2] https://orcid.org/0009-0009-0981-2922
[3] https://orcid.org/0009-0007-3087-2386

International Airport" named after Islam Karimov, allows to receive, store, maintain and repair any aircraft. There is a basic metrology service and a chemical-analytical analysis laboratory, the enterprise has a metrology service, which has the right to check about 450 types of special measuring instruments and more than 110 types of commonly used measuring instruments (Wilber, 2019; Bertuch, Pamies, 2010).

Figure 1: A radio receiver located in the nose of the aircraft.

In 2017, the Calibration Laboratory was established and got the right to calibrate measuring instruments in accordance with the requirements of ISO/MEK 17025-2009 "Uzstandart Agency, Technical Regulation". In this case, calibration according to the field of accreditation, with an indication of uncertainty, means that it is recognized by the European Aviation Safety Agency.

However, after the obtecatel is repaired, a problem arises, that is, how much of this transparency is restored, or lost. Determining the quality of Obtekatel remains a challenge. The resulting cracks are being repaired, but how much change will there be in this repaired material? To check this, it is necessary to check it in laboratory conditions, but such laboratories do not exist in Uzbekistan.

The purpose of my research paper is to make a device that measures how much transparency is reduced in radio equipment and metrological equipment in the range from 9GHz to 12GHz, and we need to measure its metrological property, and with this device, the quality of obtecatel is determined, which is a problem is considered very relevant (Zaichuk, Amelina, Kalishenko, Hordieiev, Rudnieva, 2022; Jumamuratov, Amangeldiev, Perdebaev, 2022).

In 2022, our statistical results show that the incidence of bird strikes during flight is shown in our first table below.

2 MATERIALS, METHODS AND OBJECT OF STUDY

The modern complex "UAT" carries out maintenance and repair of aircrafts and their components such as Boeing A320/B787/B767/B747, Airbus 300/310/318/319/320/321. We will try the first plane by putting a new nose part, we will put the second composite material and we will have to get about 91% 94% of the previous result (Zaichuk, Amelina, Kalishenko, Hordieiev, Rudnieva, 2022; Eshmuradov, Jumamuratov, Nabikhanova, 2024; Haruichi, Shoichiro, Takuya, Daisuke, Ramesh, Keiji, 2013).

So, three experts are made:

In the first one, we will test the newly created material.

Figure 2: Composite material testing process.

Secondly, we will check the new plane by leaving the nose part as well.

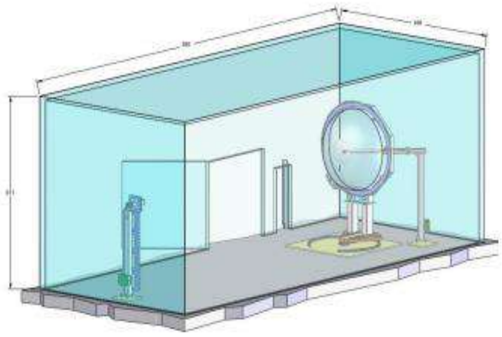


Figure 3: Test the nose section of the aircraft.

Thirdly, we will study the initial indicators of receiving radio signals.

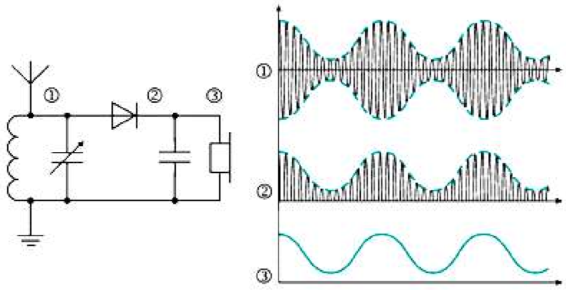


Figure 4: The scheme of the signal receiver and the shapes of the signals at different points.

3 STATEMENT OF THE PROBLEM

The difference between the maximum and minimum signal levels is the dynamic range is called

$$D = L_{max} - L_{min} \tag{2}$$

The dynamic range of the signal should be compared with the dynamic range Dk of the sound transmission channel:

$$Dk = 20lg\frac{U_{nom}}{U_n}(\Delta N_1/\Delta N_2); \tag{3}$$

in this, U_n - noise level in the channel, µV; U_{nom} - nominal voltage, V;

ΔN_1 - signal level suppressing noise and disturbances, dB (usually not less than 10 dB); ΔN_2 - overload value (3÷6) dB (Sarkisov, 2003; Sarkisov, 2011; Suzdal'cev, 2010).

When analyzing the frequency characteristics of the signal, the wide critical band of the reception setup and the widening of the spectrum of the primary signal as it changes rapidly form the following diagram:

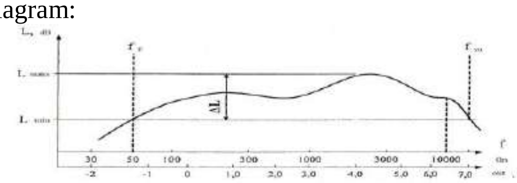


Figure 5 . Motion graph of frequency range and frequency description.

Here, L $_{max}$ and L $_{min}$ are the maximum and minimum levels of the secondary signal. Unevenness is usually measured on a logarithmic scale, in which

$$\Delta L = L_{max} - L_{min} \tag{4}$$

Disturbances are linear or amplitude-frequency, and are evaluated by the unevenness of the frequency description.

$$M = K_{max}/K_{min} \tag{5}$$

where, K_{max} and K_{min} are the maximum and minimum transmission coefficients in the given frequency range.

Frequency distortions usually occur on links that are prone to distortions. Norms of frequency disturbances are determined by experience. Low frequency distortions are more noticeable than high frequency distortions. Distortions are eliminated by frequency correction.

4 ANALYSIS RESULTS

Theory of zero-order resonant antenna based on right-handed/left-handed (CRLH) transmission line of composite materials:

A common CRLH TL consists of series capacitance (CL) and inductance (LR), as well as shunt capacitance (CR) and inductance (LL), as shown in Figure 6. It is created by cascaded N unit cells in a periodic configuration (Suzdal'cev, 2010; Geodakyan, 2006; Geodakyan, 2008;Geodakyan, 2008; Geodakyan, 2009; Suzdal'cev, 2008; Bobkova, 1994).

The lost CRLH is given by the throughput of the TL.

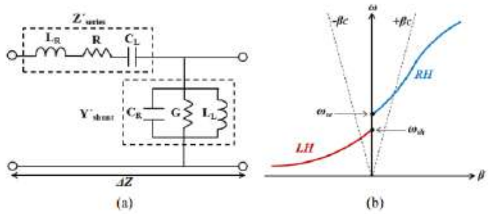


Figure 6: (a) Equivalent circuit of CRLH unit cell (b) Dispersion curve.

CRLH unit cell

$$Z_s = R + j\left(\omega L_R - \frac{1}{\omega C_L}\right); \tag{6}$$

$$Y_{sh} = G + j\left(\omega L_R - \frac{1}{\omega C_L}\right); \tag{7}$$

-where, R and G are the series resistance and shunt conductance of the lossy CRLH TL, respectively. given by series and shunt resonance frequencies.

$$\omega_s = 1/\sqrt{L_R C_L}\ rad/s; \tag{8}$$

$$\omega_s = 1/\sqrt{L_L C_R}\ rad/s\,; \tag{9}$$

Thus, the complex propagation constant (γ) and characteristic impedance (ZC) are calculated.

$$\gamma = \alpha + j\beta = \sqrt{Z_S' Y_{sh}'}; \tag{10}$$

$$Z_C = \sqrt{\frac{Z_S'}{Y_{sh}'}} = \sqrt{\frac{L_L}{C_L} \times \sqrt{\frac{(\omega/\omega_S)^2 - 1}{(\omega/\omega_{sh})^2 - 1}}}; \tag{11}$$

Since CRLH TLs have periodic boundary conditions, the Bloch-Floquet theorem can be applied, and its dispersion relation is determined by the following formula.

$$\beta(\omega) = \frac{S(\omega)}{\Delta Z}\sqrt{\omega^2 L_R C_R + \frac{1}{\omega^2 L_L C_L} - \frac{L_R C_L + L_L C_R}{L_L C_L}}; \tag{12}$$

-where $S(\omega)$ and ΔZ are the pointing function and the differential length, respectively.

This ω_s and ω_{sh} the function may not be equal in the dispersion diagram of CRLH TL based on unbalanced LC, as shown in Figure 6(b) below. $\beta = 0$ was this resonance in frequencies infinite wave length support can According to the open resonator theory with CRLH TL, its resonance occurs when.

$$\beta_n = {}^{n\pi}/_{l}\left(n = 0, \pm 1, \ldots, \pm(N-1)\right); \tag{13}$$

Here , n and N are l the physical length of the resonator, the mode number, and the number of unit cells, respectively, when n is zero, the wavelength is infinite, and the resonant frequency of the zero-order mode is independent of the size of the antenna, the most open resonator short references are presented (Russo, Colasante, Bellaveglia, Maggio, Marcellini, Scialino, Rolo, Angevain, Midthasse, 2012; Heimbs, 2011; Pulvirenti, Tromboni, Marchetti, Delogu, 2020; Kedar, Revankar, 2006).

As shown in Fig. 6(b), $\beta = 0$ the two resonance frequencies for the unbalanced CRLH TL, ω_s and ω_{sh} the corresponding load are observed. Considering an open-ended TL, here $ZL = \infty$, the apparent input impedance from one end of the resonator to the other (Z_{in}) is expressed as:

length is half the wavelength.

Thus, a more compact size antenna can be realized.

$$Z_{in}^{open} = -jZ_c \cot(\beta l) \approx^{\beta\to 0} - -jZ_c \frac{1}{\beta l} = -j\sqrt{\frac{Z_S'}{Y_{sh}'}}\left(\frac{1}{-j\sqrt{Z_S' Y_{sh}'}}\right)\frac{1}{l} = = \frac{1}{Y_{sh}' l} = \frac{1}{Z_S'(N\Delta z)}; \tag{14}$$

where Y'_{sh} - CRLH is the input of the unit cell.

times $1/Z'_{sh}$ the unit cell $1/N$, the equivalent values of L, C, G $L_L/N, NC_R$ and $1/NG$, respectively. Regardless of N, the resonant frequency of the N-cascaded open-ended ZOR circuit Z'_{sh} is determined by the resonant frequency originating from the shunt LC tank ( ). Thus, the resonant frequency of an open-ended ZOR antenna is given by Eq. (9), the result depends only on the shunt parameters of the unit cell. Considering that W_e the open-ended resonator depends only on the unit cell , the average electrical energy stored in the shunt capacitor, Z'_{sh} , is defined as (Tribovane, Caldeirinha, 2022; Conniott, Reis, Leonor, Caldeirinha, 2018; Dias, Godinho, Santos, Mendes, 2014; Godinho, Santos, Mendes, Pereira, Martins, 2016; Pavan, Chandra⇑, Abdul Ayaz, Nikhilesh Goud, 2022).

$$W_e = \frac{1}{4}|V^2| NC_R; \tag{15}$$

and the average magnetic energy stored in the shunt inductor, W_m

$$W_m = \frac{1}{4}|I_L|^2 \frac{L_L}{N} = \frac{1}{4}|V^2| \frac{N}{\omega^2 L_L}; \tag{16}$$

where is I_L the current flowing through the inductor, W_e and W_m since resonance occurs when equal to , the quality factor can be calculated as follows:

$$Q = \omega_{sh}\frac{2W_m}{P_{loss}} = \frac{1/NG}{\omega_{sh}(L_L/N)} = \frac{1/G}{\omega} = \tag{17}$$

$$= \omega_{sh}(1/NG) \cdot NC_R = \frac{1}{G}\sqrt{\frac{C_R}{L_L}};$$

5 SUMMARY

In this test process, we will have to comprehensively check the radio frequency reception process of our material used in conjunction with the test process of the composite material in the nose of the aircraft.

The above initial indicators show that our chosen material should be durable and also have high-quality and accurate transmission of radio signals.

ACKNOWLEDGEMENTS

In particular, the suitability and quality of composite materials for signals, their efficiency, as well as their development based on standards, will consist of testing and reviewing their certificates. At this point, I would like to express my gratitude to Tashkent State Technical University and the "Technical Regulation, Standardization and Certification" department to my supervisor Dilshod Elmuradovich, because he helped me in our research and gave me his time. for their generous help.

REFERENCES

Kudrin, O.I., Selivanova, Y.N., 2016. Proektirovanie radioprozrachnyh obtekatelej.

Tribovane, B., Caldeirinha, R.,2022. Radio Transparency Control of Road Electromagnetic Barriers for C-V2X Communications. 2022 16th European Conference on Antennas and Propagation (EuCAP).

Wilber, J., 2019.Low Cost, Automated, RTCA/DO-213 Compliant – Radome Test System P. 1-6

Bertuch, T., Pamies, M., 2010. System aspects of a low-cost coherent radar system with AESA antenna for maritime applications. 2010 INTERNATIONAL KHARKOV SYMPOSIUM ON PHYSICS AND ENGINEERING OF MICROWAVES, MILLIMETER AND SUBMILLIMETER WAVES. 21-26 June 2010. Kharkiv, Ukraine.

Zaichuk, A., Amelina, A., Kalishenko, Yu., Hordieiev, Yu., Rudnieva, L., 2022. Ultra-high frequency radio-transparent ceramics of celsian composition based on BaO – Al2 O3 – B2 O3 – sio2 glass: microstructure, physical and technical properties. Received 10 February 2022 Ukrainian State University of Chemical Technology Gagarina Avenue, 8, Dnipro, Ukraine, 49005 E-mail: zaychuk_av@ukr.net

Jumamuratov, B., Amangeldiev, N., Perdebaev, S., 2022. HAVO KEMALARINING RADIOPRIBORLARINI SERTIFIKATLASHTIRISHDA DIAGNOSTIKA MASALALARI. №A8. URL: https://cyberleninka.ru/article/n/havo-kemalarining-radiopriborlarini-sertifikatlashtirishda-diagnostika-masalalari (data obrashcheniya: 23.02.2024).

Zaichuk, A., Amelina, A., Kalishenko, Yu., Hordieiev, Yu., Rudnieva, L., 2022.Ultra-high frequency radio-transparent ceramics of celsian composition based on BaO – Al2 O3 – B2 O3 – sio2 glass: microstructure, physical and technical properties. Received 10 February 2022 Ukrainian State University of Chemical Technology Gagarina Avenue, 8, Dnipro, Ukraine, 49005 E-mail: zaychuk_av@ukr.net.

Eshmuradov, D. E., Jumamuratov, B.A., Nabikhanova, A. D., 2024. Kompozit materiallarning radioshaffofligini monitoring qilishning zamonaviy tizimlari va vositalari: holati va rivojlanish istiqbollari INTERNATIONAL SCIENTIFIC JOURNAL SCIENCE AND INNOVATION SPECIAL ISSUE: "MODERN PROBLEMS AND PROSPECTS OF DEVELOPMENT OF ENERGY SUPPLY OF DIGITAL TECHNOLOGY FACILITIES", MARCH.

Haruichi, K., Shoichiro, T., Takuya, H., Daisuke, K., Ramesh, K. P., Keiji, Y., 2013. Energy harvesting circuit on a one-sided directional flexible antenna, ,. Research output: Contribution to journal › Article › peer-review,. IEEE Microwave and Wireless Components Letters Published – 2013

Layers Sung Ho Lee, Sung Woo Kim, Cheol Woo Park, Hoon Eui Jeong, Jong G. Ok, Moon Kyu Kwak, 2017. Scalable Fabrication of Flexible Transparent Heaters Comprising Continuously Created Metallic Micromesh Patterns Incorporated with Biomimetic Anti-Reflection INTERNATIONAL JOURNAL OF PRECISION ENGINEERING AND MANUFACTURING-GREEN TECHNOLOGY Vol. 4, No. 2, pp. 177-181 APRIL 2017 / 177.

Sarkisov, P.D. 2003. Steklokristallicheskie materialy v strukture sovremennogo materialovedeniya/P.D. Sarkisov, N.YU. Mihajlenko, L.A. Orlova//Steklo i keramika. №9. – S.8-13.

Sarkisov, P.D., 2011. Sovremennoe sostoyanie voprosa v oblasti tekhnologii i proizvodstva sitallov na osnove alyumosilikatnyh sistem. Stekloobrazovanie, kristallizaciya i fazoobrazovanie pri poluchenii stroncij-anortitovyh i cel'zianovyh sitallov/P.D. Sarkisov, L.A. Orlova, N.V. Popovich, N.E. SHCHegoleva, YU.E. Lebedeva, D.V. Grashchenkov//Vse materialy. Enciklopedicheskij spravochnik. №8. p.17-24.

Suzdal'cev, E.I., 2010. Analiz sushchestvuyushchih radioprozrachnyh ogneupornyh materialov, kompozicij i tekhnologij dlya sozdaniya obtekatelej skorostnyh raket. CHast' I. Analiz urovnya pokazatelej svojstv i predel'nyh vozmozhnostej radioprozrachnyh ogneupornyh neorganicheskih materialov. Novye ogneupory. №6. p.45-49.

Suzdal'cev, E.I., 2010. Analiz sushchestvuyushchih radioprozrachnyh ogneupornyh materialov, kompozicij i tekhnologij dlya sozdaniya obtekatelej skorostnyh raket. CHast' II. Sravnitel'nyj analiz osnovnyh svojstv materialov, ispol'zuemyh dlya sozdaniya golovnyh obtekatelej raket. Novye ogneupory. №7. p. 38-44.

Geodakyan, D.A., 2006. Termostojkie keramicheskie kompozicii. I. Postanovka zadachi. Ogneupory i tekhnicheskaya keramika. №8. p.2-7.

Geodakyan, D.A., 2008. Termostojkie keramicheskie kompozicii. II. Komponenty sostavlyayushchie tugoplavkuyu osnovu. Ogneupory i tekhnicheskaya keramika. №5. p. 7-13.

Geodakyan, D.A., 2008. Termostojkie keramicheskie kompozicii. III. Dobavki snizhayushchie TKLR. Ogneupory i tekhnicheskaya keramika. №11. p. 22-26.

Geodakyan, D.A., 2009. Termostojkie keramicheskie kompozicii. IV. Korund-evkriptitovaya keramika. Ogneupory i tekhnicheskaya keramika. №10. p. 19-24.

Suzdal'cev, E.I., 2008. Sostoyanie rabot v oblasti sinteza radioprozrachnyh materialov i perspektivy sozdaniya novyh kompozicij s uluchshennymi radiotekhnicheskimi harakteristikami. Konstrukcii iz kompozicionnyh materialov. № 8. p.45-52.

Bobkova, N.M., 1994. Kompozicionnye materialy na osnove sitalliziruyushchegosya stekla i tekhnicheskih oksidov alyuminiya i titana. Steklo i keramika. №11-12. p. 3-5.

Rat. 2012/0058876 A1 US/Crystallized glass with negative coefficient of thermal expansion and method for manufacturing the same/Kim Taeheung, Yoon Duck Ki, Kang Taek Lee; Mar. 8.2012.

Pat. 6248678 B1 US/Low expansion glass-ceramics/Linda R. Pinekney ; Jun. 19.2000.

Pat. 6689704 B2 US/Glass material and glass ceramic product/Takashi Ota, Kazutoshi Tohyama, Masashi Fukuyama; Feb. 10.2004.

Pat. 5922271 US/Metod for the manufacture of dense-sintered glass ceramic moldings/Wolfgang Semar, Janusz Zborowski, Wolfgang Pannhorst, Waldemar Weinberg; Jul. 13.1999.

Tribovane, B., Caldeirinha, R., 2022. Radio Transparency Control of Road Electromagnetic Barriers for C-V2X Communications.

Conniott, W., Reis, J. R., Leonor, N., Caldeirinha, R. F. S., 2018. Shielding effectiveness of log barriers for radio exclusion zones. The Lough-borough Antennas Propagation Conference (LAPC 2018), pp. 1-5.

Dias, A., Godinho, L., Santos, P., Mendes, P., 2014. Low visual impact sound reduction wood barriers. Proceedings of WCTE 2014, 2014.

Godinho, L., Santos, P., Mendes, P., Pereira, A., Martins, M., 2016. Experimental and numerical analysis of sustainable sonic crystal barriers based on timber logs. Proceedings of EuroRegio 2016.

Pavan, M., Chandra⇑, M., Abdul Ayaz, P., Nikhilesh Goud, N., 2022. Sateesh Modelling and analysis of aircraft radome using different materials Volume 62, Part 6Pages 4492-4497

Military specifications radomes, General Specifications for, MIL-R-7705B.

Competition Composites Inc. (CCI) - Radome R&D White Paper, August 2013.

Russo, O., Colasante, A., Bellaveglia, G., Maggio, F., Marcellini, L., Scialino, L., Rolo, L., Angevain, J.C., Midthasse, R., 2012. State of the Art Materials for KU and KA Band Satellite Antenna Radome.Telecommunications Ground Segments Workshop, Esa/Estec.

Heimbs, S., 2011. Comput. Struct., 89, pp. 2093-2112

Pulvirenti, G., Tromboni, P. D., Marchetti, M., Delogu, A., 2020. Surveillance System Airborne Composite Radome Design. Dip. Ing. Aerospaziale Astronautica, Universita di Roma “La Sapienza”- Italy.

Kedar, A., Revankar, U.K., 2006. Parametric study of flat sandwich multilayer radome Progr. Electromagnet. Res., PIER, 66. pp. 253-265

Markov, L.N., Astistov, G.G., 1993. Antennye sistemy radioelektronnoj tekhniki Moskva. -366 s.

Perunov, YU.M., Macukevich, V.V., Vasil'ev, A.A., 2010. Zarubezhnye radioelektronnye sredstva. Kniga 3: Antenny Radiotekhnika, 304 c.

Rusin, M.YU., Vasilenko, V. V., Romashin, V. G., Stepanov, P. A., Atroshchenko, I. g., Shutkina, O. V., 2013. GNC RF OAO «ONPP», «Tekhnologiya», g. Obninsk Kaluzhskoj obl., Rossiya kompozicionnye materialy dlya radioprozrachnyh obtekatelej letatel'nyh apparatov.

Shalgunov, S.I., Trofimov, A.N, Sokolov, V.I., Morozova, I.V., Prohorova, YU.S., 2014. Osobennosti proektirovaniya i razrabotki radioprozrachnyh obtekatelej i ukrytij, rabotayushchih v santimetrovom i millimetrovom diapazonah radiovoln oao «npo stekloplastik», Moskovskaya oblast', p. Andreevka stat'ya v zhurnale - nauchnaya stat'ya №3 st-6.

Gurtovnik, I. G., 2003. Radioprozrachnye izdeliya iz ste kloplastikov / I. G. Gurtovnik, V. I. Sokolov, N. N. Trofimov [i dr.] ; pod red. V. I. Sokolova. 368 s.

Research of the Process of Preparation of High Protein Soy Feed for Farm Animals and Poultry

Georgy Georgiyevich Klasner[1], Vladislav Frantisekovich Kremyansky[2], Dmitry Olegovich Marchuk[3], Evgeniy Petrovich Buga[4]
Kuban State Agrarian University, 13 Kalinina, Krasnodar, 350044, Russia
egor.klasner.91@mail.ru

Keywords: Soy Milk; High-Protein Feed.

Abstract: Based on the results of previously conducted research, a pilot sample of the device under development was assembled operating in accordance with the proposed waste-free, resource-saving technology, which makes it possible to obtain highly productive feed for farm animals and poultry of all forms of farming as the final product. A promising direction for the further development of a soaked grain grinder for the preparation of soy milk is the development of a continuous process for preparing high-protein feed by combining the entire list of necessary technological operations into one, as well as reducing the time of grain swelling when modernizing existing feed preparation equipment

1 INTRODUCTION

Based on the analysis of technological schemes and mass-produced machines for the preparation of liquid high-protein feeds with the processing of soy protein, we can say that all of them are intended for use in large livestock facilities and feed mills, since they have high productivity, and, therefore, high energy and metal-intensive costs, the use of large-tonnage tanks to ensure the entire production cycle. All this is not acceptable when running small agricultural production.

Works devoted to the study of the grain grinding process and written by scientists V.G. Koboi, S.M. Dotsenko, A.A. Aliev, Yu.B. Kurkov, V.V. Samuylo, V.Yu. Frolov, A.P. Dmitrichenko, B.P. Shukov, T.A. Krasnoshchevskova, V.V. Petrova, V.S. Linnik et al., made it possible to outline analytical aspects in substantiating the technological process of grinding soybean grain.

2 RESEARCH METHODOLOGY

Theoretically describe the trajectory of movement of an individual soaked soybean grain during the production process of preparing liquid, high-protein feed using grinding abrasive discs.

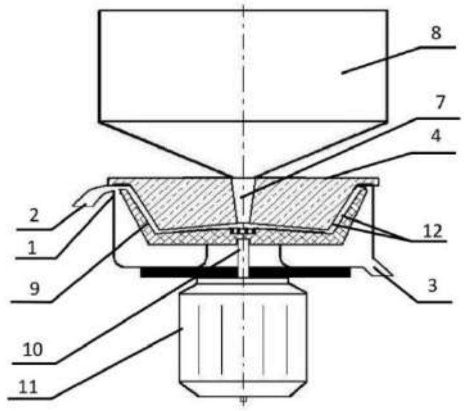


Figure 1: Chopper of soaked soybeans: 1 – body, 2 – outlet tube for okara, 3 – outlet tube, 4 – fixed abrasive disk, 5 – scraper, 6 – separator, 7 – supply tube, 8 – hopper, 9 – rotating abrasive disk,

[1] https://orcid.org/0000-0002-9549-8109
[2] https://orcid.org/0000-0001-6273-6660
[3] https://orcid.org/0000-0001-6713-6660
[4] https://orcid.org/0000-0002-9684-9454

10 – shaft, 11 – motor, 12 – through channels for removing the liquid fraction, 13 – curved marks, 14 – curved radial cavities.

Figure 2: Replaceable rotating abrasive disks.

Figure 3: Fixed abrasive disk.

Figure 4: Experimental setup.

Installation for obtaining a protein suspension (application for intellectualproperty of the Russian Federation No. 2022125758), contains a building1 with 2 outlet tubesfinished components. The inner part of the housing contains a grinding device, which consists of a separator 3 in the form of a cone, which provides the required fractional filtration, a rotating abrasive disk 4 located on the shaft 5 of the engine 6. The device has a scraper 7 for the separator 3 and a hopper 8.the vibration device is installed inside the hopper 8 on the shaft 5 of the engine 6 andIt hasrod 9 with radially directed pins 10 with a transverse rectangular section and perpendicular to the axis of rotation of the rod. The grinding device has an upper stone circle 11 with a pressing spring 12 and a lower stone circle 13, installed one above the other, with a small gap. The movable abrasive disk 4 is located on the surface of the lower millstone 13 and a removable steel plate 14 with a diameter less than the diameter of the movable abrasive disk is installed on it. The removable steel plate 14 has perforations in the form of relief notches 15 with cutting edges arranged in an Archimedes spiral. The directed movement of the okara and the solid fraction is ensured by a scraper 7 located on top of the separator 3.

The process of crushing and soaking soybeans in a crusher is as follows. The grains fall into the hopper under the influence of gravity, then through the feed tube they are fed to a horizontal disk with a rigidly fixed upper part. Simultaneously with the supply of beans, water is poured into the hopper. The lower disk, rotating, crushes the grains, and the water washes away the particles. At the same time, the suspension is divided into fractions. Over time, the particles stick together, combine into larger ones, harden and are fed into the preparation of milk replacer.

. The grain moves along a curved path from the center to the edge of the disk with radius R. The movement will be accompanied by an increase in speed

$$\vartheta_i = \omega\rho_i \,, \tag{1}$$

where ω is the angular speed of disk rotation;

ρ is a variable radius vector for a moving grain (and).$r < \rho < R$

The force tending to move the grain to the edge of the disk is determined by the formula

$$C = m\omega^2\rho. \tag{2}$$

Due to the complex movement of the grain relative to the fixed disk, its trajectory will be a multi-turn spiral.

A small gap causes a significant increase in vertical load, exceeding the mass of the grain; it is compressed.

The occurrence of a reaction in the lower and upper disks is due to compression resistance. It determines the magnitude of the friction forces between the discs and the grain. If two disks are made of the same material and move under the same conditions, they will be equal to each other. In this case, the speed of the soaked grain will have a combination of two speeds - a low relative speed of movement along the lower movable abrasive disk and a high absolute speed of movement relative to the statically fixed upper abrasive disk, and the friction force formed at different points as a result of the interaction of the grain with the abrasive surface of the disks will be directed opposite to speeds.

Let us consider the movement of grain and its particles along a movable (horizontal) disk that does not have serrations.

The particle is located on a disk rotating at a constant angular velocity near the vertical axis O (Fig. 5). It is necessary to find its speed and trajectory. It is affected by gravity and the reaction force of the upper disk.

Let us assume that a particle of a substance with mass m (a grain, its parts) reaches a horizontal plane rotating at a constant angular velocity at an infinitesimal speed.

If the rotation speed of the disk is insignificant (and the grindstone rotates at a low speed), then the particles will begin to rotate with the disk after a short time. There will be no relative motion of particles.

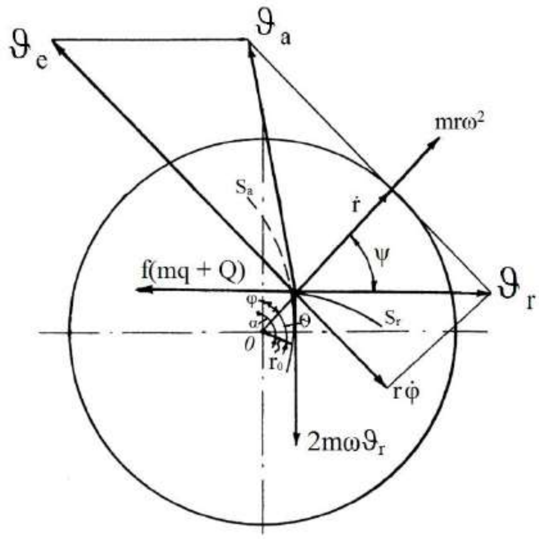


Figure 5: To derive the equation of grain motion.

Exceeding a certain speed limit will cause a change in the trajectories of Sa and Sr in the complex motion of the particle.

The absolute speed of a particle is the geometric sum of the variable speed and the relative speed, that is$\vartheta_a\vartheta_e\vartheta_r$

$$\vartheta_a = \vartheta_e + \vartheta_r\,. \qquad (3)$$

Denoting the angular displacement of a particle in absolute motion by θ, we can determine the absolute velocity from the equation for polar coordinates, written using independent coordinates r and θϑ_a

$$\vartheta_a^2 = r^2 + r^2\cdot\theta^2. \qquad (4)$$

Taking this into account for the particle m we can write the equation of the main forces, we will have:

$$T = \frac{m\vartheta_a^2}{2} = \frac{m(r^2+r^2\cdot\theta^2)}{2}. \qquad (5)$$

Based on previous studies, we will determine the applied forces in the plane of the disk. The action of two forces is directed normal to the plane of the disk: the force and pressure force of the static abrasive disk Q, transmitted to the lower abrasive disk.$J_1 = mq$

The friction force is applied in the plane of the disk and is formed by these forces J1 and Q.$F_{mp} = f\,(mq + Q)$

To determine the generalized force, we write down the expression of the basic function applied in the possible directions of movement:

$$\left.\begin{aligned} Q_r\delta r &= [-f\,(mq + Q)cos\psi]\delta r \\ Q_r\delta\theta &= P_r\delta\theta = f(mq + Q)sin\psi\cdot r\delta\theta \end{aligned}\right\}. \qquad (6)$$

After a series of transformations, we obtain a differential equation for elementary work:

$$\frac{d}{dt}(r^2 - \omega^2 r^2) + \frac{d}{dt}r^2\varphi^2 = -2f\left(q + \frac{Q}{m}\right)\vartheta_r\,. \qquad (7)$$

We integrate expression (7) taking into account the fact that$\vartheta_r dt = dS_r$

$$\vartheta_r^2 = r^2\omega^2 - 2f\left(q + \frac{Q}{m}\right)S_r + C_1\,. \qquad (8)$$

where C1 is the integration constant.

Particles are fed onto the disk vertically, so the initial conditions of motion will be at ; ; .$r = r_0 S_r = 0 \vartheta_r = r\omega$

Therefore, we write equation (8) as follows$C_1 = 0$

$$\vartheta_r^2 = \sqrt{r^2\omega^2 - 2f\left(q + \frac{Q}{m}\right)S_r}\,. \qquad (9)$$

Expression (9) allows us to conclude that the value of the relative speed is determined by the functional dependence on the parameters r and Sr, which depend on each other.

The Archimedean spiral and the involute of a circle are possible trajectories of particle motion relative to the disk, corresponding to the physical content of the problem.

$$r = r_0 e^{a\varphi}\,. \qquad (10)$$

This equation is the equation of a logarithmic spiral.

The section of the curvilinear arc is equal to

$$dS_r = r_0 e^{a\varphi}\sqrt{1 + a^2}\,d\varphi.$$

The arc length after integration will be equal to

$$S_r = \frac{r}{a}\sqrt{1 + a^2} + C_2\,, \qquad \text{(eleven)}$$

where C2 is the integration constant.

After a series of transformations, equation (9) will take the form

$$\vartheta_r = \sqrt{r^2\omega^2 - 2f\left(q + \frac{Q}{m}\right)\frac{\sqrt{1 + a^2}}{a}(r - r_0)}$$

or when $C_2 = 0$

$$\vartheta_r = \frac{dS_r}{dt} = \sqrt{l + 2mS_r + mS_r^2}\,, \qquad (12)$$

где $l = 2f\left(q + \frac{Q}{m}\right)\frac{\sqrt{1 + a^2}}{a} r_0$; $m = -f\left(q + \frac{Q}{n}\right)$; $n = \frac{a^2\omega^2}{1 + a^2}$.

From (12) we have

$$dt = \frac{dS_r}{\sqrt{n} \cdot \sqrt{\frac{l}{n} + \frac{2mS_r}{n} + S_r^2}} = \frac{dS_r}{\sqrt{n} \cdot \sqrt{\frac{l}{n} - \frac{m^2}{n^2} + \frac{m^2}{n^2}}} \qquad (13)$$

Let us denote some quantities

$$\frac{m^2}{n^2} + \frac{2mS_r}{n} + S_r^2 = \left(\frac{m}{n} + S_r\right)^2, \qquad (14)$$

$$\frac{l}{n} - \frac{m^2}{n^2} = a. \qquad (15)$$

Taking this into account, we write equation (13)

$$dt = \frac{dS_r}{\sqrt{n} \cdot \sqrt{a + \left(\frac{m}{n} + S_r\right)^2}}\,. \qquad (16)$$

Having introduced the notation, we integrate expression (16)

$$y = \frac{m}{n} + S_r\,, \qquad (17)$$

$$dy = dS_r\,. \qquad (18)$$

Taking into account formulas (17) and (18), we write equation (16)

$$dt = \frac{dy}{\sqrt{n} \cdot \sqrt{a + y^2}}\,. \qquad (19)$$

After integration (19) we obtain

$$t = \int dt = \frac{1}{\sqrt{n}} \int \frac{dy}{\sqrt{a + y^2}}\,. \qquad (20)$$

The integral of the curvilinear part (20) is equal to

$$\int \frac{dy}{\sqrt{a + y^2}} = ln(y + \sqrt{y^2 + a})\,. \qquad (21)$$

Integral (20) taking into account (21), (18), (15)

$$t = \frac{1}{\sqrt{n}} \cdot ln\left[\frac{m}{n} + S_r + \sqrt{\left(\frac{m}{n} + S_r\right)^2 + \left(\frac{l}{n} - \frac{m^2}{n^2}\right)}\right]. \qquad (22)$$

Formula (22) after transformations will have the form

$$t = \frac{1}{\sqrt{n}} \cdot ln\frac{m + nS_r + \sqrt{n} \cdot \sqrt{l + 2mS_r + nS_r^2}}{n}\,. \qquad (23)$$

Having analyzed formula (23), we can conclude that it connects time and arc length.

In order to connect between time t and the distance of the particle to the center of the disk, we substitute the expression of the arc Sr (11) into (23)

$$t = \frac{1}{\sqrt{n}} \cdot ln\frac{m + n\frac{r}{a}\sqrt{1 + a^2} + \sqrt{n} \cdot \sqrt{l + 2m\frac{n}{a}\sqrt{1}}}{n} \qquad (24)$$

It should be noted that when using equations (11), (12), (22) and (23), you must first specify the value of the coefficient. $a = 1/tg\psi$

3 CONCLUSIONS

1. The last equation establishes the relationship between time and the length of the arc from the center to the periphery, described by the soaked soybean grain along the abrasive surface of the lower, moving disk. The difference in movement speeds and forces increases as the grain moves away from the center of force to the periphery of the disk, since this increases the circumferential, and, consequently, the relative speed. This increase in speeds and forces causes complex deformations in the shells (compression, shearing, shearing), the consequence of which is the destruction of the shells (and the destruction of the grain itself and its particles) and the release of the nuclei contained in them.

2. Acknowledgments The study was carried out with the financial support of the Grant Council of the President of the Russian Federation - agreement No. 075-15-2022-589.

REFERENCES

Kotelevskaya, E. A., Klasner, G. G., Tolstov, K. S., 2020. Determination of safe conditions for moving ears to the working surface of the plant for sorting ears of seed corn. IOP Conference Series: Earth and Environmental Science : conference proceedings, Krasnoyarsk, Russia, Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations. Vol. 421. – Krasnoyarsk, Russia: Institute of Physics and IOP Publishing Limited, 2020. P. 22014.

Klasner, G. G. Tarasov, V. S., Baranov, V. P., 2019. The study of the moment of resistance of the grinder of legumes. IOP Conference Series: Earth and Environmental Science : conference proceedings, Krasnoyarsk, Russia, Krasnoyarsk Science and

Technology City Hall of the Russian Union of Scientific and Engineering Associations. Vol. 421. – Krasnoyarsk, Russia: Institute of Physics and IOP Publishing Limited, 2020. P. 22013.

Prospects for the Introduction of Unmanned Aerial Vehicles for Fire Fighting in Russia: Innovations and New Opportunities

Dmitry Totskiy[1] [1], Irina Bogdanova[1] [2], and Inna Loskutnikova[1] [3], and Anton Davidenko[2] [4]
[1]*Don State Technical University, Gagarin sq., 1, Rostov on Don, 344003, Russia*
[2] *St. Petersburg University of State Fire Service of the Ministry of Emergency Situations of Russia, Moskovsky Prospect, 149, St. Petersburg, 196105, Russia*
1971-fireman@mail.ru

Keywords: UAS, firefighting, drones.

Abstract: This paper examines the improvement of the functions of a fire safety system through the integration of unmanned aircraft systems (UAS). An analysis of the model range of modern UAS of domestic and foreign production for the needs of firefighting and rescue operations was carried out. Ways and methods of using these technologies in organizing fire extinguishing, including its subsequent expert study, are proposed.

1 INTRODUCTION

By their nature, fires are one of the most serious threats to human life and property. Conventional methods of firefighting and rescue operations can often face limitations in availability and safety, which affects the effectiveness of the work carried out. This can be especially true when working on high-rise buildings and other similar places. In the light of technological progress, unmanned aerial vehicles appear before us as an innovative solution that can expand the range of capabilities of fire services and increase the efficiency of firefighting.

The main purpose of this article is to consider the possibilities of introducing UAVs in Russia to fight fires and carry out various rescue operations. The concept of a new model range of UAVs designed to extinguish fires, their capabilities and functionality will be considered.

You need to know that in Russia, instead of the term unmanned aerial vehicles, the term unmanned aerial vehicles (UAS) is used. The very concept of UAS can be used for various classifications of aircraft, including drones for extinguishing fires. The BAS designation is used in accordance with many legal acts and regulatory documents in Russia.

The possibility of introducing such UAS will take firefighting capabilities to a new level, by ensuring the safety of both firefighters and victims.

The prospect for the development of UAS for firefighting already offers a wide range of possibilities, including work on the delivery of the necessary equipment, monitoring the situation in real time, photo and video recording. But it is worth noting that in order to ensure sustainable development of this area, it is necessary to conduct new research, develop direct cooperation between manufacturers and fire services, and improve the design of drones.

Reviewing and conducting research on the role of UAS in fire safety is an important contribution to the development of the emergency management industry.

2 REVIEW OF MODERN UAS

At the end of 2023, the opening of a research and production center for the creation of UAS was announced. The center's main priority will be the development of unmanned systems for various

[1] https://orcid.org/0000-0002-4989-5592
[2] https://orcid.org/0000-0002-7726-7374
[3] https://orcid.org/0009-0009-8730-3832
[4] https://orcid.org/0000-0003-0700-1324

purposes, including fire extinguishing and fire reconnaissance. The concept of a number of drones designed for these purposes is already known. A total of six models were presented: “Perun”, “Cyclone”, “Rain”, “Storm”, “Thunderstorm”, “Drop”.

The “Kaplya” model will be a light reconnaissance drone with a take-off weight of 7.2 kilograms. It is assumed that up to four different modules can be connected.

Other drone models are proposed to be used for direct participation in firefighting. The main direction of their activity will be aimed at extinguishing fires in high-rise buildings. They will have a take-off weight from 36 to 180 kilograms. For example, the Cyclone is planned to be equipped with a connected hose for supplying fire extinguishing agents to a height and an emergency hammer for breaking windows.

The “Groza” model will carry a fire extinguishing bomb with a volume of 25 liters, and the “Storm” will already be equipped with two such bombs and have a mass of 105 kg. "Liven" will carry four fire extinguishing bombs at once, having a take-off weight of 36 kg. “Perun” is proposed to be equipped with a 20-liter powder fire extinguisher and will also have an emergency hammer for breaking windows.

All presented models are supposed to be built on the basis of a helicopter-type UAS with four or six main rotors.

For a deeper understanding, let’s look at ways to extinguish fires using UAS:

a. Spraying fire extinguishing agents: UAS may be equipped with special devices for spraying fire extinguishing agents, such as water and/or foam solutions. They can precisely deliver fire extinguishing agents to fires.

b. Carrying extinguishing agents: UAS can also be used to deliver extinguishing agents to the scene of a fire, especially in hard-to-reach or hazardous areas. For example, they can travel with fire extinguishers or special containers containing fire extinguishing agents, and then dump them directly into the burning zone.

c. Fire detection: UAS can be equipped with fire detection systems such as thermal imagers, infrared cameras, including black-and-white static images and electromagnetic radiation. They can scan large areas and quickly locate fires, even in situations where it might be difficult for humans to do so.

d. Coordination and Communication: UAS can be used to coordinate fire services. They can transmit real-time information, such as images and videos of a fire, to aid in rapid decision-making and effective coordination of firefighting efforts.

As we have found out, these UAS will have unique capabilities that will allow them to effectively fight fires in various hard-to-reach places, especially in high-rise buildings. They will provide the ability to deliver fire extinguishing agents to places where their supply was previously difficult or completely impossible.

In addition to the above, which have just begun their production, some UAS are already in service in Russia. They are mainly divided into aircraft, helicopter and combined UAS. The most common and accessible helicopter-type devices, such as DJI Phantom 3. It gained popularity due to the high-resolution camera, which was initially installed out of the box in the UAV gimbal. Thanks to it, UAVs can be used for exploration and reconnaissance of terrain

Also, for a deeper understanding of the types of UAVs, it is worth delving into their classification. It is usually customary to classify them according to four parameters: mass, time, altitude and flight range.

Table 1: Classification of UAS.

	Weight, kg	Flight time, h	Flight altitude, km	Flight range, km
Ultralight	To 10	1	1	100
Lungs	Up to 50	2-3	3-5	100-350
Average	Up to 1000	10-12	8-10	350-1200
Heavy		24+	20	1200+

For the full use of UAS, it is necessary to carry out its certification. In Russia, UAS certification is carried out in accordance with laws and regulations that establish requirements for the safety and quality of aircraft. In total, to comply with all standards it is necessary to obtain three types of certifications:

a. Certification of compliance with technical standards in the field of safety and quality of aircraft. This certification is carried out in accordance with the requirements of the Federal Air Transport Agency Rosaviation and other competent authorities to ensure that the UAS meets the minimum safety and quality requirements.

b. UAS type certification is based on test results, evaluation of the design and manufacturing process of the UAS itself. The purpose of this certification is to confirm that a specific model meets established safety and quality requirements. After successful completion of certification, a certificate is issued that contains information about the certified BAS model.

c. UAS operator certification is conducted to evaluate the qualifications and knowledge of the operator who will operate the UAS during firefighting and various rescue operations. The operator must undergo training and education, as well as pass examinations and practical tests. After successfully completing all stages of training, the operator receives the appropriate certificate.

The review shows significant potential for the use of firefighting UAS to improve the efficiency and safety of firefighting and rescue operations. Further developments in technology will improve the functionality and navigation of these UAS, leading to more effective deployment in a variety of firefighting scenarios.

3 STATISTICS ON THE USE OF UAS IN RUSSIA

Currently in Russia, drones are not used to directly extinguish fires. However, a lot of research is being carried out aimed at designing UAVs of this type. The issue of operational use of UAS in all fires with the establishment of local airspace restrictions also remains problematic.

Statistics show that in 2020, unmanned aircraft of the Russian Ministry of Emergency Situations carried out more than 7.7 thousand flights. During 2,100 flight hours, almost 12 thousand square kilometers of territory were inspected, more than 90 fires were identified over an area of over 2 thousand square kilometers, and 270 objects were inspected.

Unmanned aerial vehicles were used to conduct search operations and rescue people lost in forests and hard-to-reach areas. 37 people were found and rescued, including 16 people in the Volga River delta.

A conclusion about the relevance and effectiveness of the use of UAS in fires and emergencies can also be made based on the statistics of their use given below. For example, in the Main Directorate of the Russian Ministry of Emergency Situations of the Nizhny Novgorod Region, in 2023, unmanned aircraft specialists carried out 558 flights (Picture 1). This unit is armed with 6 helicopter-type unmanned aerial systems.

As we can see, a large proportion of flights are for training sorties. This is due to the training of qualified specialists, as well as maintaining constant readiness to respond. Specifically in the selected unit, training flights are organized weekly.

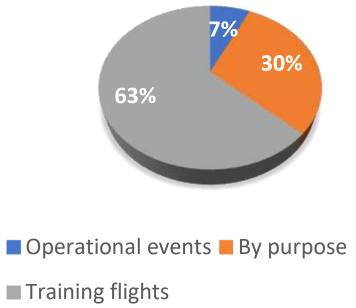


Figure 1: Flight statistics of the Main Directorate of the Ministry of Emergency Situations of the Nizhny Novgorod Region.

Below we consider statistics on the use of UAS, directly related to operational events and missions for the purpose of the UAS. Operational events refer to sorties to conduct reconnaissance while extinguishing various fires and conducting search operations. Search and rescue operations account for 15 sorties per year. Firefighting sorties – 25 per year (Picture 2).

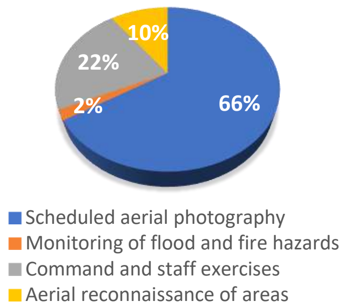


Figure 2: Detailed statistics of UAS flights by their intended purpose.

Thanks to flights from these categories, there are enormous opportunities for carrying out various preventive measures aimed at reducing the consequences of floods, floods, and so on. In this way, it is possible to limit budget expenditures on preventive measures, as well as avoid material damage to the population.

In order to make sure that drones really have many advantages, let's try to look at a specific application scenario and highlight them. Based on application experience, many disadvantages and advantages have been identified in the use of BAS. Let's consider the problem of aerial photography using drones to identify them.

Table 2: Advantages and disadvantages of aerial photography using UAS.

Advantages	Flaws
High resolution pictures	Limited shooting area
Survey results instantly or within the shortest possible time after landing	Difficulty in obtaining the necessary permits for flights
Ability to track one object and hover over it	Expensive
Spot photography in hard-to-reach places	Light payload weight
Possibility of installing additional monitoring equipment on the drone	The number of flights directly depends on the operator

At the moment, the unmanned aviation system of the Russian Ministry of Emergency Situations includes about 400 UAS units. It is being actively improved in order to update the fleet and equip units with modern multifunctional UAS. It is planned to introduce new units of unmanned aircraft, which will be equipped with mobile control points - all-terrain vehicles capable of providing mobility and autonomy.

Based on experience and achievements in the field of firefighting aviation and the use of UAS, the Russian Ministry of Emergency Situations continues to develop and improve a system for training professionals to work with unmanned aircraft systems. It includes retraining of specialists, retraining for modern UAS and advanced training of employees.

Drones are equipped with thermal imaging cameras and other sensors that can detect and transmit information about hot spots, smoke and heat sources. This allows you to quickly respond to a developing situation and direct fire brigades to where they can effectively take extinguishing measures.

Another important aspect of the use of drones is their ability to quickly and safely inspect emergency situations, including hard-to-reach and dangerous areas. Drones can monitor the edges of a fire, assess environmental characteristics, and help determine the best firefighting strategy.

The Russian government and the Russian Ministry of Emergency Situations are actively interested in the possibilities of using firefighting drones and are allocating financial and scientific resources for the further development of this area. Research is underway to determine the optimal design and functionality of firefighting drones, as well as the development of algorithms and software for automatic fire detection and classification.

The prospects for the use of firefighting drones in Russia are very encouraging. It is expected that in the coming years, not only research will be carried out, but also demonstration tests of firefighting drones for direct firefighting. This will strengthen the capabilities of fire services and ensure more effective firefighting, saving lives and reducing property losses.

The statistics provided support successful examples of the use of UAS in real-life situations. These data highlight the importance of using UAS for fire suppression, especially in high-rise buildings, and confirm their important role in ensuring the safety and effectiveness of fire extinguishing.

Statistical data is an important tool for assessing the effectiveness of the use of firefighting UAS and determining further prospects for the development of their use in Russia. They serve as the basis for decision-making and further improvement of technologies and methods for using firefighting UAS.

4 DEVELOPMENT PROSPECTS AND FURTHER APPLICATION

Considering the prospects for the development of firefighting unmanned aerial vehicles in Russia, we will consider areas of innovation and improvement, as well as the further use of these technologies.

Technical improvements and new functionality are key aspects of the development of firefighting UAS. Further progress in the field of neural networks, artificial intelligence and autonomous navigation will allow the development of aircraft software that will ensure the effective use of drones. This may include the development of algorithms for automatic detection and classification of fires, improving the accuracy of navigation and identifying potentially hazardous materials.

In addition to firefighting, UAS can be used in other areas. For example, they can be used to transport necessary equipment and materials to the scene of an incident. There are already similar examples, but these are more like experiments.

Collaboration between UAS manufacturers and fire services plays an important role in the development of this field. Fire departments should actively participate in the development of requirements and safety standards for the use of UAS in combat emergency situations. These agencies can also provide valuable statistical data to improve the functionality and adapt the UAS to real-life situations.

Future applications of UAS could potentially be expanded to other areas, such as automated fire monitoring and control, and disaster response. It is important to continue research and development in this area to maximize the potential of UAS and significantly improve the efficiency and safety of firefighting and rescue operations.

5 CONCLUSION

Progress in firefighting UAS development promises new capabilities, including the use of autonomous navigation systems, artificial intelligence and other innovative technologies. Further improving the functionality, reliability and accuracy of their actions based on the collected data will improve the effectiveness of fire suppression and maximize the protection of lives and property.

Key factors in the development of firefighting systems are further research and cooperation between manufacturers, fire services and scientific institutes. It is also important to ensure that the UAS is certified and meets all necessary safety regulations to ensure that the UAS is reliable and effective in real-world use.

The use of UAS in the field of fire safety in Russia represents a significant step in the field of fire safety. Further development of this technology and maximum use of its potential will allow us to more quickly protect lives and property, as well as improve the effectiveness of firefighting and rescue operations. In-depth research and close collaboration with practitioners and the scientific community will contribute to the development and application of firefighting UAS to ensure safety in fires and emergencies.

REFERENCES

Restas , Examining the effectiveness of aerial firefighting with the components of firebreak requirements and footprint geometry—Critics of the present practice. (2023)

Zheng, Y. J, Chen, S.Y., Ling, H.F., 2015. Evolutionary optimization for disaster relief operations: A survey.

Martemyanov, S.I., Matorina, O.S., Streltsov, O.V., Nesterova, S.V., 2024. Use of unmanned aerial vehicles to support firefighting management in emergency situations.

Boyko, A, 2020.. Firefighters and drones.

Kartenichev, A.Yu., Panfilova, E.V., 2019. Technologies of extinguishing fires using unmanned aerial vehicles. Fire safety: problems and prospects.

Andreev, M.A., Miller, A.B., Miller, B.M., Stepanyan, K.V., 2012. PATH PLANNING FOR UNMANNED AERIAL VEHICLE UNDER COMPLICATED CONDITIONS AND HAZARDS *Journal of Computer and Systems Sciences International.* T. 51. № 2. C. 328-338.

Martemyanov, S. I., Matorina, O. S., Streltsov, O. V., Nesterova, S. V., 2024. Use of unmanned aerial vehicles to support firefighting management in emergency situations. *International Research Journal,* 1(139).

Lobaty, A.A., Bumai, A.Y., Jun, D., 2019. FORMATION OF OPTIMAL PARAMETRS OF THE TRAJECTORY OF THE OVERFLIGHT OF UNMANNED AERIAL VEHICLE THROUGH THE SPECIFIED POINTS OF SPACE. Doklady BGUIR. (7-8):50-57.

Hetman M.A., Aralbaev T.Z., 2020. ORBITAL GRAPH MODELS OF FLIGHT ROUTES OF UNMANNED AERIAL VEHICLES. *Bulletin of the Ufa State Aviation Technical University,* 24 (4 (90)), 94-100.

Kazanskaya, L.F., Savitskaya,N.V., Kamzol, P.P., 2018. Prospects for the development of unmanned transport in Russia. *Bulletin of Scientific Research Results,* No. 2, pp. 18-28.

An Algorithm for Determining the Complexity of an Elective for Individual Educational Path

Reshetnikova Ekaterina Andreevna[a] and Perevalova Maria Nikolaevna[b]
University of Tyumen, 6 Volodarskogo Street, Tyumen, Russia
stud0000214391@study.utmn.ru, m.n.perevalova@utmn.ru

Keywords: Educational path, keywords extraction, clustering, complexity, elective.

Abstract: Individualization of the educational process is an actual task of the education system. During the study at the university, every semester a student chooses electives - additional subjects for studying, which make the student's path individual. Sometimes students choose electives unconsciously, poorly acquainted with the description or randomly. However, the student wants to have the subjects that he needs to study to match his level of knowledge, so that learning does not make it difficult. To solve this problem, it is necessary to determine the complexity of the discipline relative to each other and recommend electives to the student in view of the values found.

1 INTRODUCTION

At University of Tyumen an educational model 2+2+2 is being implemented. One of the tasks of which is to provide conditions for the individualization of the educational process. This allows you to make learning more effective and accessible for each student. Figure 1 shows the educational model University of Tyumen.

During the period of study at the university, each student creates his own educational path, which consists of basic disciplines and electives. The basic disciplines are provided by the educational programs of the student's direction of study, and he can choose the electives himself.

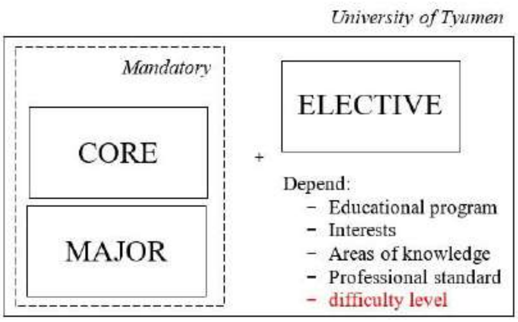


Figure 1: Educational model University of Tyumen.

Each semester, the student must choose two electives for further study. Currently, there are more than 600 electives in the database. Many students face the problem of selecting electives (Vorob'eva, 2021).

Therefore, the idea arises to help the student with the selection of disciplines for additional study based on the student's learning goal and his level of knowledge.

The aim of this study is to develop an approach of algorithm for determining the complexity of disciplines to recommend electives to students.

2 PROPOSED APPROACH

After analyzing various studies, several approaches to determine complexity were identified. Article (Martynova, 2020) presents the results of an analysis of the influence of abstractness, frequency and lexical diversity on the complexity of texts in educational materials. The study revealed a direct relationship between the Flesch-Kincaid readability index and the complexity of texts, while frequency, degree of abstraction and lexical diversity do not correlate with this indicator.

The scientific work (Morozov, 2019) analyses the factors influencing the definition of a word as

[a] https://orcid.org/0009-0001-4348-0951
[b] https://orcid.org/0000-0003-2971-3656

complex. To calculate the semantic complexity of words, a survey of native speakers was conducted, the results of which demonstrate a direct dependence of the complexity of words on their length, number of meanings, year of first fixation in the text corpus and frequency. As an algorithm for determining "semantic complexity," the authors of this publication decided to use the following: "if word X is significantly shorter and more frequent, and also has noticeably more meanings than word Y, then word X will be semantically simpler."

In the article (Vakhrusheva, 2023), during a study of five parameters of the text complexity of textbooks in 12 subject areas, formulated the following conclusions: readability is not the main factor of syntactic complexity, since during the academic year it did not increase for the majority of textbook texts , and the Flash-Kincaid Level Index, average sentence length, average word length, vocabulary frequency, and lexical diversity do not jointly produce higher text complexity by the end of the school year.

In this study, an approach to determining the complexity algorithm of electives was developed, consisting of 4 stages:

- data extraction and preprocessing;
- keywords extraction;
- determination of complexity parameters;
- clustering.

2.1 Data and preprocessing

All the information used in the study was taken from University's resources. The following are used as input data:

- information about elective disciplines in the format .json;
- curriculum for each field of study in the format .pdf;
- work programs in .pdf format;
- themes of lectures and seminars;
- knowledge and skills for each discipline;
- academic records;
- student reviews about disciplines;
- attendance statistics in .csv format;
- disciplines descriptions in formats .docx, .pdf;
- files of assessment materials for disciplines in formats .docx and .pdf, attestation questions from which are used to determine the semantic core of the disciplines.

Preprocessing is performed for each text, which includes:

- lowercase conversion;
- removing non-letter characters and stop words;
- tokenization;
- lemmatization.

2.2 Keywords extraction

Keyword extraction is figuring out which words and phrases in a piece of text are the most important.

There are many ways to detect keywords: statistical (TF-IDF, frequency), graph (TextRank, LexRank), semantic (BERT, Word Embeddings), hybrid (Rake, YAKE) and others (Vanyushkin, 2016).

A review of available publications (Mitrofanova, 2022) demonstrates the results of research conducted on various keyword extraction algorithms, the effectiveness of which depends on the data used.

The article (Alekseenko, 2022) presents the results of testing the effectiveness of TextRank, TF-IDF, and YAKE algorithms for selecting keywords from natural language texts of a collection of scientific articles. To assess the quality of these methods, the metrics ROUGE-1 and ROUGE-L were used, and YAKE became the most effective for the English-language corpus of texts when extracting bigrams.

To determine the optimal method of keyword detection, it was decided to use TextRank, Rake, YAKE and frequency methods. Figure 3 shows steps for getting sets of keywords.

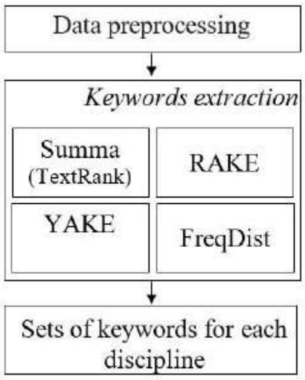


Figure 3: A scheme for obtaining sets of keywords.

The obtained results of using the algorithms were compared by the time of operation and the quality of the extracted keywords.

The frequency method of keyword extraction is ineffective for texts describing a specific topic, since it does not take into account the importance of words.

The method based on Rake performed worse than others in defining keywords of discipline descriptions: uninformative phrases including verbs and adverbs were identified as key phrases. If punctuation marks are mistakenly missed, Rake can identify incompatible phrases as key. TextRank and YAKE uninformative parts of speech were also defined as keywords, but they coped with identifying the main terms better, although they took longer to complete.

2.3 Text complexity

Determining the complexity of a text relative to another is not an easy task for automated natural language processing. The complexity of the text can be determined using morphological, lexical and syntactic analyses.

Morphological analysis is most often used to determine the difficulty of reading a text, since it is believed that complex words contain more morphemes, which complicates the understanding of these words. The lexical analysis of a text includes the definition of abstractness, density and lexical diversity. Syntactic analysis consists in studying the structure of sentences and the relationships between words. This method is based on the following revealed pattern: more complex texts usually contain complex syntactic constructions.

Lexical complexity is often calculated as the complexity of a word - the proportion of relatively unusual, rare words in the text, therefore, it is most often measured using the frequency of words in the corpus of texts. All text tokens are ranked according to the calculated frequency value: words that occur less frequently are considered more difficult (Crossley, 2013).

Based on various studies and the current set of initial data, the complexity of the discipline will be a multifactorial assessment, taking into account the lexical complexity, the complexity of mastering the material of the educational subject and the complexity of passing. Table 1 shows part of parameters that affect the complexity of disciplines.

Table 1: A part of complexity parameters.

Parameter	Value/Limitation
Educational program	$EP = \{d_{i,} i = \overline{1,10}\}$ Each d_i corresponds to a set of keywords U, where $U=\{u_{ij}, j = \overline{1,n}\}$
Semester	$S=\{s_k, k = \overline{1,11}\}$
Academic records	Grade failure rates: $\overline{0,1}$ Average grade: $\overline{2,5}$
Attendance statistic	Grade of attendance: $\overline{0,1}$
System of student reviews “Otzyvus”	Average ease rating: $\overline{1,5}$

After analyzing the available factors influencing the development of disciplines, it was decided to form an algorithm for determining the complexity of electives, depending on the direction of the student's training, the semester of study of the discipline, grades of disciplines, reviews and lexical complexity.

Each parameter is a weight in the overall assessment of determining the level of complexity of the discipline.

The first step in determining the electives recommended for study, taking into account complexity, is the clustering of disciplines, which will allow you to obtain a set of possible areas of knowledge consisting of similar subjects. The further action plan depends on the purpose of the student's education.

2.4 Clustering

The next step after data preprocessing is a vector representation. Various types of text vectorization were tested: using the CountVectorizer(), TfidfVectorizer() methods with a different value of n_grams from one to three.

The CountVectorizer from Scikit-learn is used to convert a set of text documents into a vector of the number of terms. It also allows you to pre-process text data before creating a vector representation, which makes it a flexible function representation module for text.

For each of these cases, the most significant words in each received cluster were identified, with the help of which it is possible to understand the main topic of texts from the cluster. Of the tested methods, TfidfVectorizer (ngram_range = (1,1)) turned out to be the best.

The choice of the clustering method was based on the results of research on the effectiveness of scientific publications. The results of these experiments showed the superiority of KMeans in many works (Kuz'minyh, 2022), (Parhomenko, 2017), (Ariff , 2016), so it was decided to use the KMeans method.

The KMeans algorithm is one of the machine learning algorithms that solves the clustering problem, the purpose of which is to divide n datasets into k clusters so that each dataset belongs to exactly one cluster located at the smallest distance from it.
The elbow method was used to determine the optimal number of clusters. This method consists in plotting the dependence of the sum of error squares on the number of clusters and selecting the curve bend as the number of clusters to use for further clustering.

3 SOFRWARE DEVELOPMENT

To automate data management at the University, it was decided to develop a service. Users of this service: students, teachers and other university staff will be able to use it to their advantage. So, for students this will allow them to select electives taking into account the level of complexity and their own requests.

The construction of a student's individual educational path and the selection of an elective according to its complexity will depend on the purpose of his studies at the university.

The student can independently select a learning goal in the personal account of the developed service. Over time, the student's learning goal may change, so the student can adjust his choice at any time in his personal account, and before each choice of elective disciplines, the relevance of the previously chosen goal will be clarified.

Also, in your personal account, based on all the choices made by students during the period of study, a "portrait of success" is formed. When selecting a specific sector, the student will be able to see a summary table with the full name of the disciplines, the results of the intermediate certification and semester, as well as the percentage of maturity of the field of knowledge of the corresponding sector.

The service page is written in the HTML markup language, JavaScript, page styles are described in the formal CSS language created using the markup language, which is necessary to represent the appearance of a web page. PostgreSQL is used to work with data and store it.

4 RESULTS

The obtained results of using the algorithms were compared by the time of operation and the quality of the extracted keywords. Table 2 shows the operating time of the methods for extracting keywords from the texts of 1787 basic disciplines and 685 electives.

Table 2: The working time of keywords extraction methods.

	YAKE!	Rake	TextRank	Frequency method
Subjects	69 s	60 s	72 s	31 s
Electives	198 s	134 s	289 s	93 s

Based on the results of the conducted tests of algorithms, the Yake algorithm was used to determine the main words and phrases of the training directions, a part of the results of which are shown in the Table 3.

Table 3: Part of extracted keywords for educational programs.

Educational program	Keywords
01.03.03 Mechanics and mathematical modeling	solution system, boundary value problem, linear equation, first order, linear system, Fourier transform, wave problem, heat equation, solid body, material point, stability solution, self-adjoint operator, holomorphic function, canonical type, fixed axis, elliptic type
02.03.03 Software and administration of information systems	basic operation, neural network, linear task, pattern design, machine learning, high level, relationship pattern, high language, html document, data preprocessing

The complexity of the discipline depends on several criteria. The main factors influencing complexity were identified as academic performance, learning and lexical complexity.

Initially, all texts of disciplines are clustered to obtain sets of subjects that are more similar in content. Table 4 shows topics and count of documents for each cluster.

Table 4: Topics and count of documents for each cluster.

Cluster	Documents count in cluster	Cluster theme
Cluster 0	98	Literature and art
Cluster 1	85	Mathematics
Cluster 2	131	Information technology and programming
Cluster 3	89	Pedagogy
Cluster 4	50	Finance and business
Cluster 5	170	Economics and politics
Cluster 6	63	State and law
Cluster 7	21	Chemistry
Cluster 8	40	Linguistics
Cluster 9	129	Ecology and geography
Cluster 10	68	Foreign languages

After that, a set of elective subjects is determined for each student, which is recommended to him based on his goal of studying at the university.

The purpose of training may be related to professional development, self-development in various fields, or it may not be related to studying at all, which directly affects the required complexity.

To determine the purpose of the student's education in the study, a questionnaire was implemented based on the methods "questionnaire of interests", "profile", "diagnostic questionnaire of interests", a list of questions was compiled.

The threshold values of the conditions for determining the complexity of the disciplines were determined based on the distributions of the initial data of the university. It was decided to compare the number of debtors with 15% - the value of the approximate intersection of the trend line with the abscissa axis, the third part of the maximum percentage and the relatively small value of the indicator that may arise. Figure 4 shows a diagram of the distribution of the percentage of failures in electives for the 1st semester of 2023-2024 for students of the School of Computer Science.

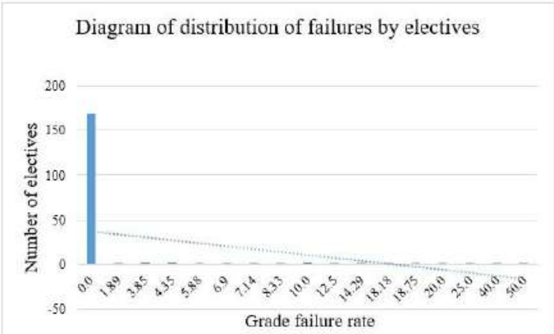


Figure 4: A diagram of the distribution of the percentage of failures in electives.

Figure 5 shows a diagram of the distribution of estimates of the ease of electives by Otzyvus.

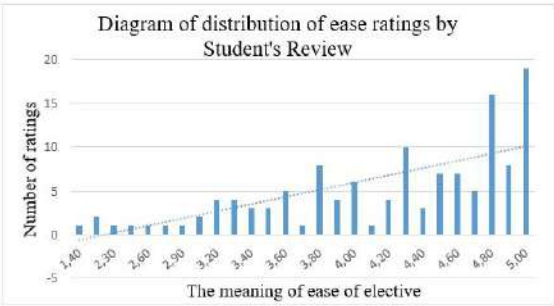


Figure 5: A diagram of the distribution of estimates of the ease rates of electives.

Based on the student's learning goal and all parameters, each student is recommended a list of electives that satisfies the complexity criterion.

5 CONCLUSIONS

The approach to the algorithm development has been tested on 3478 students from 1st to 3rd year of University of Tyumen of different groups.

Students of 98 educational programs took part in the testing, which are divided into 10 faculties, such as mathematics and computer science, finance and economics, law, ecology, biology and bioengineering, physical education, pedagogy and psychology, physico-technical, chemical, social and humanitarian.

To determine the purpose of the student's education in the study, a questionnaire was implemented the answers to which determine one of three categories.

The questionnaire is offered to the student before each stage of elective selection. Each time before testing, the questions are shuffled using the Fisher-Yates algorithm. Each result is independent of the previous one.

This study is not final, in the future it is planned to supplement the implemented service with various functionality, for example, the ability to mark an elective (according to different criteria), record for the desired elective and create a waiting list if the record is closed, as well as an application for rewriting.

REFERENCES

Crossley, S.A., Cobb, T., McNamara, D.S., 2013. Comparing count-based and band-based indices of word frequency: Implications for active vocabulary research and pedagogical applications. *System*, 41(4), 965–981.

Alekseenko A. A. , Glazkova A.V., 2022. Development of an application for the selection of keywords for scientific texts, 250-256.

Vanyushkin A.S., Grashchenko L.A. Metody i algoritmy izvlecheniya klyuchevyh slov. *Novye informacionnye tekhnologii v avtomatizirovannyh sistemah*. 2016. №19.

Vahrusheva, A. Ya., 2023. Ocenka leksicheskoj i sintaksicheskoj slozhnosti tekstov, predstavlennyh v rossijskih uchebnyh posobiyah / A. Ya. Vahrusheva // Skorinovskie chteniya – 2023. Kul'tura knigi: tradicii i novatorstvo : materialy VI Mezhdunar. foruma, Minsk, 28 - 30 sent. 2023

Martynova E.V., Solnyshkina, M. I., Merzlyakova, A. F., Gizatulina, D. Yu., 2020. Leksicheskie parametry uchebnogo teksta (na materiale tekstov uchebnogo korpusa russkogo yazyka). *Filologiya i kul'tura*. № 3(61). S. 72-80.

Morozov, D. A., 2019. Semanticheskaya slozhnost' slov russkogo yazyka i ee kriterii na primere korotkih nizkochastotnyh slov.Prikladnaya lingvistika: Materialy 57-j Mezhdunarodnoj nauchnoj studencheskoj konferencii : Materialy 57-j Mezhdunarodnoj nauchnoj studencheskoj konferencii, Novosibirsk, 14–19 aprelya 2019 goda. – Novosibirsk: Novosibirskij nacional'nyj issledovatel'skij gosudarstvennyj universitet, p. 15.

Mitrofanova, O.A., Gavrilik, D.A., 2022. Eksperimenty po avtomaticheskomu vydeleniyu klyuchevyh vyrazhenij v stilisticheski raznorodnyh korpusah russkoyazychnyh tekstov. *Terra Linguistica*. T. 13. № 4. p. 22–40.

Vorob'eva, M. S., 2021. Diagnostika predpochtenij studentov pri proektirovanii individual'nyh obrazovatel'nyh traektorij. Informatizaciya obrazovaniya i metodika elektronnogo obucheniya: cifrovye tekhnologii v obrazovanii : Materialy V Mezhdunarodnoj nauchnoj konferencii. V 2-h chastyah, Krasnoyarsk, 21–24 sentyabrya 2021 goda / Pod obshchej redakciej M.V. Noskova. Tom Chast' 2. – Krasnoyarsk: Sibirskij federal'nyj universitet. p. 60-63.

Parhomenko, P.A., Grigor'ev, A.A., Astrahancev, N.A., 2017. Obzor i eksperimental'noe sravnenie metodov klasterizacii tekstov. *Trudy instituta sistemnogo programmirovaniya ran*. №2. s. 161-200

Ariff, N. M., Bakar, M. A. A., Rahmad, M. I., 2018. Comparative Study of Document Clustering Algorithms. *International Journal of Engineering & Technology*. №7. p. 246-251.

Kwale, F.M., Wagacha, P.W., Mwaura, A. A., 2016. Text Clustering Comparison Methodology. *International Journal of Computer Applications*. №13. p. 12-19

Morozevich, E. S., 2022. Razrabotka modeli formirovaniya individual'nyh obrazovatel'nyh traektorij s ispol'zovaniem metodov mashinnogo obucheniya. *Biznes-informatika*. T. 16, № 2. p. 21-35.

Kuz'minyh, A. A., Stupnikov, A. A., 2022. Razrabotka i analiz modelej klasterizacii i klassifikacii dlya dannyh ob uchebnyh disciplinah IMiKN. Matematicheskoe i informacionnoe modelirovanie : materialy Vseros. konf. molodyh uchenyh. Tyumen' : TyumGU-Press, Vyp. 20. p. 256–264.

Algorithm For Increasing Population Loyalty To Smart City Projects

Konstantin Semyachkov[a] and Karina Veselova[b]
Ural Institute of Management of the Russian Presidential Academy of National Economy and Public Administration, 8 Marta Street, Yekaterinburg, Russia
k.semyachkov@mail.ru

Keywords: Consumer loyalty, smart city, digitalization, project, promotion algorithm.

Abstract: In the modern world, digital technologies penetrate into all spheres of society and open up completely new opportunities for the development of smart cities. The rapid spread of the Internet is leading to an increase in the number of platforms and virtual communities that allow companies to effectively harness the potential of consumers to develop new products. Despite the huge number of studies on smart city projects, an algorithm for promoting innovative smart city projects among the local population has not yet been developed, which would increase the population's loyalty to the ideas of digital transformation of urban areas. As a result of the study, the stages of promoting smart city projects among the population were identified, and a comprehensive algorithm for promoting smart city projects was developed. The scientific novelty of the obtained result lies in the development of a procedure for promoting smart city projects among the local population in order to increase loyalty to the ideas of digital transformation of urban areas.

1 INTRODUCTION

In the modern world, along with an increase in the city's population, problems arise, including overload of city services, transport collapses, increased consumption of resources, etc. To solve emerging problems, local authorities resort to digital technologies, which become the technological basis for the development of modern cities. So many cities are beginning to claim the status of "smart city" (Neirotti, De Marco, Cagliano, Mangano, & Scorrano, 2014).

In the literature, a "smart city" is understood as a safe and ecological urban center with developed infrastructure, which ensures sustainable economic growth and a high quality of life for its residents (Höjer, Wangel, 2014). In general, a smart city is described as a concept that involves the adoption and deployment of digital technology infrastructure to support social and urban growth through economic improvement, citizen engagement and improved government efficiency (Appio, Lima, & Paroutis, 2018).

The goal of developing smart city technologies is to improve the quality of management of city flows and the speed of solving complex problems. The use of smart city technology solutions allows local government structures to deal with problems more effectively and quickly than using a conventional operational approach. Thanks to digital technologies in smart cities, authorities can monitor the development of the urban environment, identify the most effective tools for improving the quality of life, and directly interact with communities and urban infrastructure (Cassandras, 2016).

In the modern world, digital technologies penetrate into all spheres of society and open up completely new opportunities for the development of smart cities (Lee, Phaal, & Lee, 2013). Thus, the relevance of this study is due to the need for targeted use of digital tools for successful interaction between residents and city authorities.

In articles concerning the formation and development of smart cities, aspects related not only to digital technologies, but also aspects of an institutional, economic, and social nature are increasingly being explored. The most important condition for the development of smart cities is the factor of human capital, the willingness and ability of the local population to participate in the

[a] https://orcid.org/0000-0003-0998-0183
[b] https://orcid.org/0009-0000-9626-5860

implementation of smart city projects, to be involved in the processes of digital transformation of urban areas, and to show loyalty to innovative solutions. Thus, the smart people factor includes various aspects: lifelong learning ability, social and ethnic plurality, flexibility, creativity, cosmopolitanism, openness and participation in public life. The development of smart cities is directly related to the ability of the local population to propose smart solutions to urban problems, and the management goals of a smart city should be focused on its residents. That is why many authors promote the idea that city residents should be considered as the final link in the chain of creating a smart city, while their expectations regarding the quality of life in the city are not always taken into account (Mayangsari, & Novani, 2015).

Modern processes associated with the digital transformation of cities affect most areas of everyday life, and thanks to the work of the "smart city" program, cities are gradually turning into intelligent ecosystems. The digital environment includes all key aspects of urban life: healthcare, education, energy, transport, resource and urban space management. In this regard, assessing the readiness of the local population to participate in the development of a smart city, the loyalty of the population to smart city projects becomes a vital condition for their successful functioning. A smart city is characterized by services for the population aimed at meeting needs. In this regard, it is important to understand how the loyalty of the population allows local authorities and businesses to develop the concept of smart cities.

Despite the huge number of studies on smart city projects, a procedure for promoting smart city projects among the local population has not yet been developed to increase loyalty to the processes of digital transformation of urban areas. Based on this, the purpose of this study is to identify the stages of promoting smart city projects to increase the loyalty of the population to the processes of digitalization of the urban environment, and to develop a comprehensive algorithm for promoting smart city projects.

With the development and emergence of new technologies, the number of tools that help the population interact with business representatives, non-profit organizations, and authorities is increasing. Such interaction and free access to information leads to the fact that local authorities and private organizations have to focus on customer focus in order to build long-term relationships and increase consumer loyalty to their products and services (Ceballos, & Larios, 2016).

Along with the progress of digital technologies, the population is given the opportunity to actively participate in the activities of various organizations. Today, there are many potential mechanisms for involving consumers in the activities of companies. Consumers can act as information intermediaries, sharing ideas with organizations regarding new products or improving existing ones. In addition, consumers also have the opportunity to directly participate in the product development process and implement innovative projects themselves.

In a market overflowing with innovative products and services, it is very important for companies to develop a strategy aimed not only at attracting new customers, but also retaining existing ones. For this purpose, types of loyalty programs are created and developed that help companies build a dialogue with the client and involve him in constant interaction (Ruiz-Mafe, Marti-Parreno, & Sanz-Blas, 2014). A business interested in its customers must constantly improve approaches and methods for analyzing customer behavior. To assess the attitude of consumers towards certain goods, services, projects, term "loyalty" is used (Uncles, Dowling, & Hammond, 2003). Loyalty makes it possible to determine the likelihood that a consumer will choose another brand, this is especially important when it undergoes changes in price or some other indicators. As loyalty increases, the propensity of consumers to perceive the actions of competitors decreases. Loyalty is reflected, first of all, in the behavior and attitude towards the goods or services of any organization or company. Loyalty is, first of all, the positive attitude of the consumer, his emotions, experiencing which he wants to seek services from the company again and again.

Modern definitions of consumer loyalty, formed in the scientific and business literature on marketing, include the definition of consumer loyalty as a set of feelings or experiences that incline the consumer to consider the possibility of making repeated purchases of specific products, as well as the possibility of making a repeated visit to an enterprise, retail outlet, Website. Consumer loyalty is the result of ensuring customer satisfaction, their required positive experience and the achieved level of product value that can be obtained from a business at a given specific point in time (Yim, & Kannan, 1999).

The loyalty has a dual nature in relation to the competitiveness of the organization. In modern conditions of competition in the service market, the formation and maintenance of customer loyalty is becoming increasingly important. However, for a customer to become loyal, it is necessary for the organization to provide competitive advantages in the form of quality services and responsive customer service (Jai, Tong, & Chen, 2022).

A factor contributing to the formation of customer loyalty is the very existence of such customers in the organization. They become a kind of competitive advantage for the institution, helping it improve its prospects in the services market. Currently, the services market is experiencing fierce competition between enterprises to attract customers. Studying the degree of customer loyalty becomes an important basis for making management decisions as part of the formation of a customer-oriented model of relationships with consumers. However, it becomes difficult to measure loyalty because every consumer does not use the same service all the time. To assess consumer loyalty, two groups of methods are used. The first group is mathematical methods that are based on constructing a loyalty curve, calculating the net support index and determining the influence of factors that form loyalty. The second group is empirical methods that allow researchers to identify customer loyalty and determine its level (Iastremska, & Strokovych, 2014).

Assessing consumer loyalty is of particular importance when implementing smart city development projects, since in this case the results of project implementation are not always obvious. Consequently, the problem arises of developing tools for promoting smart city projects among the local population to increase loyalty to the ideas of digital transformation of urban areas.

2 METHODS

Currently, there is already an extensive set of tools for conducting behavioral analysis, each of which can be successfully applied depending on specific data or requests to assess customer loyalty to a particular product. However, there is still no algorithm for promoting smart city projects to increase the loyalty of the population to the processes of digitalization of urban areas.

The object of the study is the loyalty of the population to innovative projects of smart cities; the subject of the study is the algorithm for promoting smart city projects to increase loyalty to the processes of digital transformation of the local population. The information base for the study was scientific articles on this topic, indexed in international databases of scientific publications, as well as author's developments.

The research consists of the following stages: formulation of the problem, consideration of previous studies, development of the author's algorithm for promoting smart city projects among the local population.

3 RESULTS

An algorithm for promoting smart city projects, which can be used to increase the loyalty of the local population to the processes of digital transformation of an urbanized area, is presented in Figure 1.

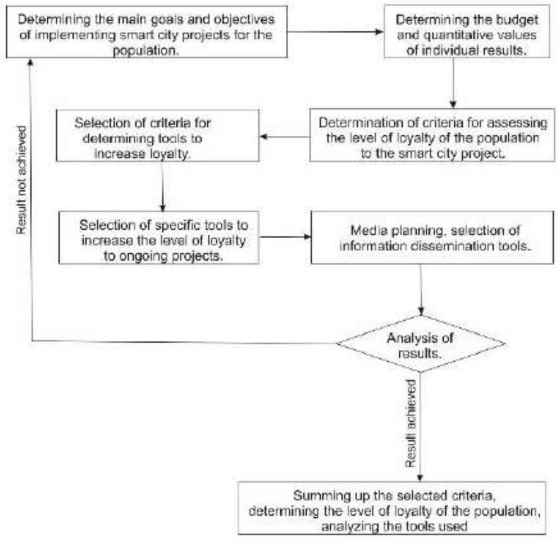


Figure 1: Algorithm for promoting smart city projects.

The presented algorithm includes seven consecutive stages. To effectively promote a smart city project, it is extremely important to determine the main goals of the innovations being introduced. As a rule, the main goals of implementing smart city projects are related to the goals of sustainable development, improving the safety of the urban environment, efficient use of resources, and solving transport problems. An important condition for achieving the desired results when promoting a smart city project is the availability of resources for the campaign to promote smart city ideas, which requires determining the budget for planned activities, as well as the allocation of certain funds. In order to implement the planned activities, it is necessary to select tools that can be used as part of the promotion of the smart city project, for which a list of criteria is formed by which the tools for promoting the smart city project can be selected. Next, specific tools are selected, as well as the implementation of planned activities. At the final stage, the results obtained are analyzed, the loyalty of the population to the smart city project is determined after the implementation of the procedure for promoting the project among the local population.

4 DISCUSSION

The results of the study show that in order to increase the loyalty of the population to smart city projects, it is necessary to alternately use all the tools. When implementing a campaign to promote smart city projects, it is necessary to empirically determine which of the methods used works and how effectively (Baek, Yoo, 2018).

At the same time, almost the entire toolkit of tools for increasing the loyalty of the population can be used when implementing smart city development projects. This is due to both the significant differentiation of companies and enterprises implementing projects for the development of smart cities, and a large arsenal of products and services that form the digital space of urbanized territories.

Each product or service has its own target market, a group of consumers to which it is directed. However, the distinction between target and non-target consumer groups is often unclear and ambiguous. This is due to the fact that consumers have different income levels, exhibit different purchasing behavior, have different levels of brand loyalty and other characteristics.

That is why it is important to identify the most significant consumers and adapt offers to them. Sometimes the diversity of customers is so broad that a one-size-fits-all offering designed for the average consumer will not satisfy anyone's needs. It is important for businesses to correctly tailor their offerings to target consumer groups based on their experiences and preferences.

This problem arises in almost all marketing activities, but it plays a special role in loyalty programs in the context of digitalization of relationships with consumers.

5 CONCLUSIONS

One of the main tasks in implementing initiatives to digitalize the urban environment is the task associated with changing the behavior of users of digital solutions, creating conditions for involving the local population in the development processes of smart city projects. User behavior is influenced by many factors. Local governance structures can influence citizens' choices in implementing development concepts through various strategies. This requires the development of consistent policies aimed at ensuring that local people use the smartest solutions. An important condition for involving the population is the formation of trust in digital solutions, as well as receiving benefits from using smart city solutions. Therefore, local authorities should be interested in encouraging public participation in the development and implementation of smart solutions. In this regard, it is important to use modern channels for obtaining information from the local population about problems in implementing smart city ideas, as well as interacting with users on the benefits, costs, timing and other attributes of smart solutions. Openness and exchange of information with users when errors occur in the service provided is especially important, so that users do not lose confidence in smart city solutions.

People living in different cities, different professions, ages and genders behave differently. Therefore, before implementing smart solutions, it is necessary to study needs or implement pilot projects to understand user behavior. Such behavioral factors should be taken into account in design decisions. Thus, the public and private sectors must work together to influence users through educational and marketing opportunities, using tools such as awareness campaigns, financial incentives, and the use of social media. Smart solutions must be innovative to attract users. In this regard, as part of the development of smart cities, new solutions related to the use of big data and artificial intelligence are being actively implemented. Big data is also a tool for personalizing many marketing and educational initiatives. Since smart solutions use personalized data in real time, user privacy and security are of utmost importance. Insufficient security of digital technology solutions is a significant factor in reducing user loyalty to such solutions. Users stop using these services after a security breach because they perceive risks in using digital technologies.

In this study, with the aim of developing an algorithm for promoting smart city projects to increase the loyalty of the population to the processes of digital transformation of urban areas, the following results were obtained.

Firstly, the scientific literature on tools for increasing consumer loyalty in the context of the formation of a digital society is analyzed and the problem of the need to develop a procedure for promoting smart city projects is formulated.

Secondly, it is proposed to distinguish seven stages when promoting smart city projects, which logically complement each other as part of the implementation of the procedure for promoting smart city projects.

Thirdly, an algorithm for promoting smart city projects is proposed to increase the loyalty of the local population to the processes of digital transformation of urbanized territories, expanding the existing tools for managing the processes of digitalization of urbanized territories.

ACKNOWLEDGEMENTS

The study was supported by the Russian Science Foundation under project no. 24-18-20036.

REFERENCES

Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G., Scorrano, F., 2014. Current trends in Smart City initiatives: Some stylised facts. Cities, 38, 25–36.

Höjer, M., Wangel, J., 2014. Smart Sustainable Cities: Definition and Challenges. ICT Innovations for Sustainability, 333–349.

Appio, F. P., Lima, M., Paroutis, S., 2018. Understanding Smart Cities: Innovation ecosystems, technological advancements, and societal challenges. Technological Forecasting and Social Change.

Cassandras, C. G., 2016. Smart Cities as Cyber-Physical Social Systems. Engineering, 2(2), 156–158.

Lee, J. H., Phaal, R., Lee, S.-H., 2013. An integrated service-device-technology roadmap for smart city development. Technological Forecasting and Social Change, 80(2), 286–306.

Mayangsari, L., Novani, S., 2015. Multi-stakeholder co-creation Analysis in Smart city Management: An Experience from Bandung, Indonesia. Procedia Manufacturing, 4, 315–321.

Ceballos, G. R., Larios, V. M., 2016. A model to promote citizen driven government in a smart city: Use case at GDL smart city. In 2016 IEEE International Smart Cities Conference (ISC2) (pp. 1-6). IEEE.

uiz-Mafe, C., Marti-Parreno, J., Sanz-Blas, S., 2014). Key drivers of consumer loyalty to Facebook fan pages. Online information review, 38(3), 362-380.

Uncles, M. D., Dowling, G. R., Hammond, K., 2003. Customer loyalty and customer loyalty programs. Journal of consumer marketing, 20(4), 294-316.

Yim, C. K., Kannan, P. K., 1999. Consumer behavioral loyalty. Journal of business research, 44(2), 75-92.

Jai, T. C., Tong, X., Chen, H. S., 2022. Building brand loyalty on social media: theories, measurements, antecedents, and consequences. Journal of Brand Management, 1-23.

Iastremska, O., Strokovych, A., 2014. Assessment of customer loyalty. The Advanced Science Journal, 6, 84-89.

Baek, T. H., Yoo, C. Y., 2018. Branded app usability: Conceptualization, measurement, and prediction of consumer loyalty. Journal of Advertising, 47(1), 70-82.

Biotesting of Water Bodies in Metropolitan Areas

Ivanov Z.A.[a], Fedorova V.I.[b], Vasyuk A.E.[c], Esyakova O. A.[d]
Reshetnev Siberian State University of Science and Technology, 31, Krasnoyarsky Rabochy Av., Krasnoyarsk, Russia
zaharivanov53345@gmail.com

Keywords: Biotesting, bioindication, toxicity, pollution, surface waters.

Abstract: Environmental monitoring of natural objects invariably remains a necessary and real reflection of the pollution level under the anthropogenic influence. This work contains a study of surface waters to determine their toxicity using biotesting, which allows to assess the quality of fishery water resources. The rivers of the Moscow city and the Krasnoyarsk city were chosen as the objects of the study. Chlorella vulgaris Beijer served as a test object for assessing the toxicity of waters. The study was conducted using photometry. Based on the results obtained, it is proposed to provide measures to reduce the recreational load and systematic quality control of rivers.

1 INTRODUCTION

Water is the most widespread, unique and amazing substance in nature. Due to its special physical, chemical and quantum mechanical properties, it occupies an exceptional position in nature and plays a special role in the existence of organic life. This liquid is a perfect source of life and human life is unthinkable without it. It is the most affordable and cheap substance, that's why its wide application in all spheres.

In order to rationalize the use of biological resources of the rivers and provide people with clean drinking water, systematic quality control of natural waters is necessary. In conditions of intensive production activity, there is a constant increase in the amount of pollutants entering the aquatic environment, including heavy metals, petroleum products, nitrates and other chemical compounds. The identification of this problem is carried out by assessing the level of water bodies pollution and the intensity of their biological self-purification.

The establishment of control over the content of toxicants in the environment by chemical methods presents certain difficulties, in addition, physico-chemical methods of indicating the state of the environment do not provide a direct answer to the question of the possible response of ecosystems to certain pollutants. In this regard, methods of biological analysis of water, soil and air are of great importance, in which algae, due to the stenotopy of many species, their high sensitivity to environmental conditions, play a major role (Onerkhan, Durmekbaeva, Akhmetova, 2019).

2 ABOUT THE METHODOLOGY

All methods of biotesting are characterized by their own characteristics. This is the speed of obtaining the result, the availability of the test object, which is determined by the possibility of their cultivation in laboratory conditions, maintaining the necessary conditions of illumination, temperature, complexity of the composition of nutrient media, air purity, and so on. In simple organisms — algae, bacteria and infusoria, the fastest reactions can be recorded to toxic effects.

Such reactions are limited to minutes or several hours. Each method is characterized by its own technical ways of implementation. For all methods, the general rule is to assess the reliability of test cultures (Volchanskaya, Zrazhevskaya, Nikolaenko, 2016).

[a] https://orcid.org/0009-0009-0682-897X
[b] https://orcid.org/0009-0000-1759-5985
[c] https://orcid.org/0009-0009-9365-572X
[d] https://orcid.org/0000-0003-3819-0543

In this work, to study the problem of water toxicity, its determination was carried out using a test culture of the green algae Chlorella vulgaris. Chlorella refers to unicellular algae having spherical cells with a thin shell, without mucus. Chlorella has a cup-shaped chromatophore with a pyrenoid, reproduces by autospores, which form 4-8, less often 16 inside the mother cell and are released through a rupture of its shell. This type of chlorella is widespread in the plankton of freshwater reservoirs.

Chlorella algae is the only one of the most well—known species of bacteria that has an extensive distribution in freshwater bodies. Algae are widely used in biotesting due to the available cultivation conditions, high reproducibility and the ability to analyze a wide range of test functions in laboratory culture. One of the main conditions is to obtain the results of sample analysis based on genetically homogeneous organisms. Thus, the differences between the control sample and the experimental one can be explained by a violation of some factor, and not by differences between test organisms (Speedinskaya, 2019).

The method is based on the detection of differences in the optical density of the selected test culture placed in an aqueous medium from various sources.

All laboratory tests were carried out strictly in accordance with the HDPE F T methodology 14.1:2:3:4.10-04. This document establishes a methodology for determining the toxicity of water samples (surface fresh, groundwater, drinking, wastewater) and aqueous extracts from ground, soil, sewage sludge, production and consumption waste by changing the optical density of the test culture of the green protococcal algae chlorella (Chlorella vulgaris Beijer) in laboratory. The optical density of the algae test culture after 22 hours of growth is measured using a photoelectric colorimeter.

Cultivators can work around the clock without requiring the constant presence of a laboratory assistant. The constant temperature is maintained by automatically turning on and off the built-in fan at the command of the device's thermal stabilization unit. The increase in the number of cells is quickly determined by measuring the light transmission of the grown algae suspension using a specialized optical density meter.

Measuring the optical density of algae makes it possible to assess the change in the number of cells in the control and experimental versions, and based on the results and their comparison, it becomes possible to draw conclusions about the toxicity of the samples under consideration. The criterion for the toxicity of aqueous samples is a change in the optical density of the samples under consideration (that is, suppression of growth or vice versa — its stimulation) compared with a control sample prepared on the basis of distilled water.

The equipment used for research is a multi-cuvette algae cultivator.

Biotesting as a method of assessing the toxicity of the aquatic environment is used:

− in the toxicological assessment of industrial, domestic wastewater, agricultural, drainage, polluted natural and other waters in order to identify potential sources of pollution,

− in the control of emergency discharges of highly toxic wastewater,

− to assess the degree of toxicity of wastewater at different stages of formation in the design of local wastewater treatment plants,

− in the control of the toxicity of wastewater supplied to biological treatment plants in order to prevent the penetration of dangerous substances for biocenoses of activated sludge,

− to determine the level of safe dilution of wastewater for aquatic organisms in order to take into account the results of biotesting when adjusting and setting the maximum permissible discharges of substances entering wastewater reservoirs,

− in the environmental assessment of new materials, purification technologies, sewage treatment plant projects and others.

The vital function or toxicity criterion is used in biotesting to characterize the response of the test object to the damaging effect of the environment. Test functions used as bioassay indicators for various objects:

− for infusoria, crustaceans, embryonic stages of mollusks, fish, insects — survival of test organisms;

− for crustaceans, fish, shellfish — fertility, the appearance of abnormal abnormalities in the early embryonic development of the body, the degree of synchronicity of egg crushing;

− for cultures of unicellular algae and infusoria — cell death, change (increase or decrease) in the number of cells in culture, cell division coefficient, average growth rate, daily increase in culture;

− for various plant objects — seed germination energy, primary root length, etc.

2.1 The objects of the study

The following rivers were selected as the studied objects for this work:

- The Moskva River;
- Bazaiha river, Krasnoyarsk city;

- Yenisei River, Krasnoyarsk city;
- Kacha River, Krasnoyarsk city.

This choice is due to the high degree of contact the population with the water bodies, for example, the Moscow River flows through the most densely populated Russian city, the Yenisei River divides the Krasnoyarsk into two banks and has close proximity to many industrial enterprises of the city, we are talking about water intakes and emissions.

The Kacha River is a left tributary of the Yenisei River, originates in the northwestern spurs of the Eastern Sayan, in the Yemelyanovsky district, flows through the territory of the Yemelyanovsky district and the city of Krasnoyarsk, flows into the Yenisei in the center of Krasnoyarsk. Kacha is a recreational gem of Krasnoyarsk, as a result, the river is experiencing constant anthropogenic stress. Every year in the spring and summer season, the Kacha River overflows its banks, washing away pollutants of organic and inorganic nature from the soil surface. The negative impact of anthropogenic and man-made factors is manifested at all levels of the ecosystem.

Bazaiha is a river in the Krasnoyarsk Territory, a right tributary of the Yenisei, flows into it within the city of Krasnoyarsk. A large private sector is located in the water protection zone of the Bazaiha River, which has a significant impact on the ecological state of the watercourse.

The main cause of watercourses pollution is unauthorized and polluted discharges of industrial enterprises.

As a result of studying the characteristics of coastal territories, the main sources of problems have been identified. Currently, the condition of urban rivers is assessed as "very dirty" as a result of increased anthropogenic and man-made loads. The key factors of pollution of coastal zones and riverbeds are individual residential buildings closely adjacent to the riverbed, as well as numerous production and storage areas, discharges of industrial enterprises.

The initial data of laboratory tests for all samples are presented in Table 1.

Table 1: Initial data for the experiment.

Concentration of the water sample, %	Dilution of the sample, times	Biotesting time, hour
control	-	22
1,2	81	
3,7	27	
11	9	
33	3	
100	1	

2.1.1 The Moscow River

The Moskva River is a left tributary of the Oka River (Volga River basin). The length is 473 km (along the old riverbed before straightening 502 km), the basin area is 17.6 thousand square kilometers. It originates on the Smolensk-Moscow upland, flows out of a swamp in the east of the Smolensk region, flows mainly through flat terrain, flows into the Oka near Kolomna. In total, 362 rivers and more than 500 streams flow into Moscow.

It has been established that 83 km of the Moskva River (out of a total of 478 km), which pass in the capital, manage to be heavily polluted by industrial effluents, which affects its unfavorable environmental condition and water quality (Yashin, Vasenev, Gareeva, Chernikov, 2015).

Figure 1 shows a satellite image of the river.

Figure 1: The Moscow River.

The basin of the Moskva River within the city of Moscow is under the influence of an industrial complex, which has a significant impact on the change in the chemical composition of the water of both the Moskva River and its tributaries. Surface runoff from the city is formed by thawed snow and rainwater, as well as irrigation and washing waters. As a rule, the runoff is not cleaned of pollution and directly enters water bodies, carrying with it a large amount of organic, suspended substances, and petroleum products. Most of the pollutants: petroleum products - 63%, suspended solids - 75%, organic substances - 64%, chlorides - 95%, enter the Moskva River with surface runoff in the winter and spring period.

For an objective assessment of the state of water bodies within the city of Moscow and the development of measures for the improvement of reservoirs, a sound system of water quality control and assessment is essential.

Biotesting included the following operations: preparation of control and experimental media, introduction of test organism cells into them, study of cell growth dynamics, comparative analysis of the data obtained.

The results of biotesting samples of the Moscow River are presented in Table 2.

Table 2: Biotesting of the Moscow River.

Concentration of the water sample, %	The value of the optical density, D		The difference D in the tested water, in % of the control	The difference D in the tested water, in fractions to the control
	control	experience		
control	-	-	-	-
1,2	0,132	0,160	-21	-0,21
3,7	0,132	0,149	-13	-0,13
11	0,132	0,130	2	0,02
33	0,132	0,055	58	0,58
100	0,132	0,082	38	0,38

Based on experimental data, it can be concluded that toxic effects occur at sample concentrations of 33 and 100 %. At lower concentrations, the growth processes of test objects in the samples are suppressed by 20 %. In the test sample, pollutants had an acute toxic effect on chlorella when diluted by 6.3 times.

Studies have shown a high sensitivity of the test object to contamination with basic pollutants. The use of biotesting technology using chlorella algae to assess the quality of natural waters is advisable.

2.1.2 The Yenisei River

The Yenisei River ranks 2nd in length among the rivers of Russia and Eurasia (after the Ob) and 7th among the rivers of the world. The Yenisei basin is characterized by a sharp asymmetry: its right-bank part is 5.6 times more extensive than the left-bank one. The Yenisei is the natural border between Western and Eastern Siberia. The Yenisei River is the most abundant, largest and longest in the Krasnoyarsk Territory.

The total length is 3,487 km, and the total area of the basin is 2,580,000 square km.

The phases of the hydrological regime are smoothed due to the location of the Sayano-Shushenskaya and Krasnoyarsk hydroelectric power plants on the river.

Anthropogenic factors of the formation of the qualitative composition of the Yenisei River in the area of the city can be attributed the presence of industrial facilities such as the Krasnoyarsk housing and communal complex, the Krasnoyarsk Metallurgical Plant, the Krasnoyarsk Aluminum Plant, the Krasnoyarsk Reinforced concrete plant (Badmaeva, Sokolova, 2017).

Figure 2 shows a satellite image of the river.

Figure 2: The Yenisei River.

On the territory of the city of Krasnoyarsk, the main pollutants of the Yenisei River are industrial and production areas, motor transport, boiler houses, cultural and household facilities.

Pollution of the river in the area of the Krasnoyarsk occurs due to:

- untreated and poorly treated wastewater;
- flushing of pollutants from fields, lands and roads by rain and snow precipitation;
- soil erosion;
- wind transfer of pollution from the environment into the water;
- smoke pollution;
- unauthorized drains;
- contaminated underwater sources;
- mechanical contamination of water.

The study of samples from the Yenisei River at the test facility was carried out in a similar way to the samples of the Moskva River.

The criterion of toxicity of the studied waters was also a significant difference in the number of chlorella cells observed in the upper zone of the cuvette in a sample containing no toxic substances (control), compared with the same indicator in the test sample (experiment).

The results of biotesting samples of the Yenisei River are presented in Table 3.

Table 3: Biotesting of the Yenisei River.

Concentration of the water sample, %	The value of the optical density, D		The difference D in the tested water, in % of the control	The difference D in the tested water, in fractions to the control
	control	experience		
control	-	-	-	-
1,2	0,132	0,132	0	0,00
3,7	0,132	0,132	0	0,00
11	0,132	0,112	15	0,15
33	0,132	0,118	11	0,11
100	0,132	0,073	45	0,45

Based on experimental data, it can be concluded that toxic effects occur at sample concentrations of 100 %, that is, in an undiluted sample. At lower concentrations, the growth processes of test objects in the samples are suppressed by 20 %. In the test sample, pollutants had an acute toxic effect on chlorella when diluted by 2.2 times.

Studies have shown a high sensitivity of the test object to contamination with basic pollutants. The use of biotesting technology using chlorella algae to assess the quality of natural waters is advisable.

2.1.3 The Bazaiha River

The object of the study is The Bazaiha River, which belongs to the basin of The Yenisei River, flowing into it near the city of Krasnoyarsk. It originates from the uninhabited settlement of Sukhaya Bazaiha. The length is 128 km, the catchment area is 1000 square km.

A large private sector is located in the water protection zone of The Bazaiha River, which has a significant impact on the ecological condition of the watercourse (Shpet, Spitsyna, 2021).

Figure 3 shows a satellite image of the river.

Figure 3: The Bazaiha River.

The results of biotesting samples of The Bazaiha River are presented in Table 4.

Table 4: Biotesting of The Bazaiha River.

Concentration of the water sample, %	The value of the optical density, D		The difference D in the tested water, in % of the control	The difference D in the tested water, in fractions to the control
	control	experience		
control	-	-	-	-
1,2	0,132	0,135	-2	-0,02
3,7	0,132	0,129	2	0,02
11	0,132	0,133	-1	-0,01
33	0,132	0,113	14	0,14

100	0,132	0,043	67	0,67

Based on experimental data, it can be concluded that toxic effects occur at sample concentrations of 100 %, that is, in an undiluted sample. At lower concentrations, the growth processes of test objects in the samples are suppressed by 20 %. In the test sample, pollutants had an acute toxic effect on chlorella when diluted by 2.6 times.

Studies have shown a high sensitivity of the test object to contamination with basic pollutants. The use of biotesting technology using chlorella algae to assess the quality of natural waters is advisable.

2.1.4 The Kacha River

The Kacha River originates near the village of Kacha in the Yemelyanovsky district of the Krasnoyarsk Territory, in the spurs of the Eastern Sayan. It flows into The Yenisei River in Krasnoyarsk. The length of the river is 103 kilometers. The original name of The Kacha River is Izyr-Su.

The Kacha River is a left tributary of the river. The Yenisei River flows through the territory of the Kozulsky and Yemelyanovsky districts. The length of The Kacha River is 120 km, the mouth is located within the city of Krasnoyarsk. The catchment area is 1,270 square kilometers. The average flow rate of the river is 0.4 – 0.5 m / sec, the depth is from 0.1 to 2 m, the average width of the riverbed is 10 – 15 m, in high water it can be 35 – 40 m. The nature of the soil is heterogeneous, rocky soil prevails in the upper reaches, pebble-sandy, silty soils in the lower reaches (Kosarikova, Turovets, Nizovtseva, 2020).

The rivers of the Krasnoyarsk Territory have repeatedly been included in the list of the dirtiest rivers in the territory of the Russian Federation, including The Kacha River.

The Kacha River is a typical mountain river with a rather narrow valley covered with taiga. In the forest-steppe zone, it has a well-developed valley with some contours of terraces. The surface of the floodplain is flat, in places excessively moistened, covered with shrubs and meadow grasses.

Over the past five years, the level in the river has decreased, and there are clear signs of pollution. Common pollutants in the river are phenols, petroleum products, metal compounds: common iron, aluminum, copper, manganese, zinc and chemical oxygen consumption. The river flows through several settlements, which grow every year, thereby increasing the load on The Kacha River system (Kalekulin, Gudaeva, 2022).

Figure 4 shows a satellite image of the river.

Figure 4: The Kacha River.

The results of biotesting samples of The Kacha River are presented in Table 5.

Table 5: Biotesting of Kacha River.

Concentration of the water sample, %	The value of the optical density, D		The difference D in the tested water, in % of the control	The difference D in the tested water, in fractions to the control
	control	experience		
control	-	-	-	-
1,2	0,126	0,109	13	0,13
3,7	0,126	0,112	11	0,11
11	0,126	0,111	12	0,12
33	0,126	0,097	23	0,23
100	0,126	0,084	33	0,33

Based on experimental data, it can be concluded that toxic effects occur at sample concentrations of 33 and 100 %. At lower concentrations, the growth processes of test objects in the samples are suppressed by 20 %. In the test sample, pollutants had an acute toxic effect on chlorella when diluted by 4.0 times.

Studies have shown a high sensitivity of the test object to contamination with basic pollutants. The use of biotesting technology using chlorella algae to assess the quality of natural waters is advisable.

3 CONCLUSION

Chlorella algae is a good biological object to reduce pollution of reservoirs, since they use pollutants as a food source.

With a high reproduction of Chlorella in the reservoir, the number of zooplankton increases, as a result of which the natural nutrition in the reservoir increases, which is a favorable factor for fish reproduction. But, despite all the advantages of this method of reducing the toxicity of waters, Chlorella tends to multiply rapidly, so there is a need to monitor and control the population of algae.

Optical measurement of cell density made it possible to observe the stimulation of their growth. This fact tells us about the increased toxicity of samples taken from different water bodies in Krasnoyarsk and Moscow. The sample taken from The Moscow River has the greatest toxicity.

The fact that a water body is located in an urban area increases the anthropogenic load on the river system. For this reason, the toxicity of the waters of The Moskva River in Moscow and The Kacha River in Krasnoyarsk is similar.

In turn, the high level of chemical pollution of The Yenisei River is known, but given that The Yenisei River occupies the first place in Russia in terms of runoff, it is obvious that the degree of dilution and the ability to self-purify contribute to reducing the overall toxicity of water samples.

The Bazaiha River, despite the fact that it flows to a greater extent outside the territory of the urban agglomeration, organic runoff from agricultural and forest lands affects the increase in water toxicity.

The significance of the study lies in the fact that the possibility of an adequate assessment of the toxicity of analyzed water samples using test organisms has been established.

At the same time, the high sensitivity of the test object, as the weakest link in the ecological system, allows predicting the final result of the toxicity assessment in vivo with high accuracy and reliability.

Thus, the use of biotesting technologies using chlorella algae to assess the quality of natural reservoirs is advisable.

The implementation of the proposed unified method of water toxicity can serve as the basis for a systematic analysis of environmental factors for the development of information and analytical models of population health, providing an assessment of risk factors.

REFERENCES

Onerkhan, G., Durmekbaeva, S. N., Akhmetova, N. P., 2019. Biotesting of Lake Kopa pollution using Chlorella sp-3K cells. *Bulletin of Science and Education.* №18 (72).

Volchanskaya, A. A., Zrazhevskaya, M. S., Nikolaenko, S. N. 2016. Assessment of water toxicity in various regions of the Southern Federal District of the Russian Federation. Young scientist. № 17 (121). P. 315-318.

Speedinskaya, A. A., 2019. Determination of the toxicity of Kurgan water using chlorella algae. Young scientist. № 5 (243). P. 100-101.

The method of determining the toxicity of samples of surface fresh, groundwater, drinking, wastewater, water extracts from soil, sewage sludge and waste by changing the optical density of chlorella algae culture (Chlorella vulgaris Beijer) HDPE 14.1:2:3:4.10-04 16.1:2.3:3.7-04. Moscow, 2004. 26 p

Yashin, I. M., Vasenev, I. I., Gareeva, I. V., Chernikov, V. A., 2015. Ecological monitoring of the waters of the Moskva River in the metropolitan metropolis. Izvestiya TSKHA. №5.

Badmaeva, S.E., Sokolova, Yu.A., 2017. Monitoring of the hydrochemical state of the Yenisei River in Krasnoyarsk. *Bulletin of the KrasGAU.* №8.

Shpet, S.D., Spitsyna, T.P., 2021. Dynamics of the surface water pollution index of the Bazaiha river of the Krasnoyarsk agglomeration for 1999-2020. *Actual problems of aviation and cosmonautics.*.

Kosarikova, D. D., Turovets, V. E., Nizovtseva, P. V., 2020. Problems of small rivers of Siberia the ecological state of the Kacha River water in the city of Krasnoyarsk. Actual problems of aviation and cosmonautics : A collection of materials of the VI International Scientific and Practical Conference dedicated to Cosmonautics Day. In 3 volumes, Krasnoyarsk, April 13-17, 2020 / Under the general editorship of Yu.Yu. Loginov. Volume 2. Krasnoyarsk: Federal State Budgetary Educational Institution of Higher Education "Siberian State University of Science and Technology named after Academician M.F. Reshetnev", P. 491-493.

Kalekulin, V. B., Gudaeva, E. A., 2022. The state and quality of the Kacha river of the Krasnoyarsk Territory. Reshetnev readings : materials of the XXVI International Scientific and Practical Conference dedicated to the memory of the General Designer of rocket and Space Systems, Academician M. F. Reshetnev, Krasnoyarsk, Volume Part 1. – Krasnoyarsk: Federal State Budgetary Educational Institution of Higher Education "Siberian State University of Science and Technology named after Academician M.F. Reshetnev", P. 772-775.

Digitalization and Digital Transformation in the Field of Russian Sports: Prospects for Legal Regulation in the Context of the Transition to a Digital Economy

Inyushkina M.N. [1], Inyushkin A.A. [2], Inyushkin A.N. [3]
Samara National Research University, Samara, Russia,
13lana13@mail.ru, inyushkin_a@mail.ru, ainyushkin@mail.ru

Keywords: Digitalization, digital transformation, Russian sports, legal regulation, digital economy, Covid-19, Lex sportiva, strategic documents of the Russian Federation.

Abstract: This article analyzes the prospects for improving the legal regulation of digitalization and digital transformation in the field of sports of the Russian Federation. The trends in these social relations, the prerequisites for digitalization and digital transformation in sports are determined. The main approaches to digital transformation in the context of the consequences of the COVID-19 coronavirus pandemic are analyzed. The stages of development the digital transformation of sports are considered through the assessment of regulatory directions for their implementation. The approaches to regulating the field of sports through various legal structures are analyzed, in particular, the analysis of the use of "Lex sportiva" for the purposes of digitalization of sports is given. This paper concludes that it is permissible to apply special legal regimes to test the mechanisms of digital transformation in the field of sports, but on a limited scale. The paper concludes that there are trends in the transition of legislation in the field of sports from the "Lex sportiva" concept to the formation of a stable regulatory framework that is associated with proven legal structures. It is proved that the Decree of the Government of the Russian Federation dated 07.02.2024 No. 264-p "On approval of the strategic direction in the field of digital transformation of physical culture and sports until 2030" has become the main regulatory act in the field of digitalization and digital transformation of sports, which is synchronized with other strategic documents of the Russian Federation in the field of digitalization and sports.

1 INTRODUCTION

In the modern conditions of the information society, when mass network communication and globalization are taking place, the development of digital technologies is becoming an important direction of state policy in the field of Russian sports. Russian legal regulation in the field of digitalization is constantly being optimized and increasingly affects certain branches of law characteristic of all spheres of human activity: economics, medicine, manufacturing, sports and education.

In the 90s and early 2000s, the process of automation was popular – the transfer of data from paper to electronic media. Nowadays, the concept of automation has undergone new changes and has become much broader. The resulting social processes are reflected in the regulatory framework and are referred to as digitalization. Many processes occur without human intervention and the emergence of artificial intelligence systems has optimized work processes and improved the quality of life. The development of robotics gives rise to regulatory challenges, including already familiar relationships associated with: "smart" machines, the Internet of Things, "smart homes", humanoid robots, and unmanned transport. The sphere of sports regulation has also developed significantly due to the influence of digitalization trends. The Decree of the Government of the Russian Federation dated 07.02.2024 No. 264-p "On approval of the strategic

[1] https://orcid.org/0009-0001-2959-0150
[2] https://orcid.org/0000-0001-8564-4275
[3] https://orcid.org/0000-0002-3678-2636

direction in the field of digital transformation of physical culture and sports until 2030" was adopted, which regulates the main targets for digitalization of various sports during digital transformation. At the same time, the reasons for significant changes in the regulation of sports and the introduction of digitalization are that, according to the results of 2020, the field of sports was significantly influenced by many key factors characteristic of this area of regulation (Hemalatha, 2023). The COVID-19 coronavirus pandemic has had an extremely negative impact on all processes in sports. Sports organizations lost income because they were unable to provide citizens with a wide range of their own services. In parallel with these processes, the sports season began for most sports, the organization of preparation and holding of competitions, the organization of various events, seminars, and training camps began. In industries that are directly or indirectly related to the sports industry, there were difficulties in their work processes. There was a need to change business strategies in the short and long term, as well as to significantly adjust regulatory documents in the field of sports. At the same time, in order to achieve maximum efficiency from the adoption of a regulatory framework in the field of sports, it was necessary to predict the model of its development. The main stages of the development of the legislative framework in the field of sports in Russia were identified, which were formed on the basis of an assessment of the ongoing social processes. The first stage in modern Russia is associated with the crisis of the sports industry – the 90s of the 20th century (lack of facilities, lack of funding, lack of motivation for sports). This is a model of exploitation that does not contain any interest in sports. Next, the second stage was identified, which dates back to the first two decades of the 21st century – stabilization of the industry (infrastructure is developing, large budgetary financing is received, the need for new services and social services appears, public-private partnership is formed in the creation of sports facilities, an interdepartmental mechanism of interaction is formed). All this reflects the infrastructural development model and the growing interest in sports. The third stage is the present time, where we can observe the expansion of the role of business in sports, the development of digital solutions, new management competencies, the uberization of the potential of industry participants, and a digital-oriented sports economy. This is already a service model of development, in which everyone is provided with their own package of services.

At a working meeting of the working group on digital transformation of the physical culture and sports sector at the Ministry of Sports of the Russian Federation, held on May 20, 2020 to stabilize the situation caused by the consequences of the COVID-19 coronavirus pandemic, the following five target groups were identified: the sports community, the population, educational organizations, entrepreneurs, regulators. Each of the groups received their own targets in the field of digitalization of sports, the implementation of which in recent years has shown the need to adjust the existing regulatory framework. The Decree of the Government of the Russian Federation dated 07.02.2024 No. 264-p "On approval of the strategic direction in the field of digital transformation of physical culture and sports until 2030" is the logical conclusion of this work and its systematic analysis allows to make predictions about the prospects for legal regulation of sports in the context of the transition to a digital economy.

2 METHODS

In this study, general and specific methods of social sciences were used. The methods of legal science, which include the method of comparative law, the method of legal modeling, and the input-output method, were applied to the special subject areas of this study. Thus, in particular, the general scientific method of historicism and a special sectoral method were used to assess the regulatory impact of by-laws. The prospects for the development of the regulatory framework under the influence of digitalization trends were analyzed using the method of legal modeling, and their specificity was examined through the method of comparative law. Assessments of social processes in the field of sports were carried out using the synthesis method, which made it possible to correlate data on the state of legal regulation with emerging social relations. Separately, in this study, the method of comparative law was applied to distinguish between private law and public law principles in regulating the digital transformation of sports.

3 RESULTS

3.1. Digitalization in the field of sports

The improvement of legislation in the field of sports significantly affects the speed of digitalization of sports. The central place in this process is occupied by regulatory acts of executive authorities. They form the regulatory basis for making a profit from this activity, which means they create economic preconditions for the introduction of new types of digital technologies in the field of sports. A clear example reflecting these processes is such a sport as football. In Russia, there are many children's and adult football schools that compete with each other and strive to increase their client base and revenue. The active integration of digital tools has become a competitive advantage for the City Football Moscow League. The system developed by Sportsoft for the football league, which cooperates with FC Spartak, has been developing for more than five years.

City Football Moscow popularizes and attracts people of all ages to football classes through digital tools. The league has more than a hundred participants. Analyzing their experience, the number of football schools, infrastructure facilities, tournaments and other projects in Moscow has increased dramatically. These processes are fully reflected in the regulatory framework of the city of Moscow. The Decree of the Moscow Government dated 20.09.2011 No. 432-ПП (as amended on 14.03.2023) "On approval of the State Program of the City of Moscow "Sports of Moscow" directly establishes the digitalization of the sports industry. The Department of Mass Sports Development and Digitalization of the Sports Industry of the Department of Sports of the City of Moscow is actively working in the structure of the Department of Sports of the City of Moscow. This is precisely where the social and synergistic effect of the interaction of private law initiatives with public law principles enshrined in the regulatory framework lies. It is worth noting that the impact of the indicators adopted at the regulatory level from the introduction of digitalization in the field of sports has significantly increased the number of places and vacancies for novice coaches, referees, sports journalists, videographers and photographers covering sports competitions.

Conducting trainings using the digital tools of the City Football Moscow league allows to create a player profile (statistics by season, progress graph), player rating based on statistical data, group profile (training dates, statistics, performance index, rating of the best players), trainer profile (personal account), automated referral system, questionnaires, e-mail newsletters.

In this way, young athletes and adult amateurs receive comprehensive information about their level of physical fitness, have the opportunity to monitor statistics and progress charts with the help of a qualified coach and thereby hone their skills. Athletes receive modern media support, including regular photo reports, video recordings of matches, and highlights. They become the heroes of interviews, thematic columns and receive valuable prizes for participating in league events.

It should be summarized that the digitalization of sports leads to a service model of the sports industry, and the main effects achieved can be divided into five groups.

Achievable effects of digitalization in sports:

1) Uberization will make the competencies of leading athletes and experts available to everyone;

2) Mobile services will increase the demand for infrastructure and services of sports facilities;

3) Digital platforms will unite industry resources and allow for the management of development and competencies;

4) Government agencies will be able to respond online to changing trends in the industry's economy, the role of CDO appears

5) New business models will ensure the transition from an "infrastructure" to a "service" development model.

The service model generated by the prerequisites for the digitalization of sports was reflected in the Decree of the Government of the Russian Federation dated 07.02.2024 No. 264-р "On approval of the strategic direction in the field of digital transformation of physical culture and sports until 2030" and has now moved from the category of regional initiatives to the federal level. This regulatory process has influenced the management structure of the digitalization of the sports industry in Russia. The following levels can be distinguished:

- federal segment – strategic and tactical;
- regional segment – tactical and operational.

Thus, digitalization in the field of sports improves service within all processes and has a positive impact on the results of its implementation. Each participant in relations in the field of sports is subject to digitalization and becomes a user of a certain set of digital services and, at the same time, becomes a producer of a certain set of data.

3.2. Digital transformation in the field of sports

Under the influence of digitalization, a systemic digital transformation is taking place in the field of sports. At the legislative level, the tasks of digital transformation have also been significantly reflected. At the same time, a comprehensive understanding of this process requires scientific understanding. Digital transformation is a comprehensive change in processes that creates a qualitatively new digital foundation. The most striking example of digital transformation is Amazon, which was a bookstore for several decades, but under the influence of digitizing all processes, formed an entire global market that significantly went beyond the original processes. In the field of sports, digital transformation is significantly related to public authorities. In particular, the Ministry of Sports of the Russian Federation is actively engaged in the implementation of digital transformation processes to adjust the model of interaction between subjects in sports. A qualitatively new unified digital platform is being formed, giving freedom to participants in sports relations and uniting them into one system. The Decree of the Government of the Russian Federation dated 21.10.2022 No. 3102-p "On approval of the Concept for the creation and operation of the unified digital platform of the Russian Federation "GosTech", the action plan ("roadmap") for the creation of the unified digital platform of the Russian Federation "GosTech", stipulates that such a system will be hosted on the "Sport" domain and will primarily include several client paths and services.

The need for digital transformation of the most important spheres of modern life is reflected in important documents such as the national projects “Digital Economy” and “Strategy for the Development of the Information Society in the Russian Federation for 2017–2030”, which reveal the main directions of development of the Russian Federation in the near future.

At the plenary session of the St. Petersburg International Economic Forum on June 2, 2017, it was indicated that the digital economy is not a separate industry, in fact, it is the basis that allows for the creation of qualitatively new models of business, trade, logistics, production, changes the format of education, healthcare, public administration, communications between people, and, consequently, sets a new paradigm for the development of the state, economy and the entire society. Thus, the process of introducing digital technologies at the current level of development of society primarily involves the digital transformation of the main functions in activities, i.e. the transition to new digital operational and business models in production and management. Similarly, digital transformation in sports should be understood as a complete restructuring of the sports training process, which includes not only the methodology and means of training, but also changes in the competency model, in the semantic model of the sports program, changes in approaches to assessing the work of coaches, as well as digital management of routine processes in a sports organization, namely personnel records, financial management, and document flow. As a result, digital transformation in sports requires a qualitative restructuring of all activities of the divisions of a sports organization. In these conditions, considerable attention should be paid to updating the model of the sports training process based on the use of modern digital information technologies, most of the components of this process, such as goals, means, content, training methods, organizational forms of implementation.

It should be noted that the digital transformation of the sports system should include a systematic update of the information infrastructure and improvement of the sports training system, including the training of relevant personnel. The availability of optimal personnel for digital transformation must include their knowledge of modern information and digital technologies and the ability to use them to solve professional problems. Such personnel must meet the criteria for the comprehensive implementation of digital technologies in the field of sports, acting as new sources and methods of obtaining information, as well as tools that allow achieving certain results in the process of training athletes.

It should be noted that a serious impetus for digital transformation in the field of sports was the use of remote work formats in the training process, caused by the spread of coronavirus infection (2019-nCoV). Modern digital information technologies, which were supposed to cover not only the training process itself, but also the timely implementation of all organizational activities, significantly accelerated the process of digital transformation in the field of sports. At the same time, many coaches faced difficulties associated with both the creation and use of digital resources in the training process. For sports organizations, the transition to remote work has become a real challenge, requiring urgent digital solutions to manage new emerging relationships. Therefore, issues related to the analysis and generalization of the experience of the digital transformation of the sports sector that have taken place in recent years are of significant importance. Considering the structure of digital transformation in sports, a number of objects, directions and technologies can be distinguished. Among the objects of digital transformation in sports, it is necessary to highlight federations, leagues, sports clubs, sports schools, infrastructure facilities, regional executive authorities and federal executive authorities. The areas of digital transformation of sports include customer experience (digital analytics of customer feedback, points of contact, revenue growth), operational processes (digitalization of employee activities, including performance management, primarily a painless transition to a remote work format), business models (digital processes within companies). Among the interesting examples of changing business models and the transition to digital globalization is the launch of franchises by sports schools. A number of local schools have become all-Russian, and some have become world-wide. Analyzing their successful experience in the field of digital transformation, the following should be highlighted: digital transfer and control of methods, digital collection of payments, digitalization of document flow, including all the consolidation of the full cycle of the technological process using information systems. Considering the third element of the structure of digital transformation in the field of sports, it is necessary to highlight the most popular technologies that have gained a dominant position in the field of sports. These include websites, mobile applications, social networks, CRM systems, video streaming, timing systems, statistical systems, video analytics systems, and health monitoring systems.

3.3. Prospects of regulation in the field of digitalization and digital transformation of sports in the Russian Federation

The Decree of the Government of the Russian Federation of 07.02.2024 No. 264-p "On approval of the strategic direction in the field of digital transformation of physical culture and sports until 2030", adopted in 2024, became the main regulatory act aimed at regulating relations in the field of digitalization and digital transformation of sports in the Russian Federation. This strategically oriented bylaw formed the legal basis for the introduction of digitalization in the field of Russian sports, and also provided the regulatory prerequisites for the digital transformation of subjects in the field of sports. The analysis of this regulatory act shows the systematic nature of legal technique in its adoption. The structure of this document allows us to speak about its programmatic nature. The relationships described in it are associated with different levels of influence on processes in the field of sports, ranging from federal tasks to regional aspects. Separately, it is worth highlighting the presence in the document of target indicators that can form the basis for analysis and statistics on the implementation of certain solutions in the field of digitalization of sports. It should be noted that the document is synchronized with other regulatory legal acts in the field of sports of the Russian Federation, first of all, with the Decree of the President of the Russian Federation dated 09.05.2017 No. 203 "On the Strategy for the Development of the Information Society in the Russian Federation for 2017-2030", as well as the Order of the Government of the Russian Federation dated 24.11.2020 No. 3081-p (as amended on 29.04.2023) "On approval of the Strategy for the Development of Physical Culture and Sports in the Russian Federation until 2030". As the authors rightly note, digitalization creates a large number of challenges for legal technology (Alimova, Afanas'eva, Bakulina, 2022; D'yakonova, Efremov, Zajcev, 2022; Budnik, Zverev, 2022). Digitalization and digital transformation in the field of sports have significantly influenced the system of sports law and trends in law enforcement practice. In the absence of special legislative acts in the field of digitalization of sports, “Lex sportiva”, which is understood as a set of rules of “soft” procedural and substantive law applicable to the resolution of sports disputes, acquires a particularly significant role (Orlova, 2006; Pogosyan, 2011; Mel'nik, 2022; Zaharova, 2019). Thus, in the absence of special legislative acts for the field of sports, digitalization processes have special legal structures optimal for launching the process of digital transformation. It is these legal mechanisms characteristic of the field of sports law that make it possible to quickly solve the tasks set in the strategic documents of digitalization and digital transformation of sports in the Russian Federation.

4 DISCUSSION

The main scientific discussion of the issues of digitalization and digital transformation of sports lies in the plane of economic and social processes (Ponkin, Red'kina, 2020; Vaganova, 2017; Petrov, 2020; Stecenko, SHirobakina, 2019). At the same time, issues of normative regulation of relations arising in this area remain outside the scope of major scientific research and are reduced to a point analysis of law enforcement acts, including decisions of international sports courts (Piduru, 2024; Alekseev, Kamenkov, Mel'nik, 2023; Peshin, 2019). In such conditions, it is extremely problematic to formulate optimal scientific approaches to developing a regulatory framework in the field of digitalization and digital transformation of sports. At the same time, the use of the “Lex sportiva” mechanisms for the prompt regulation of various new social relations in the field of sports generated by the processes of digitalization and digital transformation is quite reasonable from the point of view of the principle of legal economy. It should be noted that a number of authors recommend using special legal regimes for similar relations on digital transformation in other areas, including the regulatory sandbox regime (Bredihin, 2019; Demchenko, SHajdullina, 2020; Barakina, 2021). Such initiatives can be assessed positively, however, the specifics of sports law give rise to a large number of subtleties that cannot be resolved through special legal regimes. In these conditions, the development of special legislative acts for the implementation of a regulatory sandbox regime for digitalization and digital transformation in the field of sports does not seem to be an entirely optimal regulatory structure. At the same time, the use of theoretical developments on similar relations in the field of digitalization of other sectors of the economy and the social sphere to develop an appropriate regulatory framework in the field of sports seems reasonable and fully justified.

5 CONCLUSIONS

The spread of coronavirus infection (2019-nCoV) has significantly affected digitalization and digital transformation in the field of Russian sports. The negative consequences of the COVID-19 coronavirus pandemic have created the prerequisites for the introduction of digitalization in the field of Russian sports, as well as formed the basis for the digital transformation of most processes. Such significant changes in public relations required adjustments to the regulatory framework.

The state adopted the Order of the Government of the Russian Federation dated 07.02.2024 No. 264-p "On approval of the strategic direction in the field of digital transformation of physical culture and sports until 2030", which set the task of involving at least 70% of the population of the Russian Federation in sports by 2030. The solution to this ambitious task is possible only with the widespread digitalization and digital transformation of the sports sector. In this regard, three key areas are identified on the path to achieving the target indicators defined in the Decree of the Government of the Russian Federation dated 07.02.2024 No. 264-p:

1. Involvement of the general population in sports in the Russian Federation
2. Improving the efficiency of physical culture and sports organizations
3. Organization of systematic work in conditions of the continuing danger of the spread of infections similar to COVID-19

Analysis of the latest legislative trends demonstrates that five priority areas of digitalization in the Russian sports sector have been legally enshrined: the introduction of an open system of digital platforms in the sports industry, which combines all services for authorities, citizens and businesses; the National Sports Rating, determined on the basis of physical activity, participation in amateur and professional competitions; the system of continuous development of competencies "Sports University 2030", including digital economy competencies; regular monitoring of the health of citizens using digital services integrated with Gosuslugi service; improving digital literacy and meeting the needs of physical education and sports personnel in advanced training programs, including the formation of digital economy competencies. The Decree of the Government of the Russian Federation dated 07.02.2024 No. 264-p "On approval of the strategic direction in the field of digital transformation of physical culture and sports until 2030" has become the main regulatory act in the field of digitalization and digital transformation of sports, which is synchronized with other strategic documents of the Russian Federation in the field of digitalization and sports.

Assessing the prospects for legal regulation of digitalization and digital transformation in the field of Russian sports, it should be noted that all the main factors that have a significant impact on this area of public relations have been formed. Thus, legislation in the field of sports will gradually move from the “Lex sportiva” design to the formation of a stable regulatory framework that will be associated with proven legal structures. The use of special legal regimes, including the regulatory sandbox, is advisable only within a limited framework. Obtaining data from new legal structures within the framework of using the regulatory sandbox regime will make it possible to think through targeted adjustments to the regulatory framework in the field of digitalization and digital transformation in the field of Russian sports. Such a careful approach to the development of the regulatory framework allows us to positively assess the prospects for the development of these relations in the field of sports of the Russian Federation.

ACKNOWLEDGMENT

The study was supported by the Russian Science Foundation (Grant No. 23-28-00720).

REFERENCES

Hemalatha, Dr. N.б 2023ю Heena Begum Impact of Covid-19 on digitalization in education sector. *International journal of management (IJM)*, Volume 14, Issue 3. P. 69 - 76.

Chellammal Surianarayanan An introduction to digital transformation technologies. *International journal of advanced research in engineering and technology (IJARET)*, Volume 11. Issue 2. 2020. P. 419-425.

Informaciya s oficial'nogo sajta Ministerstva cifrovogo razvitiya, svyazi i massovyh kommunikacij RF «Pervuyu ochered' gosservisov na domene «Sport» v blizhajshee vremya perevedut na «Gostekh» URL: https://digital.gov.ru/ru/events/48824/ (data obrashcheniya: 13.04.2024).

Plenarnoe zasedanie Peterburgskogo mezhdunarodnogo ekonomicheskogo foruma. 2 iyunya 2017 g. Sankt-Peterburg. URL: http://www.kremlin.ru/events/president/news/54667 (data obrashcheniya: 13.04.2024).

Alimova, D.R., Afanas'eva, S.A., Bakulina, L.T., 2022. Probely v prave v usloviyah cifrovizacii: sbornik nauchnyh trudov. 472 s.

D'yakonova, M.O., Efremov, A.A., Zajcev, O.A., 2022. Cifrovaya ekonomika: aktual'nye napravleniya pravovogo regulirovaniya: nauchno-prakticheskoe posobie. 376 s.

Budnik, R.A., Zverev, M.O., 2022. Intellektual'nye prava gejmerov. *Zakon.* № 7. 126 - 147.

Orlova, E.V., 2006. Sport kak ob"ekt pravovogo regulirovaniya v Rossii. Sport: ekonomika, pravo, upravlenie. M.: YUrist. № 3. S. 16 - 20.

Pogosyan, E.V., 2011. Formy razresheniya sportivnyh sporov: monografiya. M.: Volters Kluver, 160 s.

Mel'nik, V.N., 2022. Garmonizaciya struktury lex sportive. *Aktual'nye problemy rossijskogo prava.* № 11. S. 100 - 110.

Zaharova, L.I., 2019. Lex mercatoria i lex sportiva: osobennosti, skhodstva i razlichiya. *Lex russica.* № 11. S. 70 - 78.

Ponkin, I.V., Red'kina, A.I., 2020. Nadlezhashchee upravlenie» v normativnom prostranstve sporta: rol' lex sportiva i Mezhdunarodnogo sportivnogo arbitrazhnogo suda. *Zakon.* № 8. S. 44 - 50.

Vaganova, O. I., 2017. Vozmozhnosti oblachnyh tekhnologij v elektronnom obuchenii. *Mezhdunarodnyj zhurnal prikladnyh i fundamental'nyh issledovanij.* № 6 (chast' 2). S. 183 - 187.

Petrov, P.K., 2020. Cifrovye informacionnye tekhnologii kak novyj etap v razvitii fizkul'turnogo obrazovaniya i sfery fizicheskoj kul'tury i sporta. Sovremennye problemy nauki i obrazovaniya. № 3.

Stecenko, N.V., SHirobakina, E.A., 2019. Cifrovizaciya v sfere fizicheskoj kul'tury i sporta: sostoyanie voprosa. *Nauka i sport: sovremennye tendencii.* №1.

Piduru, B.R., 2024. Healthcare customer experience and cybersecurity: protecting patient data in a digital era. *International journal of cyber security (IJCS)*, Volume 2, Issue 1, P. 17-27.

Alekseev, S.V., Kamenkov, V.S., Mel'nik, V.N., 2023. Garmonizaciya sistemy organov rassmotreniya i razresheniya sportivnyh sporov. *Arbitrazhnyj i grazhdanskij process.* № 6. S. 3 - 8.

Peshin, N.L., 2019. O statuse i yurisdikcii Sportivnogo arbitrazhnogo suda v Lozanne. *ZHurnal zarubezhnogo zakonodatel'stva i sravnitel'nogo pravovedeniya.* № 5. S. 125 - 139.

Bredihin, A.A., 2019. Resheniya Sportivnogo arbitrazhnogo suda i Palaty FIFA po razresheniyu sporov, obladayushchie siloj precedenta (na primere trudovyh sporov v sfere futbola). *Mezhdunarodnoe pravosudie.* № 3. S. 59 - 68.

Demchenko, M.V., SHajdullina, V.K., 2020. Pravovoe regulirovanie elektronnoj torgovli v usloviyah funkcionirovaniya special'nyh pravovyh rezhimov. *Predprinimatel'skoe pravo.* № 3. S. 37 - 45.

Barakina, E.YU., 2021. K voprosu ob ustanovlenii eksperimental'nogo pravovogo rezhima v oblasti primeneniya iskusstvennogo intellekta. *Rossijskaya yusticiya.* № 2. S. 64 - 67.

Belyh, V.S., 2024. Sovremennye vyzovy i perspektivy razvitiya bankovskoj sistemy Rossii v usloviyah cifrovizacii. *Bankovskoe pravo.* № 1. S. 39 - 47.

Formation of Sustainable Development of the Architecture of the Future in the Context of the Information Paradigm

Natalia Saprykina[1]
The Moscow Architectural Institute (State Academy), 11/4, building 1, p. 4, Rozhdestvenka Street, Moscow, Russia
nas@markhi.ru

Keywords: Global information system, Society 5.0 strategies, Big Data technology, Smart city, Integral space, Sustainable development, Architecture of the future

Abstract: The article discusses ways to form sustainable development of the architecture of the future in the context of the information paradigm. The purpose of the article is to identify trends in the formation of an integrated information space interactively connected with the living environment. The theoretical platform of the information paradigm and the prerequisites for its emergence are substantiated. The evolution of sustainable development of architecture is determined in the context of the "Society 5.0" strategy, using information technologies of cybersecurity, artificial intelligence and robotics. The use of "Big Data" technology in the formation of the "Smart City" concept in terms of intelligent automated control systems is considered. The tools of interactive technologies for the formation of the architecture of the electronic era have been identified: a global information system of interaction in architectural design with the development of a new holistic hybrid communication environment. It is noted that the integral space and the global information and communication environment have a complex relationship with the intensification of means of communication. The results of the study can be useful for the theory and practice of shaping the living space of the future, as they open up completely new possibilities for its architectural design.

1 INTRODUCTION

The rapid progress of information technology and telecommunications that has emerged throughout the world contributes to the fact that information is becoming one of the main economic resources for the development of society. Information networks form a new global information and communication environment for life, communication and production, and also create opportunities for the creation and development of network structures in various areas of public life. In a dynamically changing society, the role of architecture is being transformed in the context of the new strategy "Society 5.0" and information technologies such as "Big Data".

New information technologies are changing the idea of architectural design, as the capabilities of technology are being integrated with the corresponding human needs. In connection with the global information system as an integrated information space, interactively connected with the living environment, innovative approaches to providing information and organizing its consumption can be introduced when creating appropriate architectural objects.

The role of architecture in a dynamically changing society is transforming. Computer technologies used in architectural activities have significantly changed the possibilities of designing of vital activity objects. Information design is becoming the leading direction of architecture, which uses concepts such as interactivity, a virtual reality, parametric design (Saprykina, 2017).

With the advent of new technologies, the formation of a new aesthetics began, the so-called free form, where the ideas of dynamism, fluidity and synergy become the dominant and active elements of shaping in architecture. The implementation of this in practice is possible thanks to digital technologies and cybernetic mechanisms. As a result, architecture has the ability to change, which allows the structure, form and function of an architectural object to acquire interactivity and automation properties. Происходит

[1] https://orcid.org/0000-0003-2003-0744

моделирование объекта как некого организма, основанного на идее самоорганизации эволюционирующей системы (Gogolkina, 2018).

In this regard, it is of interest to consider the evolution of the formation of the architecture of the future in the context of the information paradigm of the development of society on the basis of objective methods developed in information science, which studies space and spatial organization of information and information systems (Saprykina, 2018). Due to the relevance of this problem, it seems appropriate to consider new approaches to the formation of the information space of the future as a separate category of the architectural environment in the context of the following areas.

2 MATERIALS AND METHODS

2.1 Theoretical Platform of the Information Paradigm and the Prerequisites for its Emergence

2.1.1 Evolution of Sustainable Development of Future Architecture in the Context of the Strategy "Society 5.0"

The declining amount of the planet's internal resources and the sharp drop in living standards necessitate a qualitatively new approach for the further development of society. An effective solution in this situation is the creation of an interactive and intelligent system for managing the country's economic development (Baitenov, 2020). In this regard, to improve the quality of human life, the recently emerged "Society 5.0" strategy is to solve social problems through the integration of the digital environment and the physical living space. It should be noted that the previously created strategies "Society 1.0 and 2.0" were based on and associated with the development of agriculture. At the next stage of the industrial revolution, the "Industry 4.0" strategy emerged, associated with the construction of smart factories and the penetration of innovative technologies into all spheres of life (Sawyer, 2017).

The model of a "super-smart" living environment within the framework of the "Society 5.0" strategy proposes the creation of integrated intelligent systems in all areas of activity in the context of sustainable development. According to the developers, this will be realized through the use of components that apply technological advantages in the following systems: robotics, drive technology, biotechnology, human interface technology, materials and nanotechnology, light and quantum technology, innovative methods of measurement, information and energy transfer (Vorozhikhin, 2016).

Many technologies that have already changed industrial production play an important role in solving social problems and transforming society to create comfortable conditions for its existence in the future. In these developments, in order to create a mutually agreed upon development of the economy and society, the main attention is paid to the rational development of energy, environmental conservation issues, the development of automation of organic farming and livestock breeding, and the qualitative development of industry. The logic of development of the vital activity environment determines an alternative understanding of architecture as a new spatial system (Balatsky, 2007).

Creating a "smart", safe and comfortable human environment is one of the objectives of the "Society 5.0" strategy as a super-intelligent society, with the aim of its technological and social development. The strategy is aimed at solving global crises that arise simultaneously with the acceleration of the pace of social life and the merging of material and cyberspace. This leads to the emergence of new opportunities for movement, automation of life support and transport systems, as well as the need to form completely new spatial typologies (Kurcheeva, Bakaev, Klochkov, 2020).

An example of this concept is the project "*House of the Future Inspired by the Matrix*" (author Kuangyi Tao) 2011 (USA), responding to emerging modern problems of overpopulation, lack of resources, etc. Using the concept of "cell body" development, a house design is proposed that is based on a system of energy and information exchange controlled by its inhabitants. The main infrastructure of the house frame is created from an alloy of memory plates, which can be located at a distance from each other. The overlay computer network used in this project operates by analogy with the work of the heart shell. The proposed material is electrically sensitive and is capable similar to cardiac muscles can expand or contracting by the various electrical stimulation. Such material reacts to changes in the object's program, for example, more intensive filling in a room leads to the expansion of its shell and an increase in space. The spatial concept of a house is similar to a living organism, capable of independently organizing and functioning depending on the changing needs of its inhabitants (Tao, 2011).

It is predicted that in the near future, many professions not related to creative search will be eliminated and replaced by automated systems in order to save resources. Architecture can provide innovative approaches to achieving the goals and initiatives of the Society 5.0 strategy. Ensuring the continuous growth of social sustainability in times of crisis becomes possible through the formation of a living space as an alternative ecosystem.

2.1.2 Use of Big Data Technology in the Formation of the Smart City Concept

Architecture as a system for the formation of artificial space is influenced by the innovation revolution taking place in the world in the context of the development of scientific and technological progress, new areas of knowledge are being attracted to architectural research, which makes it possible to form a completely new urban space that provides quality of life. Therefore, society faces the problem of ensuring sustainable coexistence of cities with the environment without causing critical damage to it.

This paradigm is implemented in the concept of forming a "Smart City" as a new integrated living environment, which includes a set of environmental problems aimed at searching for new forms of urban space using innovative engineering technologies. The new trend of a sustainable city as a complex system of metabolic processes will require a deep rethinking of the ways of its planning and management (Saprykina, 2018).

In this regard, for the integrated formation and management of a Smart City, it is advisable to use Big Data technologies in urban planning, territorial zoning, as well as in solving transport problems, security issues and social comfort. It should be noted that the concept of using Big Data can also help in solving issues of human life safety and improving transport and pedestrian communications using intelligent automated control systems (Volynskov, 2017).

At the present stage of the scientific and technological revolution, science is transforming into a leading element of the productive forces, and scientific activity is turning into a leading branch of social production. One example of the manifestation of this trend is the project "*Inform City*" (author V.I. Bodyakin) 1992 (Russia), which is a self-developing socio-economic and architectural structure. Its main task is complete information support and management of the regional infrastructure. In Inform City, in addition to the main information and management task, the entire range of production, household and leisure issues can be comprehensively solved, and many modern acute environmental problems can also be solved along the way. The project technologically merges three important areas of development: the cultural and historical component, high information and progressive socio-economic technologies. Such architectural and information facilities can have an intercontinental, regional and national level in terms of capacity with scientific, information, coordination, management and production content. Information and dispatch management and technology centers do not require a large number of service personnel and can be located at a considerable distance from each other. These new forms of providing information and organizing its consumption may well be introduced when creating appropriate objects in the global system of electronic architectural information centers (Bodyakin, 1993).

The development of information technologies for transmitting information makes it possible to create new opportunities for accessing it and servicing it, which cannot be implemented and used without powerful information centers for storing, creating and using these resources. In this regard, the use of space communication potential, which is closely connected with the information system, is of particular importance. To use an information resource, a different technological level is required, improvement of means of storing and transmitting information, as well as its full interactivity (Gogolkina, 2018).

An example of the implementation of such an approach is the project proposal "*Data Skyscraper as the Sustainable Data Center in Iceland*" (authors V. Mercuri, M. Merletti) 2016 (Italy), which is designed to host various servers used by many types of companies for store and process all the information data created on a daily basis.. Modern data centers consume a lot of electricity and have a large "carbon footprint", and equipment must be constantly cooled to avoid overheating. The proximity to the Arctic Circle allows using the cold and fresh sea breeze to cool servers, avoiding the cost of a traditional cooling system. From the outside, the center is a cylindrical tower, on the outer façade of which all hardware components are mounted. In addition, the tower façade is a flexible and continuously evolving system that changes, if necessary, the density and position of equipment elements, which allows you to freely change and increase the height of the tower (Mercuri, Merletti, 2016).

According to some researchers, the use of information storage and processing centers in the future will make it possible to create complex objects and systems in almost all parts of the city, where engineering equipment will become part of its infrastructure network using Big Data technology (Gnevanov, Ivanov, 2018).

These trends are further developed in proposals for the creation of a secure archive to preserve the world's heritage and the world's most remarkable achievements. This is because, over the centuries, many cultural relics, works of art and manuscripts have been destroyed in social and economic conflicts. An example is the project "*Data Cemetery Skyscraper*" (authors Joanna Targowica and Mateusz Binkowski) 2017 (Poland), which is based on the concept of an ever-changing world that needs a new kind of environmental object in order to perpetuate the cultural impact of people on society. The proposed architectural object is presented as a memorial tree that, due to its structural integrity, can survive harsh environmental conditions and natural disasters. Denser branches are a sign of natural disaster, war or epidemic, thinner branches represent peacetime. Information data stored inside the diamond memory is guaranteed against destruction, so the "cloud" archive, according to the authors, will be the greatest achievement of humanity and, especially, after a global cataclysm (Targowica, Binkowski, 2017).

2.2 Tools of Interactive Technology for Forming the Architecture of the Electronic Age

2.2.1 Global Information System of Interaction in Architectural Design

To identify trends in the development of the information space of the architecture of the future, it becomes advisable to consider the general direction of creating objects located in the operational field of architecture and urban planning, which use the latest information technologies and resources. This concept allows not only to understand the importance and necessity of updating the global information system in the context of the theory of knowledge, but also to determine general approaches to its formation (Ptichnikova, 2020).

New information technologies are changing our understanding of architectural design, which is a multi-level system, which necessitates the development of a new holistic hybrid environment for architectural design. The result is a hybridization of object, space, and process and design environment. A communication environment emerges, which includes means of presenting a project idea, tools for managing the project process and information support systems. The main principle of the hybrid architectural design environment is interaction through a computer, rather than interaction with a computer (Asanovich, 2007).

In accordance with the demands of the time, the information space is being allocated into a separate category of the architectural environment, based on the analytical systematization of factors and the optimal use of the ever-increasing capabilities of modern digital technologies. In this case, there is a shift in emphasis and modification of the phenomenon of architecture away from its materialization into virtual, unreal architecture. Information approach in architecture appears as the relationship of two spaces: architectural and information. Incorporating the digital world into the real world requires consideration of a model of interaction between these two spaces and a model of the language of communication, as well as a model of the architectural design process (Asanovich, 2007).

The use of this approach is especially necessary when creating a system of connections between participants in the design process using digital technologies in the development of buildings of complex geometry. This requires the creation of a unified system for integrating data obtained during the design process into ordered models that allow a complete picture of the object. These models contain all the data regarding building geometry, function, materials, maintenance and much more.

With the advent of new technologies, the formation of a new aesthetics began, the so-called free form, where the ideas of dynamism, fluidity and synergy become the dominant and active elements of shaping in architecture. At the same time, architecture has the ability to change, which allows the structure, form and function of an architectural object to acquire interactivity and automation properties. The object is modeled as a kind of organism based on the idea of self-organization of an evolving system. The development of architectural and urban planning objects in the future lies in the plane of parametric and generative design. These methods are based on the creation of a mathematical model that allows changes to be made to the parameters of an object and the relationships between them, as well as to a general algorithm that serves as a basic template for creating a specific object (Saprykina, Saprykin, 2012).

An example is the complex spatial structure of the future metropolis "*Cybertopia: Future of an Architecture Space, Death of Analogous Cities*" (by Egor Orlov) 2015 (Russia), which is formed and organized simultaneously in digital and physical space, while a completely different topography of the city is expected. The entire complex is formed by a frame structure on which cranes, components and entire blocks move. Some of the housing stock may be fixed into the structure immediately after construction is completed or deliberately left as a potential opportunity for further transformation and change in the future. The residential sector of the skyscraper is a constantly growing and developing spatial complex. A series of frames and spatial elements, 3D printed or formed by drones, act as structures for subsequent local integration and modification. The central axis of the complex contains a monorail on which a printer moves, which prints and in some cases erases spatial structures. At the author’s suggestion, huge airships dock at the complex and immediately become part of this object, its organic connection and spatial cell. After being saturated with objects, the airship sets off on its next voyage and, upon arrival at a new port city-metropolis, is connected to the new structure for an indefinite period, as an additional spatial block (Orlov, 2015).

These design methods involve the creation of an integrated space that interacts interactively with its environment and has the ability to adapt depending on changing conditions. The combination of real and virtual elements of the space itself allows it to be in constant motion and change. This is due to the fact that currently the living space, which ensures the formation of people’s daily lives and their interaction, is undergoing significant changes under the influence of the development of information technology.

2.2.2 Integral space and global information and communication environment

The development of electronic communication and information systems makes it possible to significantly reduce the dependence between spatial proximity and the performance of many functions of daily life. This is due to the currently actively developing ultra-fast and ultra-long-range means of communication. At the present stage of social development, the formation of communication connections as the most important elements of the sociocultural space is of global importance. They influence the formation of the entire system of spiritual values and needs of humanity. An information resource becomes a socially integrating factor (Dutsev, 2020).

The global information and communication environment radically changes the conditions for cultural exchange and interpersonal communication in the city, and also erases spatial, temporal, social, linguistic and other barriers. This leads to the possibility of creating new forms of virtual communities, united only by their own sociocultural preferences. The information space of the city, as part of the sociocultural space, provides new opportunities for the development of personality and to the city’s putting forward new demands on the individual consciousness and behavior of the inhabitant, which are unthinkable without that mental property designated as “information activity” (Dutsev, 2020).

Human progress is symbolized by modernization and globalization, but for all the conveniences they bring, they also absorb the key components of life: people's senses, sensory information and emotions. The “*Sensory Skyscraper*” project (authors V. Mercuri and M. Merletti) 2016 (Moldova, China) is a multifunctional laboratory for scientific research on human feelings, perception, rehabilitation of sensory information, rehabilitation of the effects of experience, motivations and expectations, etc. This lab is a cube that creates a combination of 6 pyramids that reflect how the human brain works to process different senses. Within each pyramid there are certain patterns that show functional sectors, each of which represents an open space for different types of perceptions and feelings. The pyramids can move separately and vertically, since the cubic shape is controlled by magnetic force, and the mobility of the pyramids is completely fixed. Magnetic energy is invisible and strictly controlled without harming the environment, so the object looks like an object floating in the air (Sharkov, 2015).

The intensification of communication through information technology leads to the emergence of a virtual parallel environment as a model of an alternative to the social world. Virtual space is able to repeat all the trends of real space, which is used in various fields of activity. So, in order to restore disappeared natural artifacts and entire agglomerations that have not survived to our time, with incomplete historical documents and the absence of recording the features of the natural landscape, the creation of cyberspace makes it possible to create a virtual model of this situation.

In this regard, the proposal of the skyscraper “*Memory Cube Skyscraper*” (by Keyi Shen, Zichao Zhong, Dingyu Li, Jian Yan, Yuan Zhang) 2019 (China) intends to play the role of a historical set designer and simulator of a real picture of landscape images for future people. The skyscraper carries out image simulation by collecting material parameters of the physical state, such as wind, wind speed, temperature, humidity and other basic environmental parameters. With these physical parameters, the simulation is no longer a simple display of an image, but allows people to experience the most authentic feelings on an educated stage. This building will be both a data storage center and a stage simulator for displaying historical attractions (Pincer, Chang, 2016).

Wireless connections make not only people mobile, but also things. As more and more people's lifestyles are connected to the Internet, the use of "flying robots" could easily become a common part of daily life in the future to meet the emerging demand for incorporating advanced drone technology.

As an example of this trend, a skyscraper project for landing unmanned drones "*The Hive: Drone Skyscraper*" in New York (authors Hadeel Ayed Mohammad, Yifeng Zhao Chengda) 2016 (USA) was developed. The facility is a central control terminal housing docking and charging stations for personal or commercial drones in midtown Manhattan. Modules on the skyscraper's "living façade" are designed for nine different types of drones. To ensure a secure landing on the vertical chassis around the tower, the drones are attached parallel to the façade, and to maximize surface area, two overlapping layers are proposed - outer and inner. Flickering lights on each station module help to fulfill navigation conditions and also indicate the fullness and capacity of the building (Shen, Zhong, Li, Yan, Zhang, 2019). Good wireless connectivity is especially important in areas with poor roads and undeveloped areas. People's activities increasingly rely on mobile communications across geographically dispersed spaces.

3 DISCUSSIONS OF THE RESEARCH RESULTS

As a result of the study, the areas of use of information technologies in architectural activities that have significantly changed the possibilities of designing architectural objects have been considered in scientific and design developments. This made it possible to identify tools for their formation and identify some concepts for solving this problem in the following areas.

1. Theoretical platform of the information paradigm and the prerequisites for its emergence:

• *The evolution of sustainable development of architecture in the context of the Society 5.0* strategy is associated with a new vision of a sustainable spatial living environment using information technologies of cybersecurity, artificial intelligence and robotics. Ensuring the continuous growth of social sustainability in times of crisis becomes possible through the formation of a living space as an alternative ecosystem.

• *The use of "Big Data" technology in the formation of the "Smart City"* concept as a new integrated living environment is implemented through the use of intelligent automated control systems to ensure safety, solve transport problems, security issues and social comfort. Information technology allows the successful development of cities without direct spatial dependence on developed infrastructure, that is, without the creation of large transport highways and energy networks.

2. Tools of Interactive Technology for Forming the Architecture of the Electronic Age:

• *The global information system of interaction in architectural design* is associated with the development of a new holistic hybrid communication environment, which includes means of presenting a design idea, tools for managing the design process and information support systems. These design methods involve creating an integrated space that interacts interactively with its environment and has the ability to adapt to changing conditions.

• *Integral space and the global information and communication environment* radically change the conditions for cultural exchange and interpersonal communication in the city, and also erase spatial, temporal, social, linguistic and other barriers that influence the formation of the entire system of spiritual values and needs of humanity. The intensification of communication through information technology leads to the emergence of a parallel virtual environment as a model of an alternative to the social world, which is able to repeat all the trends of real space.

4 CONCLUSIONS

Thus, the typology of architecture is replenished with new types of architectural objects, which are scientific and information denominators of the era. Traditional architecture can no longer meet the needs of dynamically developing scientific progress, which uses the latest information and technology developments. Intellectual information resources have a small material and resource component and energy intensity, as well as dynamism, easy replication and social integration.

Architecture must become interactive, responsive and adaptable to the needs of each person. In the architect's work, concepts of the future are created and innovative ideas for using information design methods in architecture are materialized. This has grown into a rapidly developing branch of architecture with the potential to dominate contemporary art in the near future. The results of the study can be useful for the theory and practice of shaping the vital activity space of the future, as they open up completely new possibilities in architecture.

ACKNOWLEDGEMENTS

The work was carried out with financial support from the Fundamental Scientific Research Program of the Ministry of Construction and Housing and Communal Services of the Russian Federation and the Russian Academy of Architecture and Construction Sciences of 2024. Research project 1.2.3.2 "Strategic resources for regulate of the instability of the residential environment: archetypes of sustainability."

REFERENCES

Saprykina, N.A., 2017. Thesaurus of parametric paradigm formation of architectural space. In: «*Architecture and Modern Information Technologies*» 3(40) pp. 281-303.

Gogolkina, O.V., 2018. Parametric Architecture in the Formation of Recreational Complexes. In: *IOP Conference Series: Materials Science and Engineering (MSE)* Vol. 463 1-6.

Saprykina, N.A., 2018. New approaches to the formation of the information space of the future as a separate category of the architectural environment In: *Architecture and Modern Information Technologies*. №1(42). pp. 317-340.

Baitenov, E., 2020. Modern Challenges and the Outline of the Future of Architecture. In: *Proceedings of the 2nd International Conference on Architecture: Heritage, Traditions and Innovations* (AHTI 2020).

Sawyer, P., 2017. From Industry 4.0 to Society 5.0. In: Computerworld Russia № 04.

Vorozhikhin, V.V., 2016. "Society 5.0" as humanity's response to the challenges of global development. In: *Financial system of Russia: trends and development alternatives*. Collection of scientific papers "Materials IV All-Russian scientific and practical conference of young scientists, graduate students, undergraduates and students". pp. 309–313. (November 9–11, 2016) Sevastopol: SevGU

Balatsky, E.V., 2007. The mechanism of interdependence of innovation and economic growth. In: *The science. Innovation. Education*. Issue 2. 54 p. Moscow: Languages of Slavic culture

Kurcheeva, G.I,, Bakaev, M.A., and Klochkov, G.A., 2020. Analysis of tools and data sources for assessment of digital city development. In: *Journal of Physics: Conference Series*, Volume 1661, International Conference on Information Technology in Business and Industry (ITBI) 6-8 April 2020, Novosibirsk, Russia.

Tao, K., 2011. House of the Future Inspired by the Matrix (USA).

Saprykina, N.A., 2018. Forecasting technology as a method of modeling and building Smart City concept. In: *IOP Conference Series: Materials Science and Engineering*, Volume 365, Smart City (022068).

Volynskov, V.E., 2017. "Big Data" in Urban Planning. In: *Academia. Architecture and construction*. № 3, pp. 99-102.

Bodyakin, V.I., 1993. Inform City - the path to a conflict-free society. In: Abstracts at the international conference "*Towards a conflict-free society - through education and awareness of the integrity of the world*", Zhukovsky, Moscow region, (September 30 - October 4, 1993).

Gogolkina, O.V., 2018. Features of design formation in parametric architecture. In: *Architecture and Modern Information Technologies*, 1 (42) pp. 355-363.

Mercuri, V., Merletti, M., 2016. Data Skyscraper: Sustainable Data Center in Iceland (Italy).

Gnevanov, M.V., Ivanov, N.A., 2018. Big data technologies and their application in urban planning. In: *Industrial and civil engineering*, № 4, pp. 83-87

Targowica, J., Binkowski, M., 2017. Data Cemetery Skyscraper (Poland),

Ptichnikova, G., 2020. Hybridization in Architecture. In: *Proceedings of the 2nd International Conference on Architecture: Heritage, Traditions and Innovations* (AHTI 2020).

Asanovich, A., 2007. Computer tools and the evolution of architectural design methodology. In: *Abstract of the dissertation for the scientific degree of Doctor of Science* (18.00.01). 341 p. Moscow – MARCHI.

Saprykina, N.A., Saprykin, I.A., 2012. "Paperless" architecture in the context of virtual reality. In: *Architecture and Modern Information Technologies*. Special release, p. 7- 12.

Orlov, E., 2015. Cybertopia: Future of an Architecture Space, Death of Analogous Cities.

Dutsev, M., 2020. The City as an Art Integration Space. In: *Proceedings of the 2nd International Conference on Architecture: Heritage, Traditions and Innovations* (AHTI 2020).

Sharkov, F.I., 2015. Visualization of media space by means of communication. In: *Collection of materials from the V International Scientific and Practical Internet Conference*. – Tomsk: Publishing House of Tomsk State University, Connect-Universum –2015. pp. 232-242

Pincer, A., Chang, H., 2016. Sensory Skyscraper (Moldova, China). Retrieved from: http://www.evolo.us/sensory-skyscraper/#more-34964

Shen K., Zhong Z., Li D., Yan J., Zhang Y., 2019. Memory Cube Skyscraper (China).

Mohammad, H.A., Chengda, Y.Z., 2016. The Hive: Drone Skyscraper (USA).

Model of a Stabilization System for a Bioengineering Object on a Manifold of Given Goal States

Kolesnikova Svetlana Ivanovna[a] and Fomenkova Anastasia Alekseevna[b]
St. Petersburg State University of Aerospace Instrumentation, Bolshaya Morskaya Street, Saint Petersburg, Russia
skolesnikova@yandex.ru, a.a.fomenkova@mail.ru

Keywords: Bioengineering object, target macrovariable, system invariant, stabilization of unstable system, transient process between target states, limiting dynamic regime.

Abstract: The problem of bioengineering object stabilization is discussed using an ideology of combining the synergetic control and the cyber-physical systems (CPSs). The CPS structure contains an analytically designed synergetic stochastic regulator, referred to as the reference regulator, for the purpose of organizing the motion of the system's reference point between the a priory specified favorable limit states with attractive properties, which are termed here as the macrostates. The stabilization of a controlled object in the space of target macrostates implies its testably functional state. In order to validate the proposed approach, a system of anaerobic biological wastewater treatment (ABWT) is selected based on an anaerobic bioreactor, which is characterized by a large number of interdependent physical, technical, and biochemical parameters. The results of this study are used in developing a monitoring and control system for an industrial bioreactor, which would possess a considerably reduced time for the historical data processing and save the computational resources.

1 INTRODUCTION

The main property of cyber-physical systems (CPSs) is their capability of self-organized life-sustaining activity aimed at a stable and rational performance of their principal functions (Estrada-Jimenez et al., 2021; Lucia et al., 2016; Lazarević, 2015; Hamdan, Mahmoud and Baroudi, 2022).

It is well known that the invariance property in nonlinear controlled objects makes the basis for designing a robust and purpose-oriented impact on them (Saridis, 1980; Kolesnikov, 2004; Kolesnikov, 2012; Sepulchre, Jankovic and Kokotovic, 2012). The concept of invariants (as stable manifolds) plays a specials role for the systems of deterministic chaos and, in particular, for the bioengineering control objects with unstable biochemical and biophysical subsystems (e.g., Antsaklis et al., 2013; Zaiets et al., 2024; Dochain, 2013; Garcia-Gen, Santos and Wouwer, 2022; Mendiola-Rodriguez and Ricardez-Sandoval, 2023; Petre, Roman and Selisteanu, 2019).

A solution of the problem of control over nonlinear and multiloop bioengineering objects is complicated by the fact that an instability does not bear a systematic character for the reasons of a) instability of biological processes and b) impossibility of a stability *transfer* in a model to the stability in a physical control system in view of the natural parametric fluctuations.

The main method for improving the robustness of the means of control (soft and/or hardware) over non-stationary structurally and functionally complex systems is the multiple (multivariant) control traced back to the works by A. M. Letov further developed in the theory of the variable-structure systems (Emel'yanov, 2006), which was bound to the Ashby's cybernetic law of requisite variety formulated as follows: *'in active regulation only variety can destroy variety'* (Ashby, 1956).

This principle admits a change of the motion trajectory of the imaging point (ODEs, or difference system of equations) due to the rule of switching between the functioning modes.

In the below-described approach to solving the stabilization problem for an object with non-

[a] https://orcid.org/0000-0001-7158-2747
[b] https://orcid.org/0000-0002-5570-6743

stationary modes in the space of the target variables the following principles are used:

1) principles of algorithmic compositions relevant for the machine learning, specifically: an individual algorithm yields the result not better than that obtained by a generalization of the outcomes of a number of basic algorithms (Vorontsov, 2000); this approach is, in its turn, traced back to the idea of constructing robust schemes from unreliable elements according to K. Shannon and J. von Neumann;
2) synergetic control theory (SCT) (Saridis, 1980; Kolesnikov, 2004; Kolesnikov, 2012), specifically, an introduction of integrators into the respective control channels, which would ensure a synthesis of adaptive systems without acquiring any current information on the variation of the parameters of the object and the external environment;
3) physical control theory (Krasovskii, 2002), using the emerging complex dissipative structures and cooperative processes taking place in nonlinear objects for purpose-oriented self-organization, which would ensure an energy efficiency of the synthesized control system;
4) selection of control strategies minimizing the dispersion of the output variable (Kolesnikova, 2022).

On its content side, the designed model for stabilizing a bioengineering object represents a controlled random walk between the neighborhoods of the stable states for the solution of the system stabilization problem to be on the whole more effective than the control with respect to one target state.

It is to be noted that the reference control that provides reaching of one of the target states is determined by the stochastic control algorithm, whose main steps are detailed elsewhere (Kolesnikova, 2022) and presented below in the example of synthesizing control for ABWT (Fomenkova, Klucharev and Kolesnikova, 2021).

It is also noteworthy that the proposed technology of sustaining the stability of a complex object is not limited by the specific character of the system discussed here and can be applied to any object with the known set of stable equilibrium states admitting an analytical solution given by $\lim_{t\to\infty}\boldsymbol{\psi}\left(\mathbf{X}(t)\right)=0$, where $\mathbf{X}$, $\boldsymbol{\psi}(\mathbf{X})$ are the vectors of states and target macrovariables, respectively.

The term *macrostate* is here convenient in view of its simultaneous brevity of naming and an indication of its formalization – the limiting equality of the macrovariable to zero, as a prescribed function of the controlled object's state.

2 MATHEMATICAL MODEL OF A BIOENGINEERING OBJECT AND THE LOCAL FORMULATIONS OF STOCHASTIC CONTROL PROBLEMS BY REACHING THE NEIGHBORHOOD OF A TARGET MANIFOLD

A mathematical description of an object, characterized by unstable regimes in an open state, can be implemented both by the continuous and discrete models (Kolesnikova and Kustova, 2023).

Let us look at the formulation of a local control problem in the form of controlled object, control aim and control quality criterion. The accepted mathematical model will be a discrete description of the object (or its explicit difference scheme in the case of the initial continuous description)

$$\begin{aligned}&\mathbf{Y}[k+1]=\mathbf{H}[k]+\mathbf{u}[k]+\xi[k+1]+c\xi[k],\\&\mathbf{Y}[k_0]=\mathbf{Y}_0,\ k=k_0,k_0+1,...\end{aligned}\tag{1}$$

where $\mathbf{Y}[k]=\left(Y_1[k],...,Y_n[k]\right)^T$, $\mathbf{H}[k]:=\mathbf{H}\left(\mathbf{Y}[k]\right)\in\mathrm{R}^n$, $\mathbf{u}\in\mathrm{R}^m$, $m\le n$ are the vectors of states and nonlinear function describing the dynamics of variation of the object's states and control, respectively, $\xi[k]\in\mathrm{R}^l$, $l\le m$ are the random non-correlated functions, $\mathbf{E}\{\xi_i[k]\}=0,\ \mathbf{D}\{\xi_i[k]\}=\sigma^2, i=\overline{1,l},\ |c|<1$.

Traditionally, one poses local problems of an object's reaching one of the knowledge-based practically acceptable states and, in so doing, it is desirable to further maintain the object in the neighborhood of one of them, according to the quality criterion (considering the description discreteness)

$$
\begin{aligned}
&\Phi = \Phi(\boldsymbol{\psi}) = \\
&= \mathbf{M}\left(\sum_{t=t_0}^{\infty}\sum_{j=1}^{m}\left(\alpha_j^2\left(\psi_j[t]\right)^2 + \left(\Delta\psi_j[t]\right)^2\right)\right) \to \min, \\
&\Delta\psi_j[t] = \psi_j[t] - \psi_j[t-1],\ t = t_0+1,...; \qquad (2) \\
&\psi_j[t_0] = \psi_j(\mathbf{Y}[t_0]), \mathbf{Y}[t_0] = \mathbf{Y}_0,\ \Delta\psi_j[t_0] = 0, \\
&\mathbf{D}\left(\psi_j[t+1] + \lambda\psi_j[t]\right) \to \min,\ |\lambda| < 1.
\end{aligned}
$$

The parameters of the law of control α, λ have a major effect on the control quality, and they are selected numerically based on the acceptability of the transient process indices and the radius of the admissible neighborhood of a manifold $\lim\limits_{k\to\infty}\boldsymbol{\psi}(\mathbf{Y}[k]) = 0$.

For instance, for a model of an anaerobic bioreactor (Klucharev and Fomenkova, 2019) with a weighted-sedimented biomass given by an ODE and a vector control (in terms of the temperature and the input stream concentration) description (1) will acquire the following form:

$$
\begin{aligned}
&Y_i[k+1] = Y_i[k] + h\left(F_i[k] + g_i\left(u_j[k] + \xi_j[k+1] + c\xi_j[k]\right)\right),\ k = k_0, k_0+1,... \\
&\mathbf{Y} = \|Y_i\|_{1\times 7} = (S, B_1, P, B_2, G, \theta, Q)^{\mathrm{T}}, \mathbf{G} = \|g_i\|_{1\times 7} = (0,0,0,0,0,1,1)^{\mathrm{T}},\ \mathbf{Y}[k_0] = \mathbf{Y}_0, \\
&F_1 = Q(S_{in} - S) - k_1(\theta)B_1 - k_2(\theta)\frac{SB_1}{k_3(\theta)+S}, \\
&F_2 = -QB_1 + k_4(\theta)\frac{SB_1}{k_3(\theta)+S}, \qquad (3) \\
&F_3 = -QP + k_5(\theta)B_1 + k_6(\theta)\frac{SB_1}{k_3(\theta)+S} - k_7(\theta)B_2 - k_8(\theta)\frac{PB_2}{k_9(\theta)+P}, \\
&F_4 = -QB_2 + k_{10}(\theta)\frac{PB_2}{k_9(\theta)+P}, \\
&F_5 = -G(t) + k_{11}(\theta)\frac{PB_2}{k_9(\theta)+P}\frac{k_{12}(\theta)}{k_{12}(\theta)+P},\quad F_6 = 0,\quad F_7 = 0.
\end{aligned}
$$

In Eq. (2), $\mathbf{Y} \in \mathrm{R}^7$ is the state vector (concentration of initial substrate S, acidogenic biomass B1, intermediary fermentation product P, methanogenic biomass B2, co-product – methane G, bioreactor operating temperature θ, substrate dilution rate in bioreactor Q); $k_i(\theta)$ are the known kinetic parameters of a process with the known variation law. Then u and ξ are the sought-for law of vector control and the unknown random vector function, respectively. For the above-presented description (3) of the object in Eq. (2), parameter m=2.

Note that in contrast to the classical stochastic regulation schemes, no assumptions are made in the proposed model as to the type of the law of the probability distribution of random variablesξ, it is only the assumption of their boundedness which counts.

Let the aim of control for a system of anaerobic waste water treatment (ABWT) in accordance with the STC be given by $\lim\limits_{k\to\infty}\boldsymbol{\psi}(\mathbf{Y}[k]) = 0, \boldsymbol{\psi} \in \mathrm{R}^2$, with possible variants conditioned, on the one hand, by the expert commentary and, on the other hand – via the solution of the issue of a physical STC-control availability for a given set of target macrovariables, such as the following (Fomenkova, Klucharev and Kolesnikova, 2021; Kolesnikova and Fomenkova, 2023):

$$\psi_1(t) = S(t) + P(t) - S^* \to 0,\ \ \psi_2(t) = G(t) - G^* \to 0,$$

or

$$\psi_1 = \frac{1}{Q} - HRT_{\min} \to 0,\ \ \psi_2 = P - P_{\min} \to 0,$$

where V is the bioreactor volume, $Q := Q_{in}$ is the influent wastewater volume per unit time, $HRT = \frac{V}{Q_{in}} = \frac{1}{Q}$ is the hydraulic retention time/day, P is the content of volatile fatty acids, sign “*” indicates the expert-specified values.

3 STABILIZATION MODEL OF BIOENGINEERING OBJECTS IN THE SPACE OF THE SET MACROSTATES WITH AN ATTRACTIVE PROPERTY

A poor formalizability and a weak controllability of bioengineering objects are caused by the parametric fluctuations, the deterministic chaos phenomena inherent in biosystems, the random disturbances in the control channels, etc.

Considering the unavoidable presence of a unmodeled dynamics in these objects and the peculiarities of a digital control, the stabilization problem for the imaging point in a dynamic system in the space of the set target macrovariables with a capacity of switching between them (between the types of regulators) is quite important.

Formulate the problem for $\{\boldsymbol{\psi}^l(\mathbf{Y}), \mathbf{u}^j(\mathbf{Y}), \mathbf{Y}_0\}, l = \overline{1, N_\psi}, j = \overline{1, N_u}$, the set of technologically functional and/or energy efficient expertise-based target macrostates $\boldsymbol{\psi}^l(\mathbf{Y})$, admissible in control $\mathbf{u}^j(\mathbf{Y})$, and initial states $\mathbf{Y}_0$, respectively, and the object's initial description given by (1) and (2), and design a control system ensuring stability in the space of equilibrium states with an attractive properties.

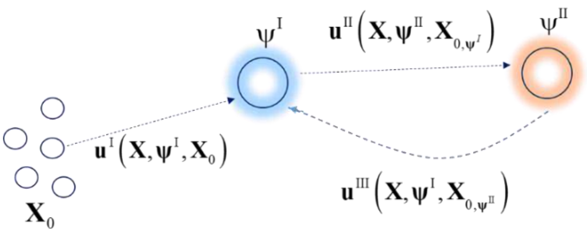


Figure 1: Conceptual stabilization scheme for the state of a stochastic bioengineering object under noise conditions in the space of set macrostates.

The functional scheme (Fig. 1) of stabilization of a complex system under the conditions of systematic and/or random disturbances implements the main control unit (MCU) in the cyberphysical system for a bioengineering object (Fig. 2).

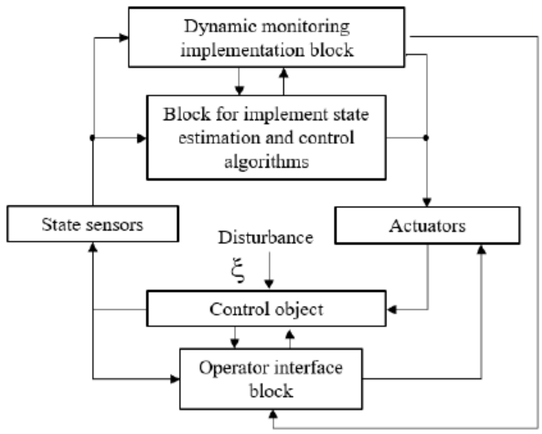


Figure 2: Schematics of a monitoring cyberphysical system.

4 SOLUTION OF THE STABILIZATION PROBLEM FOR AN OBJECT IN THE SPACE OF THE TARGET MACROVARIABLES

A functional stabilization model for a bioengineering system under the above-specified conditions can be constructed in the form the interdependent blocks of the reference stochastic SCT-regulator, the state observer, the set of the criteria-based functions for optimizing the principal operations, and the switching rule between the regulation mechanisms, in other words, between the control systems (Fig. 3).

The specific features of the presented model for stabilization of a multidimensional, multiloop object with the modes of deterministic chaos consist in the following:

- the dimensionality of a set of expert-specified target states is not rigid: it varies dynamically with the accumulating object's history;
- the trajectory of the purpose-oriented random walk of the imaging point of the system can obey the energy-saving criterion, but under real conditions it is the stability factor of the entire system which counts most of all;
- the system is additive, it changes the regulator structure in accordance with the global criterion of the control quality assessment and in response to the factors of the disturbance character and/or the internal instability inherent in the bioengineering objects;
- the system is controlled and stabilized in accordance with the principle of the Krasovskii

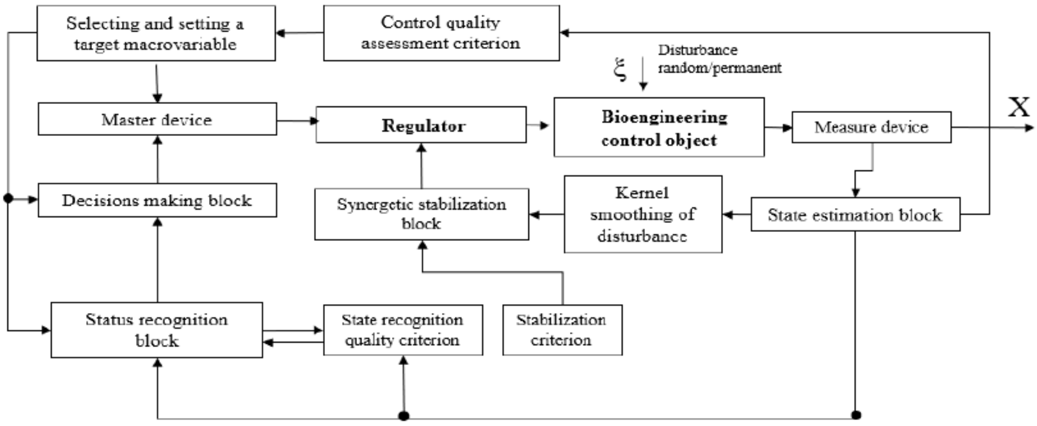


Figure 3: Functional scheme for reaching and maintaining a stable state of a bioengineering object under noisy conditions.

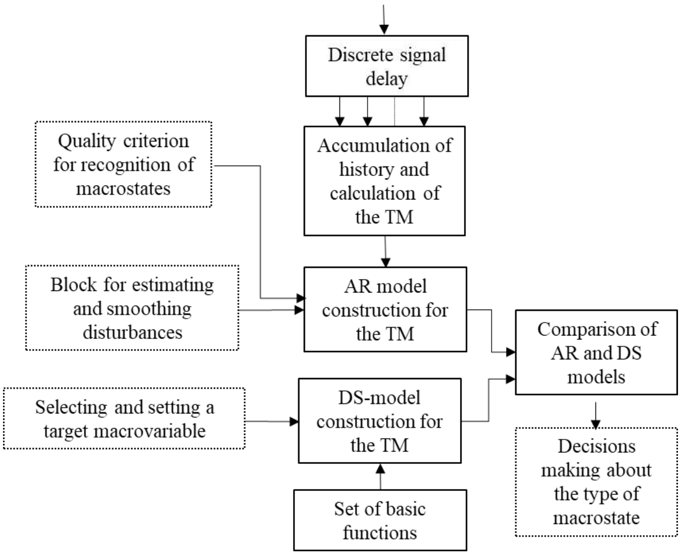


Figure 4: Detailed diagram of the state image recognition and decision making block; DS and AR – designation of operations for obtaining the difference scheme and autoregressive model parameters, respectively; TMV target macrovariable; DM – decision making.

physical control theory (Krasovskii, 2002) and the directional self-organizing dynamics (Saridis, 1980; Kolesnikov, 2004; Kolesnikov, 2012; Sepulchre, Jankovic and Kokotovic, 2012; Astolfi, Karagiannis and Ortega, 2008; Kolesnikova and Kustova, 2023).

Let us briefly turn to the mathematical and algorithmic tools for the initial functional scheme 3.

4.1 Algorithm for Macrostate Recognition

The detailed structure of the state image recognition and decision making block (Fig. 4) is based on a comparison of the distances between the vectors of the autoregressive parameters of a time series section against the current observations and the difference scheme parameters against the revealed macrostates as the attributes of these states (Kolesnikova, 2011).

Figure 4 presents the structure of an algorithm for recognition of the states as classes (images), which exhibits a high discrimination capacity and relies on a comparison of the distances between the vectors of the autoregressive parameters, corresponding to the time series section of the current observations, and the difference scheme parameters put against the revealed macrostates as their attributes.

4.2 Algorithm for a reference control based on the SCT principles

The block for formulating the law of a reference stochastic control relies on the formation of a set of SCT-controls (Kolesnikova, 2022; Kolesnikova and Kustova, 2023) out of which one selects the strategies minimizing the dispersion of the target variable. The SCT involves the following concept: the controlled object selects a practically acceptable behavior trajectory объект relying on the least-action principle and the physical laws, which implies a minimal interference into its natural motion, and, hence, an energy-efficiency of the designed regulator.

The main steps of a stochastic algorithm for synthesizing a regulator based on the SCT-principles, self-organization and selection of appropriate control strategies are the following:

1) determine the structure of the SCT-regulator at a fixed macrovariable in an assumption of a completely described object, relying on the method of analytical design of aggregated regulators (ADAR);

2) select the strategies out of the admissible control set, which would ensure the minimal dispersion of the target macrovariable (Kolesnikova, 2022);

3) form an estimate of disturbances affecting the object through the control channel, relying on the found control law as a function of the macrostates.

The block of kernel smoothing (Fig. 2) of the disturbance estimate $\boldsymbol{\xi}$ implements the kernel regression algorithm (Narendra and Harshangi, 2015) for obtaining the estimate $\hat{\xi}$, which improves the control precision or merely reduces the radius of the target state neighborhood $\boldsymbol{\psi}(\mathbf{X}(t))=0$.

The algorithm for the above-given example with description (2) will acquire the following form.

Let us denote the initial description (1) as

$$\Sigma=(\mathbf{Y};\ \mathbf{u}+\zeta),\mathbf{x}\in R^7,\mathbf{u},\zeta\in R^2,$$
$$\mathbf{u}^{\mathrm{ADAR}}[t]:=h\mathbf{u}[t],\ \zeta[t+1]=h(\boldsymbol{\xi}[t+1]+c\boldsymbol{\xi}[t]),$$
$$t=t_0,t_0+1,\ldots.$$

Step 1. Vector controller structure formation under the assumption that the right side of the description (3) is known:

$$\Sigma^{\mathrm{ADAR}}=(\mathbf{Y};\ \mathbf{u}^{\mathrm{ADAR}}+\zeta),\mathbf{u}^{\mathrm{ADAR}}=\mathbf{U}(\mathbf{Y},\boldsymbol{\psi}),$$
$$\boldsymbol{\psi}=(\psi_1,\psi_2)^{\mathrm{T}},\psi_j[t+1]+\lambda_j\psi_j[t]=0, \tag{4}$$
$$\lambda_j=\mathrm{const},\ |\lambda_j|<1,\ j=1,2,\ t=t_0,t_0+1,\ldots$$

Remark. Parameters α_j and λ_j in (2), and (4) are regulator parameters and ensure the finiteness of the functional from (2), according to SCT (Kolesnikov, 2004; Kolesnikov, 2012).

Step 2. Perform the operation of conditional mathematical expectation from random function $\mathbf{u}^{\mathrm{ADAR}}$:

$$\mathbf{u}^{\mathbf{CM}}[t]=\mathbf{E}\{\mathbf{u}^{\mathrm{ADAR}}[t]\,|\boldsymbol{\xi}^t\},$$
$$\boldsymbol{\xi}^t=(\xi[t_0],\ldots,\xi[t]),\ \ t=t_0,t_0+1,\ldots \tag{5}$$

Step 2. Decompose of system (3) on the manifold $\boldsymbol{\psi}=0$, taking into account the relations $\mathbf{u}^{\mathbf{CM}}$, and obtain forms of expression for $\hat{\boldsymbol{\xi}}[t]$:

$$\boldsymbol{\psi}^{(1)}[t]+\boldsymbol{\lambda}\boldsymbol{\psi}^{(1)}[t-1]=h\hat{\boldsymbol{\xi}}[t], \tag{6}$$

Here the sign "(1)" indicates the hierarchy number of the STU control synthesis process.

Step 3. Substitute $\hat{\boldsymbol{\xi}}[t]$ from (6) instead of $\boldsymbol{\xi}[t]$ into the final expression (5). The designing of a stochastic discrete regulator is over.

4.3 Switching rule for reference regulators

Let the target macrovariable be selected as $\boldsymbol{\psi}^j(\mathbf{X})$. Then, according to algorithm 3.2, the reference control $\mathbf{u}^j=\mathbf{u}^j(\mathbf{X},\mathbf{X}_0,\boldsymbol{\alpha},\boldsymbol{\lambda})$ becomes actual, and the respective system of equations will be defined as $\Sigma^j(\mathbf{X})$.

1. Set the values of $\boldsymbol{\delta}_j$ to the neighborhood radius of macrostate $\boldsymbol{\psi}^j(\mathbf{X})$ and the restrictions on control $|\mathbf{u}^j(\mathbf{X})|<\boldsymbol{\gamma}_j$, and define these conditions as follows:

$$A_\psi=|\boldsymbol{\psi}(\mathbf{X})-\boldsymbol{\psi}^j(\mathbf{X})|<\boldsymbol{\delta}_j,$$
$$A_u=|\mathbf{u}^j(\mathbf{X})|<\boldsymbol{\gamma}_j. \tag{7}$$

2. Formulate the rule: if at the point of observation conditions (4) are valid, then the initial object has been stabilized and no switching is required; if at least one of these conditions has not been satisfied, then perform the following operations:

$$\mathbf{X}_0:=\mathbf{X}(t),$$
$$j_0:=\arg\min_{i=\overline{1,N_\psi},i\neq j}\{\rho(\boldsymbol{\psi}^i(\mathbf{X}),\boldsymbol{\psi}^j(\mathbf{X}))\}.$$

Here $\rho(A, B)$ is one of the similarity metrics of the compared variables *A* and *B*.

5 CONCLUSIONS

The issue of improving the quality of control over bioengineering objects has been discussed using a case study of an ABWT facility (without limiting the generality). The approach used in this work relies on the concept of self-organization of multi-loop systems forming a certain structure of relationships between unstable subsystems for the sake of achieving an overall stability for the system.

The problem of stabilizing an unstable biochemical object in the space of several practically *favorable* target states has been discussed, for which there are available stochastic SCT-regulators. The transitions between the macrostates are ensured by the following sequence of operations:

- assessment and recognition of the current state;
- assessment of the proximity of the current image of the state to other macrostates, whose set is prescribed *a priori*;
- decision making as to the target change during functioning of the object;
- control over the transition from one macrostate to another;

The theoretical and applied value of the presented method for deriving an optimization rule of control over a bioengineering object consists in the following achievements:

- Analytical design of a stochastic regulator for the object to reach a local stable state, referred to as a reference regulator;
- Possibility of identifying new properties of biochemical processes under a forced change of the target requirements;
- Prediction of the object model behavior in the case of roughly set parameters;
- Recommendations with respect to the model controllability depending on the level and nature of the disturbances inevitably affecting the behavior of an object unstable in an open state.

The conceptual apparatus presented in this work is a tool for modeling and studying the bioengineering mechanisms underlying the complicated present-day systems.

ACKNOWLEDGEMENTS

This work was supported by the Russian Science Foundation under grant no. 23-29-00336.

REFERENCES

Antsaklis, P. J., Goodwine, B., Gupta, V., McCourt, M. J., Wang, Y., Wu, P., Xia, M., Yu, H., Zhu, F., 2013. *Control of cyberphysical systems using passivity and dissipativity based methods*. European Journal of Control, Vol. 19, Issue 5, pp. 379-388.

Ashby, W. R., 1956. *An Introduction to Cybernetics*. London: Chapman & Hall Ltd, 295 p.

Astolfi, D., Karagiannis, R., Ortega., 2008. *Nonlinear and Adaptive Control with Applications*. Springer. 290 p.

Dochain, D., 2013. *Automatic control of bioprocesses*. John Wiley & Sons Publ., 244 p.

Emel'yanov, S. V., 2006. *Automatic control systems with variable structure: synthesis of scalar and vector systems by state and by output. Collected articles*. Nelinejnaya dinamika i upravlenie [Nonlinear dynamics and control], Is. 5. pp. 5-24.

Estrada-Jimenez, L. A., Pulikottil, T., Peres, S. R., Nikghadam-Hojjati, S., Barata, J., 2021. *Complexity theory and self-organization in Cyber-Physical Production Systems.* Procedia CIRP, Vol. 104, pp. 1831-1836,

Fomenkova, A. A., Klucharev, A. A., Kolesnikova, S. I., 2021. *Formalization of target invariants and designing an adaptive control system for the model of anaerobic biological wastewater treatment*. Journal of Physics: Conference Series, 2099 012035.

Garcia-Gen, S., Santos, L. O., Wouwer A. V., 2022. *Application of a Nonlinear Model Predictive Controller to the Anaerobic Digestion of Readily Biodegradable Wastes.* IFAC PapersOnLine 55-7, pp. 909–914.

Hamdan, M. M., Mahmoud M. S., Baroudi, U. A., 2022. *Event-triggering control scheme for discrete time Cyberphysical Systems in the presence of simultaneous hybrid stochastic attacks*. ISA Transactions, Vol. 122, pp. 1-12.

Klucharev, A. A., Fomenkova, A. A., 2019. *Mathematical model of an anaerobic bioreactor with fixed biomass as a control object*. Information control systems, no. 2, pp. 44-51.

Kolesnikov, A. A., 2012. *Synergistic Methods of Control Complex Systems: The Theory of System Synthesis*. Librokom, Moscow, Russia, pp. 71–148.

Kolesnikov, A. A., 2004. *Synergetics and problems of control theory: Collected articles.* Kolesnikov A. A., Ed.; Fizmatlit, Moscow, Russia, pp. 130–204.

Kolesnikova, S. I., 2011. *A method for recognizing and evaluating states of weakly formalized dynamic object based on labeling a time series.* Journal of Computer and Systems Sciences International, Vol. 50, no 5, pp. 722-733.

Kolesnikova, S. I., Fomenkova, A. A., 2023. *Dynamic strategies for control over the quality of monitoring of a complex bioengineering object*. Informacionnoupravljajushhie sistemy [Information and control systems], no 2, pp. 51–60.

Kolesnikova, S., Kustova, E., 2023. *Application of a Stochastic Extension of the Analytical Design of Aggregated Regulators to a Multidimensional Biomedical Object*. Mathematics, Vol. 11(21), 4484.

Kolesnikova, S.I. *Synthesis of Controller for Vector Plant, Based on Integral Adaptation Method for Disturbance Suppression*. Differential equations and control processes, 2022, no. 3, pp. 27-45.

Krasovskii, A. A., 2002. *Mathematical and Applied Theory. Selected Works*. Nauka, Moscow, Russia, 2002, pp. 169–238.

Lazarević, M. P., 2015. *Elements of mathematical phenomenology of self-organization nonlinear dynamical systems: Synergetics and fractional calculus approach*. International Journal of Non-Linear Mechanics, vol. 73, pp. 31-42.

Lucia, S., Kögel, M., Zometa, P., Quevedo, D. E., Findeisen, R., 2016. *Predictive control, embedded cyberphysical systems and systems of systems – A perspective.* Annual Reviews in Control, Vol. 41, pp. 193-207.

Mendiola-Rodriguez, T. A., Ricardez-Sandoval, L. A., 2023. *Integration of design and control for renewable energy systems with an application to anaerobic digestion: A deep deterministic policy gradient framework.* Energy 274, 127212.

Narendra, K. S., Harshangi, P., 2015. *Unstable systems stabilizing each other through adaptation*. Proceedings of American Control Conference (ACC), pp. 856 – 861.

Petre, E., Roman, M., Selisteanu, D., 2019. *Nonlinear estimation and control schemes for a complex anaerobic digestion of microalgae with unknown kinetics and inputs*. Bioresource Technology 287, 121429.

Saridis, J., 1980. *Self-organizing Stochastic Control Systems*. Nauka, Moscow, Russia, pp. 308-370.

Sepulchre, R., Jankovic, M., Kokotovic, P. V., 2012. *Constructive nonlinear control.* Springer Science & Business Media, 313 p.

Vorontsov, K. V., 2000. *Optimization methods for linear and monotonic correction in the algebraic approach to the recognition problem.* Computational Mathematics and Mathematical Physics, Vol. 40, no. 1, pp. 166–176.

Zaiets, N., Lutska, N., Lysenko, V., Bolbot, I., Osadchiy, S., 2024. *Design and development of intelligent control strategies and algorithms for automated control of biotechnical objects under uncertainty*. Decision Analytics Journal, Vol. 10, 100416.

Algorithm for Promoting Smart City Projects on Social Networks

Konstantin Semyachkov[a] and Svetlana Dubik[b]
Ural Institute of Management of the Russian Presidential Academy of National Economy and Public Administration, 8 Marta Street, Yekaterinburg, Russia
k.semyachkov@mail.ru

Keywords: Smart city, digitalization, project, promotion algorithm, social network.

Abstract: An analysis of the results of published studies shows the existence of a problem on the absence of a systematic approach to apply various tools for promoting innovative projects on social networks. The purpose of this study is to develop an algorithm for promoting a smart city projects on social networks. The object of this study is social networks. The subject of the study is an algorithm for promoting innovative projects of smart cities on social networks. As a result of the study, the stages of the procedure for promoting innovative projects of the smart city on social networks were identified, the features of each of the stages of promoting innovative projects on social networks were considered. The author's algorithm for promoting the smart city projects on social networks is presented, supplementing the existing management tools for the implementation of the digital transformation of urbanized territories based on the use of social networks.

1 INTRODUCTION

In the context of global demographic changes and accelerated urbanization, an increasing number of cities are striving to create innovative spaces, becoming "smart cities", where advanced technologies are used to improve the quality of life of citizens, optimize infrastructure and resources, improve conditions of transport mobility and ensure environmental sustainability (Albino, Berardi, & Dangelico, 2015).

In the context of the formation of a digital society, smart city projects are becoming increasingly relevant. The development of digital technologies, the spread of the Internet and the growth in the number of networked devices make it possible to create smart cities with more efficient and convenient infrastructure. As part of the digital society, cities are actively implementing innovative projects, such as smart lighting, automated transport management, smart sensors for monitoring air quality, video surveillance systems, etc.

Nowadays, smart cities are becoming increasingly popular as they offer innovative solutions to improve the quality of life of citizens (Rabari & Storper, 2014). However, in order to successfully implement a smart city project, it is necessary to develop effective methods for promoting smart city initiatives among stakeholders, including business and the local population.

However, despite rapid technological progress and innovation, the successful promotion and implementation of smart city projects faces serious obstacles. One of the key problems is the lack of a procedure for promoting smart city projects, effective promotion methods that can ensure widespread dissemination of innovative smart city projects and maximum involvement of stakeholders. This challenge requires an integrated approach that combines scientific research, the development of practical models and strategies, and professional skills in marketing, project management and public relations. Based on this, the purpose of this study is to develop an algorithm for promoting smart city projects in social networks.

An important factor in promoting smart city projects is public involvement. Successful smart cities are built on the inclusion of all citizens in decision-making and project development. This requires the creation of open platforms for discussion and feedback, as well as regular consultations with the local community (Anttiroiko, 2016).

[a] https://orcid.org/0000-0003-0998-0183
[b] https://orcid.org/0009-0002-9352-6046

The promotion of smart city projects is based on ideas about maximizing the popularization of the processes of digital transformation of urban areas. As part of the implementation of campaigns to promote smart city ideas, a huge range of marketing communications is used, including tools such as Internet marketing, brand management, and SMM promotion. All of them are intertwined with traditional means of promotion - advertising, sales promotion, public relations and personal selling.

Another important factor in promoting smart city projects is partnerships with the private sector. Effective smart cities actively engage with private companies and startups to attract innovative technologies and investment. To do this, it is necessary to create favorable conditions for the development of the high-tech industry and small businesses, as well as create public-private partnership mechanisms (Dupont, Morel, Guidat, 2015). Thus, promoting smart city projects requires an integrated approach that includes the use of digital platforms, participation in events and the use of social networks. Active promotion of smart city projects allows local authorities to attract the attention of investors, partners and the general public, which contributes to the successful implementation of innovative solutions in the urban environment.

Projects of smart cities are becoming more and more popular in the modern world. They combine the latest technologies and innovative approaches to improve the quality of life of citizens and optimize the city infrastructure. However, the successful implementation of such projects requires effective methods and promotion strategies.

In scientific publications in this field, several main methods of promoting projects of a smart city can be distinguished:

1. The involvement of interested parties. Projects of the smart city often require cooperation of various interested parties, such as city authorities, private companies, academic institutions and civilian societies. The involvement of all participants will help create strong support and interest in the project, as well as guarantee its successful implementation (Lee & Lee, 2014).

2. Education and information campaign. An important part of the promotion of smart city projects is the creation of an information campaign for citizens and other interested parties. This will help increase awareness about the goals and advantages of the project, as well as create a positive attitude towards it (Kowalik, 2021).

3. Pilot projects and demonstration sites. Conducting pilot projects and creating demonstration sites allows city authorities to demonstrate the advantages of a smart city in practice. It also helps to establish confidence in the project by interested parties and citizens (Meijer & Thaens, 2016).

4. The use of digital and media platforms. Digital and media platforms can be used to disseminate information about the project, as well as to involve the public through various online tools (Blasi, Gobbo, & Sedita, 2022).

5. Participation in international campaigns and events. Participation in international campaigns and events in the field of smart cities can help draw attention to the project in the world arena, as well as provide access to international resources and experience (Appio, Lima, & Paroutis, 2018).

Studies show that the successful promotion of the smart city projects requires an integrated approach, which includes involving interested parties, creating an information campaign, holding pilot projects, using digital and media platforms, as well as participation in international campaigns and events. Development of a promotion strategy is an important stage in the implementation of smart cities projects, which requires a professional and competent approach.

When discussing the development of innovative technologies, entrepreneurship and other issues, the problem of effective and rapid dissemination of information about innovations arises. With this comes the challenge of choosing the right tools to promote innovation and use resources efficiently. One of the most effective tools for promoting innovative projects in the modern world is social networks (Ugljanin, Stojanović, Kajan, & Maamar, 2018).

In a general sense, a social network is a complex system of connections between people, groups and organizations that have a certain structure. A social network is a social structure that includes various entities such as people, groups, communities and organizations, as well as their interconnections or social relationships. In a broad sense, a social network is a group of people united by common interests, activities or other reasons for direct interaction. A philosophical approach to a social network includes various social actors and a certain set of relationships between them. Social networks are used in various fields, including sociology, psychology, economics, politics, etc. They are actively used for the analysis of social movements, the study of intercultural relations, risk analysis and decision making (Ajayi, 2021).

An important aspect of social networks is their ability to convey information, share experiences and ideas, making them an integral tool for expanding connections and achieving personal and professional goals. Over time, social networks are becoming increasingly popular not only in the personal sphere, but also as a means of promoting business and innovative projects. Using social networks as a tool for promoting innovative projects is one of the effective ways to attract the target audience and, in the future, implement such projects (Madyatmadja, Abdurachman, Gaol, Pudjianto, & Hapsara, 2018).

Promoting innovative projects on social networks pursues the following goals: increasing awareness of the promoted product (service); attracting investments; partnership and cooperation; optimization and modernization of the project taking into account consumer feedback; creating and strengthening the image of the presenting company.

Users of social networks can familiarize themselves with the project, delve into the details and possibly leave feedback. This feedback can be either positive or negative, which can cause certain difficulties and perception problems. By analyzing the opinions of each user and their comments, local authorities can upgrade the project to a state in which it will work successfully after the first implementation. The opinions of leaders play an important role in promoting new ideas, goods and services on the market, as well as in economics and politics. These may be people who have a significant influence on public consciousness and are very popular. On the Internet, bloggers often play this role. With their help, it is possible to attract people's attention to the need to implement a certain idea. Opinion leaders are also able to inform their viewers and readers about the creation of new innovative projects, talk about their advantages and express their point of view for followers. In this way, innovative projects can reach a wide audience of society. The feedback can then be analyzed.

An analysis of the results of published research shows that there is a problem in the lack of a systematic approach to the use of various tools for promoting innovative projects in social networks.

2 METHODS

Currently, there is already an extensive set of tools for analyzing the promotion of innovative projects on social networks, each of which can be applied successfully depending on specific conditions. However, there is still no algorithm for promoting smart city projects on social networks to increase the involvement of stakeholders in the processes of digitalization of urban areas.

The object of the study is the processes of promoting smart city projects. The subject of the study is an algorithm for promoting smart city projects on social networks. The information base for the study was scientific articles on this topic, indexed in international databases of scientific publications for 2015–2023, as well as author’s developments.

The research consists of the following stages: formulation of the problem, consideration of previous studies, development of the author’s algorithm for promoting smart city projects among the local population.

3 RESULTS

An algorithm for promoting smart city projects in social networks, which can be used to involve stakeholders in the processes of digital transformation of an urbanized area, is presented in Figure 1.

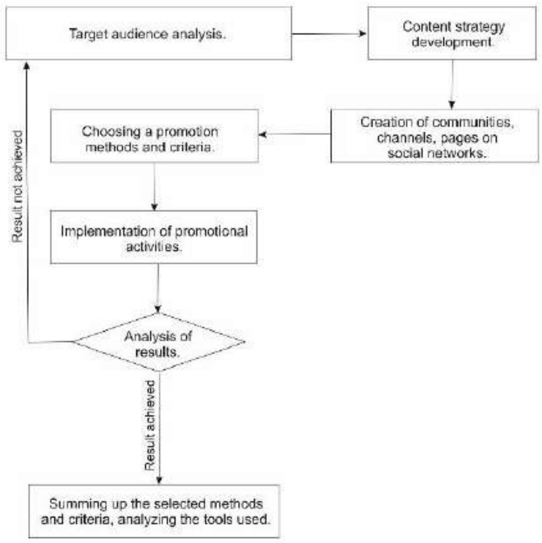


Figure 1: Algorithm for promoting smart city projects on social networks.

The first step of the algorithm is to analyze the target audience. To successfully promote a project, it is necessary to understand who its potential users are. Analysis of the target audience allows local authorities to determine the main communication channels and select the most effective social networks for promoting the project.

The second step of the algorithm is the development of a content strategy. Content strategy determines what information will be published on social networks and how it will be presented. It is important to take into account the interests and needs of the target audience so that the content is interesting and useful for users. The content strategy should also include a plan to gradually involve users in the project and stimulate their activity.

The third step of the algorithm is to create a community on social networks. Creating a community allows local authorities to unite users interested in a smart city project and ensure active interaction between them. The community has the opportunity to hold discussions, share news and information about the project, organize competitions and promotions. It is important to create an atmosphere of interaction and support so that users feel part of the project and are motivated to actively participate in it.

The fourth step of the algorithm is the selection of tools, promotion methods and determination of criteria for assessing the effectiveness of the results. Defining specific activities and criteria for their evaluation allows local authorities to make the promotion procedure more understandable and predictable.

The fifth step of the algorithm is to implement planned activities aimed at promoting smart city projects on social networks. Here it is important to determine the budget of the events, performers, timing of the events and other parameters.

The sixth step of the algorithm is monitoring and analyzing the results. It is important to monitor the effectiveness of project promotion on social networks and analyze the results obtained. Monitoring allows local authorities to identify successful and unsuccessful moments in promotion and make adjustments to the algorithm. Analyzing the results helps management structures determine which strategies and tactics were most effective and use them in the future.

If the planned indicators are achieved, it is necessary to analyze the methods used, identify their advantages and disadvantages, and possibilities for future use.

As a result, the algorithm for promoting smart city projects on social networks is an important tool for attracting the attention of the audience and the successful implementation of innovative ideas. A properly developed algorithm will allow local authorities to effectively use the power of social networks and achieve the desired results. The development and use of an algorithm for promoting smart cities in social networks allows management structures not only to attract attention to projects, but also to create an active community of support and involve citizens in the process of improving the urban environment.

4 DISCUSSION

Currently, smart cities are becoming increasingly popular and in demand. They represent innovative urban projects based on the use of modern technologies, digital solutions and network infrastructures. The goal of smart cities is to improve the quality of life of citizens, optimize the management of urban resources and create a sustainable and environmentally friendly environment.

However, in order to successfully implement smart city projects, it is necessary not only to develop an innovative solution, but also to promote it among the population. Social networks, which have become an integral part of our lives, play an important role in this. Social networks provide a unique opportunity to promote smart city projects, as they gather a huge number of users willing to interact and share information.

One of the main problems is the low awareness of citizens about the concept of smart cities and the projects being implemented in their cities. Most people do not understand the benefits a smart city can bring and why it is important to support such projects. Here, social media plays a key role in disseminating information and attracting attention to smart city projects. In this regard, it is necessary to develop effective communication strategies to transform some abstract and complex concepts into clear and engaging stories that can interest and engage the target audience.

Evaluating methods for promoting smart city projects is necessary for the effective implementation of their goals. It is important to use modern marketing and advertising techniques to inform citizens about the benefits and opportunities of smart cities. It is also necessary to actively involve the public, hold events and promotions to generate interest and support from residents. Only joint efforts and correctly chosen promotion methods can ensure the successful implementation of smart city projects and their implementation in the everyday life of society.

Smart cities are a concept that is actively developing in the modern world. The idea of a smart city is to use advanced technologies to improve the quality of life of residents, improve infrastructure and optimize resources. Smart city projects involve the introduction of modern digital technologies in order to improve the lives of citizens and optimize the urban environment.

One of the key points in promoting smart city projects on social networks is creating interesting and engaging content. Articles, videos, photographs, animations - all this should be unique and attract the attention of the target audience. Such content must be relevant and informative to interest users. Modern cities are becoming more and more technologically advanced and smart, thanks to the introduction of various innovative projects. One of the key points when developing such projects is their promotion and attracting the attention of a wide audience. Nowadays, social networks play an important role in promoting smart city projects.

However, it is worth noting that each project requires an individual approach, and knowledge of the main advancement tools helps to make the right choice and achieve success on social networks.

5 CONCLUSIONS

In this study, in order to develop an algorithm for promoting projects of a smart city on social networks, the following theoretical and practical results were obtained.

Firstly, the analysis of the results of published studies revealed the existence of a problem on the lack of a systematic approach to promote smart cities on social networks.

Secondly, the stages of promotion of smart city projects on social networks are highlighted.

Thirdly, a comprehensive mechanism for promoting the smart city projects on social networks is presented based on the use of modern promotion tools.

The practical significance of the results obtained is to develop the basis of the applied apparatus planning for the use of various tools for promoting projects of a smart city on social networks.

ACKNOWLEDGEMENTS

The study was supported by the Russian Science Foundation under project no. 24-18-20036.

REFERENCES

Albino, V., Berardi, U., Dangelico, R. M., 2015. Smart Cities: Definitions, Dimensions, Performance, and Initiatives. Journal of Urban Technology, 22(1), 3–21.

Rabari, C., Storper, M., 2014). The digital skin of cities: urban theory and research in the age of the sensored and metered city, ubiquitous computing and big data. Cambridge Journal of Regions, Economy and Society, 8(1), 27–42.

Anttiroiko, A.-V., 2016). City-as-a-Platform: The Rise of Participatory Innovation Platforms in Finnish Cities. Sustainability, 8(9), 922.

Dupont, L., Morel, L., Guidat, C., 2015. Innovative public-private partnership to support Smart City: the case of “Chaire REVES”. Journal of Strategy and Management, 8(3), 245-265

Lee, J., Lee, H., 2014. Developing and validating a citizen-centric typology for smart city services. Government Information Quarterly, 31, 93–105.

Kowalik, K., 2021. Social media as a distribution of emotions, not participation. Polish exploratory study in the EU smart city communication context. Cities, 108, 102995.

Meijer, A., Thaens, M., 2016. Urban Technological Innovation: Developing and Testing a Sociotechnical Framework for Studying Smart City Projects. Urban Affairs Review, 54(2), 363–387.

Blasi, S., Gobbo, E., Sedita, S. R., 2022. Smart cities and citizen engagement: Evidence from Twitter data analysis on Italian municipalities. Journal of Urban Management, 11(2), 153-165.

Appio, F. P., Lima, M., Paroutis, S., 2018. Understanding Smart Cities: Innovation ecosystems, technological advancements, and societal challenges. Technological Forecasting and Social Change.

Ugljanin, E., Stojanović, D., Kajan, E., Maamar, Z., 2018. Re-engineering of smart city's business processes based on social networks and Internet of Things. Facta Universitatis, Series: Automatic Control and Robotics, 16, 275.

Ajayi, O., 2021. Evaluation of social media as a tool enabler for smart city development–A study of selected local governments in LagosNigeria. CJMR, 2(2), 219-228.

Madyatmadja, E. D., Abdurachman, E., Gaol, F. L., Pudjianto, B. W., Hapsara, M., 2018. Potential impact of social media to support government services in Jakarta smart city. In 2018 International Conference on Information Management and Technology (ICIMTech) (pp. 534-538). IEEE.

Digital Technologies and Artificial Intelligence in Architectural Education

Viktoriia Vitalievna Sidorova[a], Vyacheslav Gennadievich Podolsky[b], Viktoriia Viktorovna Zhivitsa[c] and Konstantin Vadimovich Bubnov[d],
V.I. Vernadsky Crimean Federal University, Institute "Academy of Construction and Architecture", Kievskaya str. 181, Simferopol, Russian Federation

Keywords: artificial intelligence, building design, urban planning, smart cities, digitalization of education, Building Information Modeling.

Abstract: The article provides an overview and comparison of modern innovations in the field of educational activities for future architects in the Russian Federation. An analysis has been made of the most widely used computer programs for architectural education, features and prospects for the use of artificial intelligence in world practice in general. An analysis of the capabilities of artificial intelligence programs and chats was also carried out. The advantages and disadvantages identified during the analysis and use of artificial intelligence for design in the field of urban planning, architecture and design are outlined. BIM design is considered as a modern approach to design and construction. The BIM extension – Historical Building Information Modeling (HBIM) (Historical BIM) is highlighted as the most relevant for the preservation and popularization of architectural monuments, urban planning, archeology and history. It has been determined that the most promising technology for the development of the architectural environment in a broad sense is the development of digital analogues of buildings. Recommendations for the optimal formation of educational programs and curricula with the mandatory presence of traditional manual design methods and modern technologies are outlined.

1 INTRODUCTION

Currently, for successful work, a specialist in the field of design, construction, urban planning, reconstruction, restoration and similar specialties must master at a higher educational institution and throughout his professional activity constantly develop and improve knowledge, skills and abilities in working with digital technologies. And recently, in addition to confident mastery of professional programs, the need to know the principles of working with artificial intelligence has been added.

"Taking into account demographic challenges in the coming years, the Russian economy will experience a high need and even a shortage of personnel. ... It is critically important to increase labor productivity, modernize industry, the agro-industrial complex, the service sector, and many other sectors of the economy and social sphere using digital technologies, production automation and management processes, which in turn should directly lead to improved working conditions for specialists and an increase in their income." – President of Russia V.V. Putin (Putin, 2024).

The purpose of the study is to analyze the current situation regarding the use of artificial intelligence and digital technologies in the field of architectural education, as well as to make a forecast about the results of their use.

2 RESEARCH METHODOLOGY

During the study, the following methods were used: scientific analysis, comparison, generalization, forecasting.

[a] https://orcid.org/0000-0002-0071-7875
[b] https://orcid.org/0000-0001-6427-4260
[c] https://orcid.org/0000-0002-1501-5235
[d] https://orcid.org/0009-0009-3540-7357

3 RESEARCH RESULTS

Currently, the traditional view of training a future architect or urban planner requires significant reassessment and clarification.

In this regard, many leading universities in the Russian Federation are already making adjustments to their curricula, opening new digital departments, developing advanced training courses and programs for additional professional education in the field of using digital technologies and artificial intelligence. Due to the political situation, work is being carried out on import substitution of software. Based on the results of an analysis of the experience of using computer programs and complexes in the educational process in Russian architectural universities, the most popular products were identified: Photoshop, CorelDRAW, SketchUp, AutoCAD, 3D Studio MAX, ArchiCAD, Lumion 3d, Revit, Renga. Domestic software developments by Renga, nanoCAD, and Revit are gaining popularity. A review of the application features and advantages of the selected software products has been made, as a result of which it has been proven that for full-fledged work, an architect must have a complex of knowledge and skills of several programs for competent professional activity and continuously self-train taking into account updates to software products.

BIM design (Building Information Modeling), which allows you to design an object comprehensively, taking into account the entire life cycle, has occupied a special place in the mandatory basic educational process. Also, during the BIM study, a very relevant extension of it was identified - Information Modeling of Historical Buildings (HBIM or Historical BIM), which allows you to work with cultural heritage objects at a new modern level. This extension is also recommended for future architects to add to their knowledge base.

The development of digital technologies is not just a trend of our time, but an entire government strategy. Digital twins are now actively developing in the new design and operation of buildings and structures, in urban planning, and in the optimization of industrial processes. Right now it is necessary to think about creating a digital asset and a unified register of digital twins of cultural heritage objects .

Digital education is an integral part of architectural education and, in the modern world, plays one of the key roles in unlocking the creative potential of students and how they apply knowledge and skills in the digital environment of professional activity.

It is undoubtedly easier for students to master new technologies due to the physiological characteristics of a young organism and their impact on cognitive abilities. Scientists have proven that the speed of information processing grows until the age of 18-19, and then gradually begins to decline. After 35 years, memorization begins to become worse for a person, and it takes more and more time to draw any conclusions and make a decision. Of course, a person learns and accumulates information throughout his life, but it is during his student years that its assimilation, associated with high brain productivity, is most effective (Stasevich, 2024).

An important factor indicating the priority of obtaining the necessary knowledge during their student years is the relative freedom of students from unnecessary obligations: urgent work, obligations to the family and other circumstances that complicate the allocation of time for additional education or advanced training necessary for further development in the professional field.

Therefore, it seems extremely relevant to include in the curricula of higher educational institutions that train specialists in the fields of architectural, urban planning, reconstruction and restoration of buildings and structures, academic disciplines in information technology and the use of artificial intelligence, forming their digital instrumental literacy.

As a result of generalizing information about modern architectural activity, the main components of its tools have been identified: digital tools, digital resources, graphical computer tools (tablet, stylus, interactive tablet, VR tools, etc.), as well as specialized computer programs for creating and visualizing architectural models, and software systems based on BIM design.

Artificial intelligence is identified as a new challenge in architectural activity. The main areas of application of artificial intelligence have been identified:

• Building design:

- Idea generation: AI can generate various design options, helping architects find optimal solutions.

- Data analytics: AI can process large amounts of data on climate, lighting, energy efficiency, etc. to optimize building design.

- Automate routine tasks: AI can automate tasks such as creating drawings and 3D models, freeing up architects' time for more creative work.

• Urban planning:

- Smart Cities: AI can be used to create smart cities that are more efficient, sustainable and livable.

- Transportation planning: AI can optimize transportation systems, reducing congestion and air pollution.

- Social planning: AI can help plan social facilities such as schools, hospitals and parks based on the needs of the population.

Benefits of using AI:

- Increased efficiency: AI can speed up the design and construction process and improve the quality of the final product.

- Cost reduction: AI can help reduce design and construction costs.

- Improving the quality of life: AI can make cities more comfortable, safe and environmentally friendly.

The analysis of artificial intelligence identified its main advantages (automation, cost reduction, increased security, improved design, speed) and disadvantages (limited creativity, ethical problems, limited availability, dependence on technology). The increasing influence of artificial intelligence on the profession of architect is predicted, which will radically change the principle of training specialists.

An important task for heads of educational programs at present is to find a balance in the need for mandatory mastery of hand-made graphics, basic knowledge and skills for the formation of taste, a sense of harmony and beauty among students, as well as their mastery of modern tools of architectural activity.

4 DISCUSSION OF RESULTS

During the study, an extensive analysis of publications related to important modern methods of teaching architecture students in higher educational institutions of Russia was made. Issues of professional training of architectural specialties were dealt with by O.V. Solnyshkova. (Solnyshkova, 2013),Terskova M.T. (Terskova, 2023),Tokmakov A.A., Kober O.I. (Tokmakov, Kober, 2017), Titov A.L. (Titov, 2022), Mironova N.S. (Mironova, 2023), Bagrova N.V., Zhurin N.P., Pustovetov G.I., Filonov S.V. (Bagrova,. Zhurin,, Pustovetov, Filonov, 2020), Erokhin G.P., Rodionova Yu.V. (Erokhin, Rodionova, 2020) and others.

The Russian state education system has identified interactivity and practical orientation of the learning process as components of the new Federal State Educational Standards for Higher Professional Education. When hiring, specialists who know how to use computer-aided design systems and other specialized software are especially in demand (Solnyshkova, 2013).

The concept of digital instrumental literacy is formulated in the work of Terskova M.T. (Terskova, 2023) as a person’s ability to use digital tools to achieve his goal in the fastest and most effective way, both in material and digital space.

It should be noted that digital instrumental literacy is not only knowledge of computer technologies and technical aspects of working with digital tools, but also the ability to use them to solve professional problems.

In the educational process, computer technologies, among others, can realize the following opportunities:

• consolidation of professional knowledge, skills and abilities acquired in other disciplines;

• increasing the level of self-education;

• development of intellectual and creative abilities;

• use of various sources of information, and, therefore, coverage of more knowledge;

• search for non-standard solutions for performing certain design tasks, etc (Tokmakov, Kober, 2017). It is also necessary to take into account the ultra-fast development of technologies based on neural networks, called artificial intelligence.

Today, the concept of “digitalization” occupies more and more space in the human environment and is used in all sectors of the state. Digital literacy began to manifest itself in various fields of science and formed new concepts of “digital environment”, “digital community”, “digital economy”, “digitalization of education”, etc.

Review of the use of Artificial Intelligence and Digital Technologies in universities.

The effective use of information and computer technologies, the implementation of their capabilities is an integral part of the training of future architects at Orenburg State University, Altai State Academy of Education V. M. Shukshin; Moscow Architectural University (the department of “Information Technologies in Architecture” was created here - the former educational and research center “Architecture and Computer Technologies”); Ural State University of Architecture and Art N.S. Alferova; St. Petersburg State University of Architecture and Civil Engineering (the Department of Information Technologies was created); Volgograd State Technical University (the department “Digital Technologies in Urbanism, Architecture and Construction” was created); Southern Federal University (the department of graphics and information technologies of architectural design was created), also, digital departments were created at the

Crimean Federal University in 2023 and many other universities in the country.

For example, at Orenburg State University future architects study a multifunctional computer-aided design package, working with computer information systems: Adobe PhotoShop, Corel Graphics Suite; SketchUp, Autodesk 3ds Max, ArchiCAD, AutoCAD, Lumion 3d; Photodex ProShow Producer (Tokmakov, Kober, 2017).

At the Ural State University of Architecture and Art named after N.S. Alferova, Ekaterinburg, Russia (UrGAHU) students study: Photoshop, CorelDRAW, SketchUp, AutoCAD, 3D Studio MAX, ArchiCAD, Revit, Renga (Titov, 2022)

The Department of Information Technologies in Architecture (MARCHI) carries out educational, educational, methodological and scientific activities in the field of computer support for architectural design. The department implements the following disciplines: "Fundamentals of GIS. Tools for urban context analysis." "Digital means of parametric shaping." "Computer graphics" "Computer technologies in architectural design" "Computer composition-combinatorial course" .

The Department of Information Technologies (SPbGASU) actively introduces BIM technologies into the educational process and scientific work, and also acts as the organizer of the annual international scientific and practical conference "BIM modeling in construction and architecture problems.".

The Department of Digital Technologies in Urbanism, Architecture and Construction (DTUAS) of Volgograd State Technical University is developing several scientific areas:

1. Application of ontological engineering at all stages of the life cycle of construction projects and elements of the urban planning system;

2. Analysis of the visual urban environment (computer vision technologies for recognizing elements of the architectural environment, urban areas; development of recommendation systems);

3. Modules for geographic information systems (extraction, processing and generation of data to solve specific practical problems; generation of interactive maps in the field of environmental safety; analysis of the road transport system, etc.; work with plants, climate and terrain);

4. Development of extensions/additions/plugins for specialized software systems (Renga, nanoCAD, Revit, etc.) used in the field of construction and architecture, including the introduction of BIM technologies;

5. Additive technologies and Internet of things (IoT) in the field of construction and architecture;

6. Projects using AR/VR technologies, etc.

Many universities today are working on import substitution of software. The possibilities of domestic developments, such as Renga and nanoCAD, are being studied, and the experimental implementation of these programs in the educational process is being carried out.

BIM (Building Information Modeling) has occupied a special basic niche. The main vector of BIM is aimed at automating the design process, creating a digital model of the building in dynamics and taking into account the entire life cycle of the object in coordination.

Historical Building Information Modeling (HBIM) is an extension of BIM developed specifically for historical buildings and cultural heritage sites. It focuses on managing and documenting historical structures using parametric objects (models) created from both current data and historical research. In 2009, Murphy, McGovern and Pavia coined the term as a combination of building information modelling (BIM) and historic preservation.

Purpose of HBIM:

1. Preservation through documentation: A project can significantly change a historical structure. The project team can capture and document existing conditions for archival purposes.

2. Analysis: HBIM is a powerful tool for understanding underlying problems (such as structural or material failures) that cannot be corrected. This data can allow engineers to plan potential interventions. A good example is the numerous problems that the Leaning Tower of Pisa faced over the years until it finally stabilized in the 21st century.

3. Restoration: All major projects begin with documentation. Restoration projects are no different. Once information is visually archived, the project team can use the HBIM environment to plan, visualize and execute restoration projects in a data-rich context.

4. Management: Conservation societies can use a variety of HBIM platforms such as Layer App to manage the ongoing maintenance, management and protection of cultural heritage assets (Lee, 2023).

Romanov A.S. proposes to introduce a separate concept for wooden architecture objects: HWBIM (Historical Wooden BIM) or Information Model of a Historical Wooden Building. He also notes that to optimize the process of working with objects of Russian wooden architecture, a unified algorithm for constructing an information model is necessary (Romanov, 2023).

Let's highlight the importance of creating digital twins of buildings. These technologies are the future of architecture, construction and operation of facilities under construction. The Russian Federation has approved GOST, which establishes the concept of a digital twin. A digital twin is a virtual model of an object that accurately reproduces the form and actions of the original and is synchronized with it. The technology helps to simulate what will happen to the building under different operating conditions.

In the process of training architecture students, it is necessary not only to adhere to classical educational methods, but also to give them the opportunity to get acquainted with modern technologies. For example, how a digital twin of a building, both designed and reconstructed, is created and for what purposes can it be used.

One of the technologies that allows you to create a digital twin of a historical building quickly is laser scanning. The object is scanned with a laser scanner, all data is uploaded to a computer, which subsequently still needs to be "stitched" into a digital model, into a single field of points. Further, students, scientists, and restorers can work with this model. In the future, these models made by students could be included in a unified digital register of historical objects, buildings and structures. The main disadvantage is the high price of laser equipment and software (for example, Trimble RealWorks).

There is another way, but it is more labor-intensive and time-consuming. This is collecting materials in the classical way - collecting materials in archives, measurements, research. Based on the work done, you can create a digital twin using software and BIM technologies.

Creating digital twins of historical objects will allow preserving lost invaluable experience and the appearance of cultural objects, recreating lost materials, the design, skill of the author, planning and urban planning solutions in the digital environment (Mironova, 2023).

Features of the use of various computer programs during teaching architecture were described in their works by: Gerasimenko A. (Gerasimenko, 2021), Sukhanova I. I., Fedorov S. V., Stolbikhin Yu. V., Sukhanov K. O. (Sukhanova, 2024), Lozhkina E. A. (Lozhkina, Lozhkin, 2019), Smorodina E. I. (Smorodina, 2020), Zelenina V. (Zelenina, Puysans, 2007) and others.

Today, there are many software packages that can answer the frequently asked questions of modern architects and designers. But in order to analyze such an abundance of programs, they should be structured according to functions and tasks that can be solved in a particular program, but taking into account an integrated approach when developing a project:

1. Programs based on BIM technologies
2. Local programs for specific tasks

Of course, the absolute favorites in the development of software products for the design and modeling of buildings and structures, especially for architectural specialties, are the foreign companies AUTODESK and GRAPHISOFT, which develop software for industrial and civil construction projects based on building information modeling technology.

1. AUTODESK AutoCAD is one of the most famous computer-aided design systems (Gerasimenko, 2021). The first version of the program appeared on the market in December 1982 and already had impressive potential in the field of two-dimensional drawing. Throughout its existence, the program has been constantly improved, new modules and plug-ins have been added, digital processes have been optimized, a full range of creating and editing 3D models of bodies and surfaces has been included, and a database of normative, reference and technical documentation has also been included.

The main product areas for the architectural and construction industry: AutoCAD Architecture and AutoCAD Civil 3D.

This program is still in great demand for design specialties.

2. AUTODESK Revit. A software package designed for computer-aided design that implements the principle of building information modeling (Sukhanova, 2024). This program is more in demand for architectural specialties due to the creation of three-dimensional prototypes of buildings and structures that can be visualized. One of the key features of Revit is the relationship of project elements with each other, and the slightest change in one element is immediately reflected in others, thus eliminating inaccuracies in the project.

3. AUTODESK 3ds Max. This program is one of the most difficult to master, but has serious potential for an integrated approach to project development. Main areas of the program: three-dimensional modeling; creating animation and dynamics in the environment; rendering and compositing (Lozhkina, Lozhkin, 2019). The program has advanced tools for creating complex, varied shapes and three-dimensional computer models using different techniques. Visualization is represented by a large number of modules for any task (V-Ray, FinalRender, Corona Renderer, etc.), and the high quality of post-processing of design solutions (interiors, exteriors,

environment, etc.) makes the program very popular for its development.

Of course, such products cannot but have disadvantages. 3ds Max is subject to high requirements in terms of mastering functional elements and operating skills, as well as having high specifications for computer equipment.

4. GRAPHISOHT ArchiCAD is more focused on architects, however, given the functionality of the program, it can also be targeted at other specialties. ArchiCAD, like the previously mentioned products, works on the basis of BIM technology, which allows you to solve many problems at a high level (Smorodina, 2020).

The main functionality of the program: three-dimensional modeling of objects, creation of floor plans, the ability to edit project elements in real time in connection with the entire model, and also has an impressive package of software:

- SketchUp - a program for creating 3D design and architectural design. Most often used by architects for designing and modeling capital construction projects, creating and visualizing the environment. A distinctive feature of the program is its support for the Google Earth software resource (virtual globe).

- Sweet Home 3D. This program is presented for the design of individual premises. It has a fairly rich catalog of interior decoration elements and the ability to edit them.

- Plan Pro. Another product for creating quick and easy plans for frame houses. The program allows you to develop the appearance of buildings, design individual rooms, and organize the interior space.

- Lumion – a program for 3D visualization and rendering. The program has the ability to simulate the internal space of an object and create an environment, but more often the program is used as a visualization tool in a pre-prepared project. The program is compatible with many raster and vector formats.

5. Programs for processing orthogonal views of a project, with the help of which you can create a nice picture and compose a design solution. Suitable programs are: Adobe Photoshop, Adobe Illustration, Corel, etc. (Zelenina, Puysans, 2007).

As a result of analysis of publications (Litvinenko, 2023; Vlasova, Vlasova, Borovikova, Karelin, 2023) and our own observations let's take a closer look at the benefits of using AI:

- Increased efficiency: AI can speed up the design and construction process and improve the quality of the final product.

- Cost reduction: AI can help reduce design and construction costs.

- Improving the quality of life: AI can make cities more comfortable, safe and environmentally friendly.

- Automation: AI can automate routine tasks such as drafting, 3D modeling, data analysis and documentation. This frees up architects to be more creative and strategic. AI can be used to generate design options, allowing architects to find optimal solutions faster and more efficiently.

- Design improvement: AI can be used to analyze data about users and the environment, leading to more comfortable and functional buildings. AI can be used to optimize energy consumption and other aspects of sustainability.

- Increased security: AI can be used to identify potential safety issues during the design phase. AI can be used to monitor the condition of buildings and structures, which allows timely measures to be taken to prevent accidents.

Disadvantages of AI in architecture identified from the analysis of publications (Milgizin, Baeva, 2017; Popescu, 2023; Meyrand, 2023; Babich, 2021; Khokhlova, 2017; Bakunov, 2022) and experimental work of the authors:

- Limited creativity: AI is not capable of original ideas and solutions. AI can only generate designs that are based on available data.

- Ethical issues: AI can be used to create buildings that do not take human needs into account. AI can be used to create surveillance and control systems that can violate people's privacy.

- Limited Availability: AI technologies in architecture are still at an early stage of development. Only large companies and research centers have access to these technologies.

- Dependence on technology: overuse of AI may cause architects to lose their manual design skills. If AI systems fail, serious problems can arise.

5 CONCLUSIONS

The basis of the professional competence of an architect is readiness for design activities, since the meaning of his work is to create a social-production system that realizes the needs of society in organizing the spatial environment of life. Many projects of the 21st century are created exclusively with the help of computer technology, therefore, for the productive work of an architect in the modern information world, fundamental basic computer graphics training is needed.

However, in the field of higher architectural education, the potential of modern information technologies is far from being fully used. The creative capabilities of computer technologies are not used, which shifts the emphasis of professional architectural education towards technocratization to the detriment of the creative, artistic component.

Currently, it is obvious that training in modern IT technologies is necessary for bachelors of architects and urban planners. But the implementation of these programs leads to a simplification of the architecture itself, to the suppression of individual author's styles. After all, in the estimated time allotted for design, it is easier for a student to make a simple model and get a high grade for it than to try to show his individuality.

Therefore, from junior design courses, teachers need to show the importance of acquiring basic architectural and artistic knowledge and hand-graphics skills for a conscious choice of artistic preferences, for practicing their own compositional and figurative techniques, their own author's style, although this will take a lot of time.

Despite the availability of information modelling technology in modern software products, when developing design and working documentation, you should still have the skills to work in several programs. And the reason for this is the optimization and tailoring of each program for specific tasks. The article discusses examples of programs in which all problems can be solved, but the method of solving them can be presented in different ways: in one action, two or more; what knowledge and skills will be required to solve a specific problem; what resources will be used, etc.

The profession of an architect has always been complex and multi-tasking, and with the development of scientific and technological progress in the form of the emergence of CAD systems and the establishment of requirements for the development of relevant documentation, it is necessary to constantly improve and optimize the work process by studying new software systems.

AI has great potential to transform architecture. However, it is important to use these technologies responsibly and ethically.

In conclusion, it should be summarized that artificial intelligence does not replace architects, but complements their capabilities. AI can help architects create more beautiful, functional and sustainable buildings in less time.

REFERENCES

Putin, V., 2024. The economy is facing a shortage of personnel, so labor productivity needs to be increased. - URL: https://tass.ru/ekonomika/20445159 (access date: 04/07/2024).

The future of construction lies in digital twins? Ministry of Construction of Russia. - URL: https://minstroyrf.gov.ru/press/budushchee-stroitelstva-za-tsifrovymi-dvoynikami-/.

Stasevich, K., 2024, April No. 04. *Journal of Science and Life.* How mental abilities change with age.

Didactic properties and functions of information - communication technologies URL: https://ido.tsu.ru/other_res/ep/ikt_umk/text/f3_1.html.

Solnyshkova, O.V., 2013. The use of interactive electronic educational resources in the process of training students of architectural and construction fields. *Modern problems of science and education*, No. 5.

Terskova, M.T., 2023. Digital instrumental literacy of bachelors of design. *New information technologies in architecture and construction. Proceedings of the VI International Scientific and Practical Conference*. November 2–3, p. 74.

Tokmakov, A.A., Kober, O.I., 2017. The role of information technology in the training of architects in higher education.

Titov, A.L., 2022. Features of choosing programs for design by students majoring in architecture. *New information technologies in architecture and construction: mat. V international scientific-practical Conference. Ekaterinburg:* UrGAKhU, p. 54. (access date: 04/12/2024)

Mironova, N.S., 2023. The importance of creating a digital twin of a building in the process of conducting educational practice by architecture students. *New information technologies in architecture and construction. Materials of the VI International Scientific and Practical Conference.* November 2–3, 57 pages.

Bagrova,. N.V., Zhurin,. N.P., Pustovetov,. G.I., Filonov, S.V., 2020. Siberian architectural and art school: yesterday and today. *Journal Project Baikal.* No. 64. pp.110-114. ISSN 2307-4485.

Erokhin, G.P., Rodionova, Yu.V., 2020. Novosibirsk school of parametric urban planning. *Journal Project Baikal*. No. 64. pp.118-125. ISSN 2307-4485.

Working programs of Ural State Agrarian University disciplines. . *Department website*. - URL: https://www.usaaa.ru/sveden/education/rabochie-programmydisciplin/arhitektura-2022 (access date: 04/13/2024)

Information technologies in architecture. *Department website*. - URL: https://marhi.ru/vicomp/

Department of Information Technologies . *Department website*. - URL: https://www.spbgasu.ru/university/faculties-and-departments/kafedra-informatsionnykh-tekhnologiy/

Digital technologies in urbanism, architecture and construction . *Department website*. - URL: https://www.vstu.ru/university/fakultety-i-kafedry/iais/fagr/kafedry/ctvuais (access date: 04/10/2024)

Lee, M., 2023. Historic or Heritage BIM. . *Journal LAYER.*

Romanov, A.S., 2023. Features of information modeling of wooden structures - architectural monuments. *New information technologies in architecture and construction. Materials of the VI International Scientific and Practical Conference* November 2–3. 64 pages. (access date: 04/12/2024)

GOST 57700.37-2021. Computer models and simulation. Digital twins of products. General provisions. - URL: https://files.stroyinf.ru/Data/758/75810.pdf (access date: 04/10/2024)

Gerasimenko, A., 2021. Design in AutoCAD 2020. Moscow: DMK Press, 436 p.

Sukhanova, I. I., 2024. *The book,* Design of engineering systems based on a BIM model in Autodesk Revit MEP: textbook for universities St. Petersburg: Lan, Publisher. 148 pp.

Lozhkina, E. A., Lozhkin, V. S., 2019. *The book*, Design in the 3ds Max environment: tutorial. Novosibirsk: NSTU Publisher. 180 pp.

Smorodina, E. I., 2020. *The book,* Computer technologies in environmental design. ArchiCAD software package: tutorial. Omsk State Technical University Publisher. 83 pp.

Zelenina, V.G., Puysans, S. G., 2007. *The book,* CAD in construction. Perm: PNIPU. Architecture: textbook Publisher. 232 pp.

Neurosphere on vc.ru. (n.d.). Artificial intelligence in architecture: How neural networks are changing design and construction. As of 2024. - URL: https://vc.ru/u/2055179-neyrosfera/770135-iskusstvennyy-intellekt-v-arhitekture-kak-neyroseti-izmenyayut-proektirovanie-i-stroitelstvo (access date: 04/14/2024)

Litvinenko, D.G., 2023. Application of artificial intelligence in design and construction. *Journal of Science.* no. *11(3). 936-939 pp.*

Vlasova, E.L., Vlasova, M.L., Borovikova, N.V., Karelin, D.V., 2023. Artificial intelligence in architectural and urban design. *Journal Architecture and Modern Information Technologies*. no. 4(65). 311-324 pp.

Smart home. (n.d.). How artificial intelligence influences architecture. As of 2024. URL: https://www.smart4smart.ru/blog/ai-in-architecture (access date: 04/10/2024).

Amazon Web Services, Inc. (n.d.). What is intelligent automation? As of 2024. URL: https://aws.amazon.com/ru/what-is/intelligent-automation/ (access date: 04/10/2024).

29.Designs.ai. (n.d.). FACE SWAPPER. Design generator. As of 2024. URL: https://designs.ai/ru (access date: 04/10/2024).

Microsoft. (n.d.). Artificial intelligence and machine learning. As of 2024. URL: https://learn.microsoft.com/ru-ru/azure/architecture/ai-ml/ (access date: 04/10/2024).

RBC Trends. (n.d.). Green technologies. As of 2024. URL: https://trends.rbc.ru/trends/green/cmrm/637cb9859a7947827130e5be (access date: 04/10/2024).

VC.ru. (2023). Using the power of artificial intelligence to optimize production and sales in 2023. URL: https://vc.ru/future/636034-ispolzovanie-vozmozhnostey-iskusstvennogo-intellekta-dlya-optimizacii-proizvodstva-i-prodazh-v-2023-godu (access date: 04/10/2024).

Third Opinion. (n.d.). Monitoring the condition of buildings. As of 2024. URL: https://thirdopinion.ai/monitoring (access date: 04/10/2024).

Milgizin, I.E., Baeva, L.V., 2017. On the issue of creativity in artificial intelligence neural networks. *Journal Philosophical problems of information technology and cyberspace.* no 1(13). 62-71 pp. - URL: https://cyberleninka.ru/article/n/k-voprosu-o-kreativnosti-v-neyrosetyah-iskusstvennogo-intellekta (access date: 04/10/2024)

Popescu, V., 2023. AI Art Generator without limits. *MSPoweruser. (n.d.).*

Meyrand, R., 2023. Artificial Intelligence: Ethical Issues. *Journal* UNESCO Courier.

Babich, M. Yu., 2021. Artificial intelligence and creation of complex organizational and technical systems (Part 1). Izvestiya vysshikh uchebnykh zavedeniy. Povolzhskiy region. Tekhnicheskie nauki. University proceedings. Volga region. *Engineering sciences.* 34–42 pp. (In Russ.).

Khokhlova, D., 2017. The stage of AI development is now at the level of a two-year-old child. Lecture notes from the Director of Technology Distribution at Yandex.

Bakunov, G., 2022. VC.ru. - URL: https://vc.ru/future/23238-sberdays-bakunov (access date: 04/10/2024)

OHCHR, 2022. Humanity should get the best from AI, not the worst - UN disability rights expert. URL: https://www.ohchr.org/ru/stories/2022/05/humanity-should-get-best-ai-not-worst-un-disability-rights-expert

Euronews, 2023. Skills you don't need to learn thanks to AI. URL: https://ru.euronews.com/next/2023/03/14/skills-to-skip-learning-thanks-to-ai (access date: 04/10/2024)

Dzen.ru. (n.d.). In case of failure of AI systems. As of 2024. URL: https://dzen.ru/a/ZarkaPqCO1XCeWoZ (access date: 04/10/2024)

Socio-Cultural, Scientific-Technological, Economic Aspects Reflected in the Basic Provisions of the “Heart in Eurasia” Forum

Salikhova Elvina Akhnafovna[1], Emelin Sergei Mikhailovich[2]
R.G. Kuzeev Institute for Ethnological Research – Subdivision of Federal State Budget Scientific Institution Ufa Federal Research Centre of the Russian Academy of Sciences, 6 K.Marks st., Ufa, Bashkortostan, Russia
Salelah12@yandex.ru, Emelin_sm@mail.ru

Keywords: geopolitics, cultural investment, cultural heritage, economy.

Abstract: The XVI International Business Week held in Ufa, traditionally organised by the Government of the Republic of Bashkortostan, was marked by a number of positive results. First of all, it brought Bashkortostan and the whole of Russia new mutually beneficial contacts, including those in the field of economic and cultural cooperation. There were other important points in its process that need to be addressed. These are not even purely economic, but rather politico-economic (one can say geopolitical and economic), and general socio-cultural aspects of the functioning and development of the modern economy. The authors link the results of the event with the socio-economic, socio-cultural, scientific, and technical features of the region's development, the innovative components of the process, based on brief descriptions of achievements in these areas, and the prognostic methodology of the study.

1 INTRODUCTION

Recently, Ufa has become a venue for major international events. In June last year, the republican capital hosted the X Forum of Regions of Russia and Belarus, which gathered a record number of participants. Delegations from 58 regions of our country and all regions of Belarus arrived. At the last XIX Forum of Interregional Cooperation between Russia and Kazakhstan, the President of Russia said that the next, XX Forum, would be held in Ufa. 2024 was a special year for Bashkortostan. The celebration of the 450th anniversary of Ufa is expected, a large-scale forum "Russia – a sports power" will also be held, in April the presentation of the republic will be held in Beijing. All this together will give a tangible synergistic effect, and will also strengthen the position of Bashkortostan in the international arena.

2 MANUSCRIPT PREPARATION

The composition of the participants and the course of the Forum's work clearly showed the already clearly established political and geographical reorientation of Russia's foreign economic relations – to the CIS countries, to the countries of Asia, and the "global South". And it is not just about Western sanctions against Russia, which destroyed, largely to the detriment of the West itself, the previously established chains of economic cooperation. This is only an additional factor that has accelerated the awareness of profound changes in the global economy. Today, the world is witnessing the formation of new centres of the economic development, new systems of interaction and foreign economic relations. And these processes are primarily in the countries of the East and South, against the background of the economies of Europe and the United States, which are increasingly falling into crisis, gradually losing their leading role and influence. Moreover, this process of reformatting the world economy is further stimulated by the world community's growing rejection of the West's self-serving hegemonic policy.

In these conditions, Russia's economic strategy is also changing. In terms of foreign policy, three main areas can be distinguished. Firstly, it is a natural desire, together with friendly CIS states in the post-Soviet space, to establish mutually beneficial cooperation in the Eurasian region, which is common

[1] https://orcid.org/0000-0001-9570-1763
[2] https://orcid.org/0000-0002-1733-6569

to all of us. Secondly, the establishment of qualitatively new ties with the growing economies of the East and promising economies of the South, in return for the West's spoiled ties with its economies, because of which the damage is increasingly borne by the West. Thirdly, a significant change in the very nature of Russia's foreign economic policy is the reduction of the raw material component of imports and an increase in the share of high-tech products, a decrease in the share of imports in the economy. (Emelin, 2023).

2.1 Scenario method for expert assessment and degree of knowledge of the topic

This study has found the application of the scenario method to assess the current socio-economic and socio-cultural situation in the Republic of Bashkortostan, which is considered by us as the most effective in planning. The scenario approach in the development of predictive models increases the productivity of socio-economic and socio-cultural policy measures, predicts and prevents conflicts, and contributes to the search for problem-solving mechanisms (Salikhova, 2015).

Studies that develop concepts and methodological tools for predictive models are often related primarily to the field of economics, international relations (Biglin, 2016; Davydchuk, Mehlhausen, Priesmeyer-Tkocz et al. 2018).

In the Russian-language scientific discourse, there are practically no studies of the scenario methodology for studying the future cultural diversity and the methodology for socio-economic forecasting. In this regard, this scientific topic should be considered new, aimed at studying the future of Russia.

The scenario methodology of the study is at the stage of formation. Conceptual and methodological foundations for forecasting are found in a number of foreign and domestic works. In this article, we continue to expand the research base of forecasting, develop a multifactorial model for forecasting the development of ethno-cultural diversity and analyse effective scenarios of socio-economic policy.

2.2 The development of human capital is the key to the progress of the Russian economy, science and culture

In terms of domestic economic activity, today we see a powerful process of import substitution, extremely positive for the future of Russia, although sometimes associated with certain difficulties. This process means the development of our own production facilities, technologies, design and scientific activities, the training of qualified personnel and the creation of new jobs, i.e. the development of the most important capital – human capital. Connecting Russia's richest natural resources with educated and technologically advanced workers is the key to our progress.

It should be noted that the experience of the beginning of the XXI century showed the unsuitability of both the absolutisation of spontaneous market processes and the restriction of the understanding of economic efficiency to purely formal indicators. A state that seeks to be sovereign and ensure the security of its citizens must regulate its economy in a certain way, ensure its self-sufficiency, i.e. the ability to meet all the basic needs of society independently. And the fact that Russia can currently increase its exports by reducing imports shows that we are on the right track.

It is also important that not only today's problems were discussed at the Forum, but also what will happen to the economy "the day after tomorrow". Notable is the fact that the future of the country lies in an innovative, dynamic economy based on real production, rather than financial speculation, and introducing knowledge-intensive information technologies, increasingly using artificial intelligence, which contributes to the creative initiative of employees.

Western sanctions against Russia have led to an unexpected result for their initiators. Overcoming possible problems, the Russian economy not only did not collapse, but, on the contrary, is clearly strengthening and recovering. The fact is that in this situation, the process that has been developing since the beginning of the XXI century — the gradual overcoming of the negative consequences of the liberal version of market reforms carried out in Russia at the end of the XX century — has accelerated. This is the absolutisation of the market's role, the rejection of state regulation of its spontaneous processes. This is also associated with overcoming the complete freedom of capital movement across state borders, allowing foreign business to control key strategic sectors of the former national economy of our country. Also, solely for reasons of immediate economic benefit, a complete replacement of our own vital industries for the purchase of imported products was allowed. In fact, there was a thoughtless and complete inclusion in the system of the international division of labour created by the West, to which exclusively Western companies found themselves in the most profitable role of process organisers and manufacturers of the final product. In this regard, one can agree with the historian and economist A. Yu. Bykov, who argues that the self-sufficiency of the economy for the development of the state is more important than economic profit (Bykov, 2022). Indeed, no profit can overcome dependence on foreign forces, which Western countries have tried to achieve with their sanctions. However, Russia not only retained, but also began to increase its potential for self-sufficiency by the 2010s – that is why it was able to withstand the sanctions aggression. Of course, the question of the ratio of profit and self-sufficiency for the state forces us to turn to the main potential of market fundamentalism — the priority in the economic development of narrowly understood economic efficiency, usually reduced to banal monetary profit. Accordingly, not only "unprofitable" sectors of the national economy, suppressed by cheaper and more profitable imported goods, but also such system-forming spheres as science and culture, came into decline. If the main task of educational institutions, cultural institutions, and even medical organisations is considered to be making a profit, the foundations of a normal, independent life of society are destroyed.

2.3 The relationship between economic, socio-cultural, scientific and technical security in Bashkortostan

If we focus on the course of socio-economic, scientific, technical and innovative development carried out by Russia, then Bashkortostan is carrying out the main transformations in the course of systemic modernisation — the process of improvement through the renewal of social views, culture, as well as equipment, reforms, which consists in changes in the political, social and other spheres of population activity (Innovative development of the Russian Federation in 2020).

Innovations, as a necessary element in the transition to Industry 4.0 and 5.0, are considered to be the main factors of social production and scientific progress, which is recognised as decisive in ensuring economic security (Zemskova, Baranova, 2019: 65). In the "Strategy of Economic Security of the Russian Federation until 2030" approved by Decree No. 208 of the President of the Russian Federation dated May 13, 2017, the threats to the economic security of the country include weak innovative activity, a lag in the development and introduction of new and promising technologies, an insufficient level of qualification and key competencies of domestic specialists.

Innovative security is characterised by such key concepts as "the ability to innovate" (creation when combining technological capabilities and social needs, taking into account the presence of certain institutions in society), "sustainability" (the ability to maintain production in the planned volume in force majeure circumstances, in case of violation of production links to restore it in the shortest possible time), "competitiveness" (the ability to withstand competition with their own kind), "the ability to self-development and progress" (implementation, protection of national interests and constant development of intellectual potential), which leads to an increase in the quality of life of the population and strengthening of the country's competitiveness (Zemskova, Baranova, 2019: 67).

Table 1: A set of indicators characterising and describing the innovative security of the state.

Indicator Name	Guidance Threshold
Indicators for assessing risk factors	
Volume index of GDP, %	50
Share of foreign investment in total investment in fixed assets, %	20
Indicators characterising the severity of the crisis situation in the innovation sector	
Share of domestic expenditure on research and development of GDP, %	not less than 2
Share of high-tech and knowledge-intensive products in the gross domestic product, %	not less than 30
Share of innovative products in the total volume of shipped sold products, %	not less than 30
The ratio of the volume of shipped innovative products and the cost of technological innovation	not less than 5
Ratio of inventive activities, %	not less than 5
The share of costs for the development of new products, services and production processes in the total cost of technological innovation, %	not less than 50
Share of GDP of state spending on science, %	not less than 2
Number of personnel engaged in research and development per 10,000 employed in the economy, people	not less than 33
Financing of science from the federal budget, % of GDP	not less than 3
Share in exports of high-tech products, %	10-15
Degree of depreciation of fixed assets, %	30-40
Indicators used to assess damage (socio-economic consequences)	
Human development index (HDI)	0.800
Ratio of average salary to subsistence minimum	1:3

Based on the work of well-known domestic and foreign researchers, a system of indicators and threshold values was developed to assess the innovative security of the state (Table 1). The basis of the selected indicators of development of the country and the region is selected from European methods for calculating the country's competitiveness indices (GGI), the innovation activity index (EIS), developments proposed by leading Russian scientists (V. K. Sechagov, S. Yu. Glazyev et al.).

Table 2 shows the results of the assessment of the current situation and prospects in the field of innovative security of Russia and Republic of Bashkortostan to the indicators and thresholds used in

Table 1. Diagnosing the levels of innovative security listed in the table, the authors focused on the remoteness of current indicators from thresholds. The provisions of the zone theory were used to rank the indicators.

Table 2: Quantitative indicators of threshold values of innovation security indicators and their meaning in 2019-2021.

Parameter names and units of measurement	2019-2021		
	2019	2020	2021
GDP, total, RUB billion, increase in GDP compared to the previous year, %	91843.2	103862 13.09	109242 5.18
GDP per capita, in thousands of roubles, increase over previous year (%)	625.63	707.02 13.1	744.15 5.25
Share of small business in GDP, %	22	692.6	627
Foreign trade turnover, USD billion	587.6	452.6	424.6
Export volume, USD billion	359.1	240.5	247.4
Import volume, USD billion	228.5	211.6	177.2
Balance of trade, USD billion	130.6	-	-
External debt of Russia, USD billion	529.1	453.8	481.5
Investments in fixed assets, % of GDP	21.4	20	20.6
Defence spending, USD billion	66	61.4	65.1
Labour productivity index, %	1031	103.1	102.6
The level of depreciation of fixed production assets, %	47.3	46.6	37.8
Share of high-tech goods, works and services in the total volume of goods shipped, works and services performed, %	14.1	11.8	12.2
Share of high-tech goods in the volume of imports, %	71.5	67.3	66.8
Expenses for innovative activities, RUB billion	140.49	1472	1964.1

Analysing the indicators of innovative security of the Republic of Bashkortostan based on the values of Table 2, it can be concluded that some positions do not reach the threshold values, i.e. the indicators characterising the transfer of technologies and the efficiency of the innovation process are lower than the average Russian ones. Critical indicators include:

– indicator of inventive activity: 1.18% with an average Russian value of 1.59%;

– domestic research costs: 8.8% in 2021, which is 1.8% lower than the average Russian value.

– the parameter characterising the human resource of the regional innovation system is 15.4% behind the average Russian value by 3.25 times.

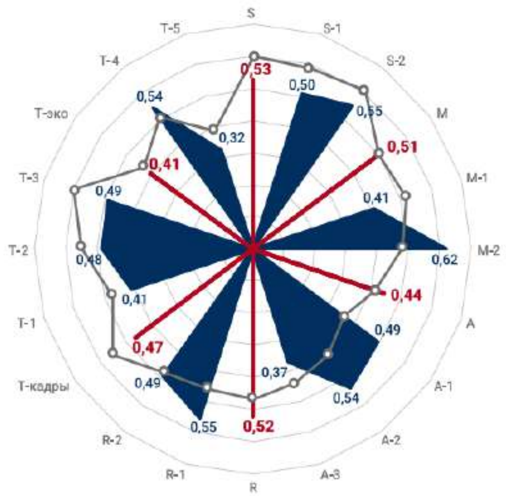


Figure 1: Comparison of the relative values of indicators of the Republic of Bashkortostan in the rankings of 2021 and 2020 ("Rating Regions Russia Smart Association Innovative Regions of Russia" 22).

The standardised values of private indicators are marked in blue; the average values of the index by sub-rankings are highlighted in red; the colourless zone is on average in Russia

2.4 On an active policy for the development of an innovation system: creating infrastructure

As it is known, the basis of the innovation process is the creation and development of new technologies, including the results of fundamental and applied scientific research, engineering and technical developments.

For the real sector of the economy part, the level of demand for the results of scientific activity is very low. Basically, scientific research is aimed at the future needs of new high-tech sectors of the economy of 5 and 6 technological modes, which are currently absent in the republic (Kurguzova, 2018).

The analysis shows that Bashkortostan has the prerequisites for the intensification of innovation activity, manifested in the production potential, active work of scientific organisations, higher educational institutions, sectoral research institutes, existing elements of the innovation infrastructure (Association of Innovative Regions of Russia).

Since in 2020-2021 there was a 1.35-fold reduction in the number of researchers, it is possible to propose to the republic's government to make a number of strategic decisions to avoid crisis phenomena in the regional economy. The measures taken to increase the innovative attractiveness of the region should solve such problems as insufficient funding for research and development associated with low wages, that barely motivate innovative creativity, high subsidies to the regional budget, a decline in reproduction and scientific potential, as a result of which there is a decrease in the volume of scientific and technical work performed.

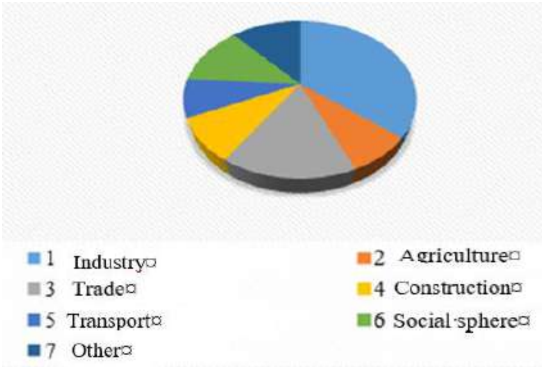


Figure 2: Sectoral structure of the economy of the Republic of Bashkortostan.

The country has a developed fuel and energy complex, which is the main feature of the industry. Bashkortostan is one of the oil-producing regions of Russia. It presents the extraction and processing of oil, gas, brown coal, the production of heat and electricity, an extensive system of pipelines and power lines. The Petrochemical Territorial Cluster has been established in the Republic of Bashkortostan since 2012. Currently, the cluster unites 211 participants. More than 75% of all innovative organisations are concentrated in the chemical and petrochemical industries, as well as in mechanical engineering. The Republic has a State Program "Development of Industry and Increase of its Competitiveness in the Republic of Bashkortostan 2019-2024". The total amount of financial support for the state program will be 593 108.8 thousand roubles ("Rating Regions Russia Smart Association Innovative Regions of Russia" 22).

One of the most important indicators of the economic development of the region is the share of the subject of the Federation in the all-Russian indicators. The gross regional product of the Republic of Bashkortostan is 1,391.2 billion roubles, this is the 9th place in Russia in terms of GRP, the economy of the republic continues to develop steadily. The rise occurs due to the development of the industrial sector, innovative products, as well as the restoration of growth rates in agriculture. The volume of trade turnover is 344 billion roubles, exports in the country account for 64.7%, imports — 35.3% (Rating of regions by scientific and technological development).

Positive changes in the period under review include:

– significant effectiveness of innovation and competitiveness, expressed in a noticeable excess of the share of innovative products in the volume of shipped sold products of the Republic of Bashkortostan — 35.3% with an average for Russia of 29.3%. This indicator is in the "stability" zone;

– the percentage of high-tech and knowledge-intensive products in the GRP in 2021 is 23, which does not pose a threat or risk to the innovative and economic security of the region.

In the rating of the Association of Innovative Regions of Russia for 2021, our republic is on the 12th place and is among the 21 constituent entities of the Russian Federation among medium-strong innovators, in terms of the level of development of research and development, Bashkiria ranks 10th out of 60.

The country pursues an "active policy for the development of the innovation system: the creation of an innovative infrastructure, an increase in funds for investing in innovative activities, as well as stimulating the development of small and medium-sized businesses in the scientific and technical sphere." One of the urgent modern tasks is also the creation of a stable and powerful financial infrastructure for innovation. This refers to funds engaged in financing innovative projects (Kurguzova, 2018). It should also be mentioned that Bashkiria can become one of the pilot regions for the creation of a network of the Circle Movement of Scientific and Technical Research (STR).

The latter is an all-Russian community of technological enthusiasts. Its goal is to shape the next generation of entrepreneurs, engineers, scientists and managers. As the press service of the STR Circle Movement emphasises, this work will be carried out in cooperation with the Ministry of Science and Higher Education of the Russian Federation. The department plans to create studios of student technological entrepreneurship or so-called start-up studios in universities. Special attention will be paid to the topic of mentoring for teams of young technological entrepreneurs. It is planned to launch a large-scale mentor training program in higher education, also taking into account the experience of the STR Circle Movement in training mentors for school and student project teams together with the Skolkovo Academy of Mentors. By 2025, it is planned that about 500 thousand schoolchildren and students will be engaged in STR technology circles on the basis of 30 thousand schools, resource centres, universities and other sites involved in the network form of the STR circle, about 10 thousand technological teams capable of solving technological challenges will be formed.

According to the Address of the President of the Russian Federation V. V. Putin to the Federal Assembly on December 4, 2014, STR is one of the priorities of state policy. It serves as a certain basis for developing an understanding and long-term forecasting of the development of advanced technological solutions to ensure national security, improve the quality of life of people, and develop industries of a new technological order.

The STR takes into account the development of global markets in the perspective of 15-20 years in the context of the ongoing technological (digital) revolution. The main priority for the development of global markets, according to STR developers (see Fig. 3), there will be an end user – a person.

2.5 Discussion

Meanwhile, not only domestic, but also many well-known Western economists convincingly argued that the economy is not a self-sufficient and isolated form of activity from other spheres of public life. Thus, the American economist D. North, known for his work in the field of new institutional economics, contrasted the "complexity of human motivation", which includes many norms and values, with a one-dimensional desire for economic benefit (North, 1990), and another American economist, as well as the previous winner of the Nobel Prize in Economics, the author of popular books on economic theory R. Shiller believes that certain social ideas (the so-called "narratives" that form the "narrative economy") have a powerful influence on the economy (Shiller, 2020).

A prominent Russian economist, academician of the Russian Academy of Sciences S. Yu. Glazyev, noting that the development of the global market economy according to the modern Western model with US hegemony has exhausted itself and does not meet the interests of Russia and other countries at all. He considers the "integral" world economic system, which implements a combination of a market economy, social values, private entrepreneurship and state regulation, with a favourable susceptibility to modern scientific and technological achievements, to be promising (Glazyev, 2019).

We believe that Russia's modern economic strategy should proceed from the social and political significance of the economy, its role in ensuring the country's sovereignty and influence on the life of the population. Work on import substitution, development of new foreign economic relations (mutually beneficial and not putting Russia in a dependent and vulnerable position), a combination of private initiative and market mechanisms with the regulatory role of the state based on the principles of social policy. The leading role should belong to the state, especially in the field of education and training, and especially in promoting the development of science and modern technologies, on which the future of any country depends today. The main thing is to ensure the systematic, self-sufficient, holistic development of the economy, which is the guarantee of Russia's sovereignty, the key to improving the quality of life of our multinational people. We believe that we are now following this path.

Turning to the realities of the republic, we note that Bashkortostan has retained the fifth place in the National Rating of the Investment Climate, which is formed by the Agency for Strategic Initiatives. In an interview with RBC-Ufa, the director of the Management Company of the Academy of Sciences of the Republic of Bashkortostan, Doctor of Economics I. Burenina drew attention to the fact that in our republic the growth rate of investment in the economy reached 105.1% in 2021 with a total investment of 419.4 billion roubles. Key sectors of the economy became the growth points for investment indicators, including manufacturing, logistics, mining, water supply, wastewater disposal, waste and pollution management, trade and construction. The investment portfolio includes 1,790 investment projects worth 1.3 trillion roubles, which will create about 60 thousand jobs, while 280 of the largest projects have priority status. The number of small and medium-sized businesses is almost 4% more than last year. There is a direct dialogue with business at all levels – the "Investment Hours" are held personally by the Head of the Republic of Bashkortostan and the heads of municipalities.

The fifth place of the republic in the National rating of the state of the investment climate is a very high indicator. He says that a lot of fruitful work is being done in Bashkiria. Investors are attracted primarily by stability and the preferential conditions created for them for the location of production facilities, the availability of labour resources. The republic has all this at its disposal – we have five PSEDAs, the special economic zone "Alga". Everything necessary for investors is available, so the assessment that Bashkiria received is deserved and justified.

3 COPYRIGHT FORM

All authors made equivalent contributions to the preparation of the publication. The authors declare no conflict of interest.

4 CONCLUSIONS

In the light of these trends, the Forum highly appreciated the prospects for the development of Bashkortostan and the economic policy pursued by its leadership. During the post-Soviet period, the republic not only did not lose, but also increased its production potential. Having prevented "shock" reforms in the economy on its territory, today Bashkortostan is dynamically updating and improving its economic potential, relying not only on serious production capacities and rich natural resources, but also on the preserved system of personnel training, vocational education. The pace of development of the republic's economy today exceeds the average Russian indicators. Our region is not only a highly developed industry and agriculture, it is also a genuine "Heart of Eurasia", where Eastern and Western traditions of the rich Russian history are combined. Therefore, it was noted at the Forum that Bashkortostan can and should become a key region of Russia in its "Eurasian turn", while maintaining its self-sufficiency.

We believe that today the economic, scientific and cultural spaces of Russia and Bashkortostan should combine the regulatory market with elements of state planning and strong social policy. At the same time, an important place in its development is given to the innovative focus provided by
broad socio-economic creativity, some approaches to the development of which were developed by scientists of the Ufa Federal Research Centre of the Russian Academy of Sciences in 2021-2022. This economy, which combines components of market approaches with positive Soviet experience, is the most promising for the further development of the country.

Based on the above, we would like to formulate some important, in our opinion, management decisions that are relevant for further scientific, cultural, economic development, including strengthening the economic innovation security of the Republic of Bashkortostan.

1. Development of industrial production through the development and implementation of investment projects, modernisation of production, creation and development of industrial parks, approval of new standards of the Industrial Development Fund of the Republic of Bashkortostan.

2. Support for small and medium businesses.

3. Development of housing construction by stimulating demand for housing under construction through various preferential programs.

4. Stabilisation of the situation on the labour market through the implementation of new social programs, wage growth. It is advisable to build innovative enterprises that will solve the problem of unemployment and lower wages in the region.

5. To improve foreign economic activity, support measures are needed, such as subsidies from the regional budget to reimburse part of the costs associated with the transportation of goods, including pilot batches, the provision of various grants, etc.

6. Welcoming large-scale investment agreements, which are one of the main leitmotifs of the forums held in Bashkortostan. The XVI International Business Week was no exception. The Republic is of interest from the standpoint of profitable investment.

7. Improvement and detailing of the developed foundations of the state cultural policy – a wide intersectional phenomenon covering such spheres of state and public life as all types of cultural activity, humanities, education, interethnic relations, support for Russian culture abroad, international humanitarian, cultural and scientific cooperation, as well as education and self-education of citizens, education, development of children and youth movement, formation of the information space of the country.

In conclusion, we note that, despite certain problematic aspects of the topic under consideration, the Republic of Bashkortostan is the region that, despite everything, continues to develop and has a stable level of socio-economic development, which largely determines the socio-cultural level.

ACKNOWLEDGEMENTS

The article was prepared within the framework of research work on the state assignment "Historical and cultural heritage of the Southern Urals and the Urals: study, preservation and museumification", No. 122031400062-7 Institute of Ethnological Research named after. R.G. Kuzeev Ufa Federal Centre of the Russian Academy of Sciences for 2022–2024.

REFERENCES

Association of Innovative Regions of Russia [Electronic resource]. URL: https://i-regions.org/regions/the-republic-of-bashkortostan

Biglin, M., 2016. *The state of future in international relations* In *Futures*. Vol. 82.

Bykov, F. Yu, 2022. Inflation as a phenomenon of economics. In *Our contemporary*. No. 1.

Glazyev, S. Yu., 2019. *Leap into the future*. Moscow: Book World.

Davydchuk, M., Mehlhausen, T., Priesmeyer-Tkocz, W., 2018. The price of success, the benefit of setbacks: Alternative futures of EU-Ukraine relations In *Futures*. Vol. 97.

Innovative development of the Russian Federation in 2020. URL: https://www.miiris.ru/digest/analitika_RF.pdf.

Efficiency of the Russian economy: Federal State Statistics Service [Electronic resource]. URL: https://rosstat.gov.ru/folder/11186?print=1 .

Emelin, S.M., 2023. Problems and prospects of legal support for the unity of Eurasian Russia. In *Bulletin of the Institute of Law of the Bashkir State University*. No. 4.

Emelin, S.M., Ermolaev, O.I., 2024. Migration policy as a way to protect against interference in the internal affairs of the state. In Migration Law No. 01.

Kurguzova, A. S., 2018. Innovative potential of the Republic of Bashkortostan in *humanitarian research*. No. [Electronic resource]. URL: https://human.snauka.ru/2018/11/25290

North, D.C., 1990. *Institutions: Institutional Change and Economic Performance*. Cambridge: Cambridge Univ. Press, 1999.

Osipov, V.I., 2009. *Security of Russia. Legal, socio-economic and scientific-technical aspects. Regional security problems taking into account the risk of natural and man-made disasters*. Moscow: Knowledge.

Rating of regions by scientific and technological development. URL: https://riarating.ru/infografika/20231023/630251402.html

*Rating Regipns Russia Smart Association Innovative Regions of Russia"*22. URL: https://i-regions.org/reiting/reyting-regionov-smart/

Salikhova, E.A., 2015. *Modeling the Processes of Mastering and Using the Psychological Structure of Word Meaning in Bilingualism*. Moscow: Flint.

Salikhova, E.A., Kiseleva, L.A., 2022. *Ethnolinguistic Space of Modern Bashkortostan: Sociolinguistic Essay*. Moscow: Flint.

Shiller, R.J., 2020. *Narrative Economics. Princeton*, NJ; Oxford: Princeton Univ. Press.

Shubina, N.V., 2017. Conceptual approaches to understanding the economic security of the region: essence. Structure, factors and conditions In *Bulletin of UrFU. Ser. Economics and Management*. Vol. 16. No. 2.

Zemskova, E.S., Baranova, N.N., 2019. Innovative security as a subsystem of economic security In *Contentus*. No. 3.80

Development of Skills of Students of Higher Educational Institutions in the Field of Social Cooperation

Bakhtikhon Kurbanova[1]
Ferghana State University, Uzbekistan
baxtixon78@gmail.com

Keywords: pedagogy of cooperation, social cooperation, cooperation in world pedagogy, joint activity of teacher and student, pedagogical essence of cooperation.

Abstract: The effectiveness of educational institutions in improving their activities under the influence of modern technologies in the decision-making process of communication is being researched. This article discusses the concept of cooperation, the basis of cooperative pedagogy, and the development of strategies for high school students to demonstrate activity in social cooperation. Theoretical issues on clarifying and analyzing cooperation concepts, the basis of cooperative pedagogy, and the development of strategies for high school students to demonstrate activity in social cooperation were classified, descriptive, comparative, transformation methods were used. The result of this article is that effectiveness of mechanisms for preparing students for social life was identified in the teaching process by developing traditional and non-traditional tasks, clarity of pedagogical processes, and dynamics. In conclusion, in this article, propaedeutic-constructivist creativity, freedom of expression, and group communication, individuality, and innovation-integrative activities were effectively implemented in adaptation to educational goals.

1 INTRODUCTION

In recent years, under the influence of new approaches to education, the problem of deciding on a technological approach has been researched as an important sign of improving the activities of educational institutions. In addition, the established theory and practice of education shows the need to improve the activity of all educational institutions on a general scientific and methodological basis.

To date, the relevance of the problem of cooperative pedagogy is based on the following:

firstly, the fact that social and pedagogical processes in a new and broad sense are being rapidly implemented in the educational system;

secondly, the state of general, mass pedagogical practice (insufficient pedagogical support for teachers and learners, their dissatisfaction with the educational process; teachers' humane and friendly relationship with learners insufficient organizational skills, etc.);

thirdly, students' great need for new educational innovations.

In many research works, the concepts of "cooperation", "partnership", "coordination", "joint action" have been used as synonyms. In our opinion, the concept of "cooperation" is broad and requires joint effective activities to achieve common goals.

2 LITERATURE ANALYSIS

As the basis of cooperative pedagogy, high moral and humanitarian views were reflected in the works of our famous scientists who lived and created during the Central Asian Renaissance in the form of very clear theories.

In particular, our great grandfathers Abu Nasr Farabi, Abu Rayhan Beruni, Abu Ali ibn Sinola put forward the important ideas of humanism and cooperation necessary for the prosperity of the social system and the state, and developed the stages, criteria and principles of humanization (Sulaymonova, 1997).

According to his social ideals, Farobi was highly social and humanitarian. He considered a person as a

[1] https://orcid.org/0000-0002-5754-5891

social phenomenon and believed that cooperative relations between people arised on the basis of their interests, desires and mutual association. According to Farobi, the fate of a person was not predetermined, each person acted according to his own will, created his own happiness and decided his own fate. People were created the same, but they changed under the influence of education and environment. The scientist attached great importance to education in this place. Farabi believed that one of the most important qualities of a perfect person was the desire to learn and study science.

At this point, it should be noted that the role of Farabi’s teaching in the formation and development of the great scientists who developed in the East and created the foundations of universal culture - Beruni, Ibn Sina, Ibn Turayl, al-Kifti, Ibn Rushd and many other scientists were incomparable. Ibn Sina insisted on the necessity of a society in which there was harmony and mutual understanding in the relations of people. "A person cannot satisfy his personal needs alone, surrounded, he could achieve these goals only in communication with other people. People got rid of worries only by mutual communication and helping each other. If man had tried alone to get rid of all worries, he would not have been able to bear such a heavy burden. It turns out that justice and standards established by law were necessary between people..." (Khoshimov, Nishonova, Inomova, Hasanov, 1996).

As a result of the analysis of Ibn Sina's works, we are convinced that he advocated the view of cooperative pedagogy. His pedagogical views were extremely progressive with a focus on humanistic essence and were in many ways compatible with modern pedagogical theories. The main principles of the scientist's pedagogy were to bring up positive aspects in the child's character, teach him exemplary behavior and accustom him to useful habits. The thinker showed enthusiasm for the need for children and young people to receive all-round education and training, develop literacy, learn the basics of science, crafts, trade, and art, thereby preparing them for life (Khoshimov, Nishonova, Inomova, Hasanov, 1996)..

Based on the thoughts and ideas of Central Asian thinkers, it can be said that cooperative pedagogy is an activity aimed at making certain changes in the general practice of educational institutions, improving the educational process in higher education.

In the pedagogical dictionary, collaborative pedagogy is a science (Asqarova, 2014) that shows the content, principles, forms, methods, and means of effective learning based on the interaction between teachers and students of various disciplines or specializations.

A number of scientific researches have been carried out on the issue of using approaches related to the theory of cooperation in world pedagogy. Including V.Arshinov, M.Boguslavsky, V.Budanov, V.Vinenko, L.Zorina, V.Ignatova, S.Kapitsa, E.Knyazeva, G.Malinetsky, V.Matkin, L.Novikova, E.Pugacheva, N.Talanchuk, D.Trubetskov, O.Fedorov, Yu.Sharonin, A.Bochkarev, E.Kopylova, V.Petrova, O.Gataulina, G.Sumina, L.V.Surchalova, Yu.V.Talagaev, R.Johnson, SH.Sharon, R.Gane, Dj.Briggs, Levi Strauss researches have reflected the advantages of collaborative teaching, the leading ideas of teacher-learner collaboration.

In the theory and practice of foreign education, cooperative learning has been widely researched as an alternative to traditional education. The analysis shows that the efficiency of cooperation ensures the interactivity, interrelationship and mutual responsibility of the participants and its improvement, individual responsibility and direction of the constructive mutual action of the group participants at the expense of the overall result.

By scientists from Uzbekistan such as N.Azizkhodjayeva (Azizkhodjayeva, 2000), J.Yoldoshev (Yoldoshev, Usmonov, 2004), R.Safarova (Yoldoshev, Usmonov, 2004), B.Khodjayev (Khoshimov, Nishonova, Inomova, Hasanov, 1996), Sh.Abdullayeva (Abdullaeva, 2017), N.Dilova (Dilova, 2018) cooperative pedagogy, strategies for formation of cooperative activity skills in students based on mutual friendly relations were highlighted.

The analysis of pedagogical and psychological literature (N.Dezhnikova, I.Pervin (Dezhnikova, Pervin, 1991), V.Dyachenko, D.Johnson, R.Johnson (Johnson, Johnson, 2008), R.Slavin (Slavin, 1978), etc.) showed that cooperation in group and ensures effective achievement of the goal set by the subjects in joint activities in the organization of collective work forms. As a result of such efficiency, partners move together in educational activities based on the principles of mutual assistance and active cooperation. Therefore, cooperation requires mutual responsibility, friendship, mutual support, mutual respect, and mutual sincerity. As a result of active cooperation, learners acquire the skills of conscious and active social partnership and solving social and household tasks in the educational process.

3 RESEARCH METHODOLOGY

Interpretation of the concept of cooperation, the basis of cooperation pedagogy, identification of theoretical problems of higher education students in the development of social cooperation skills and their analysis, classification, descriptive, oppositional, comparative, and transformational methods were used.

4 ANALYSIS AND RESULTS

Collaborative pedagogy - unlike traditional teaching, focuses on establishing a friendly relationship with the student. Pedagogical activity is organized in the case of "We" instead of "I", i.e. in cooperation - "subject" - "subject" relationship. The principle of "working in cooperation" is based on a deep knowledge of the learner's personality. Before completing educational tasks, a strategic goal is set, and then a sense of self-confidence is formed in the child to fulfill it. In other words, cooperative pedagogy has a positive effect on the student's personality, warmness, cooperation, directs one's will to a single goal - education.

On the basis of analysis and results, the possibilities of improving the mechanisms of preparing students for social life on the basis of cooperative pedagogy, the compatibility and intensity of joint actions focused on values in the process of dialogic and creative cooperation, the ability to rationally define goals and tasks, and educational-integrative, communicative-role and collective-group components improved on the basis of stable maintenance of harmony;

The model for the development of student socialization mechanisms is a combination of person-oriented, axeological and reflexive approaches, reasoning, working with data and purposeful, methodological, organizational, meaningful block and monitoring, student subjectivity, the ability to create a creative environment, and the reflexive concept. improved based on prioritization of provision in stages;

The effectiveness of improving the mechanisms of preparing students for social life, didactic design of traditional and non-traditional tasks in the course of the lesson, openness, dynamism, propaedeutic-constructiveness of pedagogical processes, creative unity, free expression of ideas and collective communicativeness, individuality and innovative-integrative actions to educational goals improved on the basis of active adaptation;

the stages of development of student socialization mechanisms are improved on the basis of propaedeutic-diagnostic, mutual constructive communication, separation of the action algorithm of group adaptation, modeling of the level of reflection and gradual adjustment of the dynamics of strategic, tactical and operational monitoring to the dynamics of quantitative and qualitative indicators;

criteria for the development of student socialization are emotional stability, orientation to correct decision-making in non-standard situations, regular adaptation of the skills of establishing stable subject-subject relations to creative-process, research-integrative processes, and strategic parameters and indicators related to social activity improved based on forecasting.

According to N.Dilova, pedagogy based on cooperation is a system that represents the joint activity of a teacher and a student, and in this process, the team's creative powers and efficiency of activity are manifested. The opportunity to realize new goals will be provided. This goal is to teach a group of learners to achieve additional creative results using their strengths. Collaborative pedagogy optimizes the communication process with the help of computer technology with new tools and produces information products. Therefore, cooperative pedagogy uses new educational methods in the processing of educational materials for use in the educational process. To this end, collaborative pedagogy intersects with a number of disciplines. In particular, the theory of social communication, information technologies, logic, linguistics, as well as personal observations, experimental test results, and psychological knowledge are among these (Dilova, 2018).

The concept of "cooperation" expresses the leading concept of modern humanistic pedagogy. Cooperation - in the most general sense, is the interaction of people in work, that is, their joint activity.

In higher education, the traditional one-size-fits-all teaching methods may not be effective for all students, as they often fail to accommodate individual differences in learning styles, abilities, and interests (Dziuban, Moskal, Hartman, 2016). Advances in educational technology, such as learning management systems, adaptive learning platforms, and learning analytics, have further facilitated the implementation of personalized learning in various educational contexts (Selwyn, 2016; Prinsloo, Slade, 2017).

G.A.Sukerman stated that the essence of cooperation is expressed in the mutual movement of all participants, through which the opportunity to achieve the goal of individual and joint activity is created (Tsukerman, 1992).

Cooperation reflects the main features of joint activity. These include the unity of the goal, the joint cooperation of the participants, the division of the whole process into separate interrelated parts, their distribution among the participants, the coordination and management of individual activities, the existence of a single final result.

The pedagogical essence of cooperation acquires a more precise essence based on S.L.Rubinstein's psychological law about the connection between activity and personality development (Rubinstein, 2004).

Joint action is one of the main ways to activate self-development and self-expression of learners. In the course of cooperative activity, the abilities and opportunities of the learners are revealed even more. By complementing each other, they reach a qualitatively new level of development.

D.B.Elkonin and V.V.Davydov analyzed in their work that all forms of interaction acquire a general character and require working in small groups, which is reflected in group emotional support at the same time (Davydov, Slobodchikov, Tsukerman, 2010).

A.A.Ivin in his scientific studies specifically recognizes that, in contrast to relationships, relationships with peers are, first of all, the provision of mutual equality. Communication with peers provides the student with equal communication, a critical attitude to the thoughts, words and actions of other people, independent of their freedom and wishes. For this, it is necessary to be able to see, evaluate, accept or not the point of view of other people, the main thing is the ability to own one's own point of view, views, and protect it in contrast to others (Ivan, 2010).

Students engaging with ill-defined problem-solving tasks in educational settings demonstrate enhanced abilities to transfer knowledge across domains, apply academic insights beyond conventional contexts, and generate novel ideas and innovations (Walker & Leary, 2009). These diverse ill-defined problem-solving tasks not only foster critical-thinking skills (Liu & Pasztor, 2022) but also play a pivotal role in motivating students to learn by presenting authentic and engaging challenges (Demirel & Dagyar, 2016) (Urban, Děchtěrenko, Lukavský, Hrabalová, Svacha, Brom, Urban, 2024).

The area of student life where communication and cooperation with peers is not fully realized is related to educational activities. For them, it is forbidden to sit in their place in the classroom, to have a free conversation, to distract each other in the process of studying the subject, it is impossible to help each other during the lesson, often this situation is "telling each other is evaluated as standing". It turns out that in the process of education, they are deprived of a group of peers, or rather, an important factor of normal development. Learners do not communicate during the lesson, they rarely turn to each other for advice or mutual assistance without the help of a teacher. Children study together, but they do not cooperate with each other (Arefyeva, 2015).

Appropriate organization of cooperative activities of learners from a pedagogical point of view has a positive effect on the development of a child's personality and leads to all-round development.

The development of a person as a person and subject of activity during higher education requires taking into account the following aspects: 1) development of intellect; 2) development of the emotional sphere; 3) building stability to stresses; 4) determination of self-confidence; 6) development of a positive attitude towards the world and acceptance of others; 7) creating motivation for self-improvement and development.

In this case, stimulation of learning motivation appears as an important element of self-development. (A.A. Rean and Ya.L. Kolominsky) (Rean, Kolominsky, 1999).

The concept of "cooperation" described by I.A.Zimnyaya means the cooperative development activities of children and adults, bonding through mutual understanding, spiritual closeness to each other, joint analysis of the implementation and results of activities (Zimnyaya, 2000).

5 CONCLUSION

It should be emphasized that in the new requirements for the qualifications of learners, the results of education are clearly defined. One such requirement is metasubject outcomes, which require the formation of reading and collaborative learning skills. It also discusses the expected outcomes of the new qualification requirements. Strictly speaking, these results are expressed in connection with communicative universal educational activities. On the basis of communicative learning activities, learners take into account different opinions, coordinate different points of view in cooperation; in case of matching of interests, it is envisaged to reach common solutions in joint activities.

Based on these thoughts, we can say that these forms of educational organization are of great importance, and the organization of the entire pedagogical process based on cooperative pedagogy serves to improve the quality of education.

REFERENCES

Asqarova, O., 2014. Usmonboyeva M. Raxmatova X. Ehsonova F. Asqarova F. (Pedagogy. "Navro'z" Publishing House - Tashkent:. 67 p.

Abdullaeva, Sh. A., 2017. Collaborative Pedagogy. : T.:Science and Technology - Tashkent:. 178. c.

Abu Nasr Farabi The City of Virtuous People: T.:Qodiriy A.People's Heritage Publishing House 1993. 222 c.

Azizkhodjayeva, N. N., 2000. Pedagogical Technology of Teacher Preparation: - T.: TDPU, 52 c.

Arefyeva, O. M., 2015. Features of Developing Communicative Universal Learning Skills in Primary School Students: Primary School Plus Before and After. No. 2. 28 c.

Davydov, V. V., Slobodchikov, V. I., Tsukerman, G. I., 2010. Younger Schoolchild as a Subject of Learning Activity : Questions of Psychology, No. 3-4. 23 c.

Dezhnikova, N. S., Pervin, I. B., 1991. Schoolchildren's Mutual Assistance. : M .: Pedagogy, 112 c.

Dilova, N. G., 2018. Enhancing the Mechanisms of Creating a Collaborative Learning Environment in Primary Education: Doctor of Philosophy (PhD) in Pedagogy thesis.: Nukus, 152 c.

Johnson, D. W., Johnson, R. T., 2008. Cooperation and the Use of Technology. In Spector J. M. Merrill M. D. Merrienboer van J. & Driscoll (Eds.) M. Handbook of Research on Educational Communications and Technology. - New York: Taylor & Francis, P. 1017-1044.

Zimnyaya, I. A., 2000. Pedagogical Psychology. : M .: Logos - Handbook of Research on Educational Communications and Technology - New York: Taylor & Francis, 384 c.

Ivan, A. A., 2010. The Art of Thinking Correctly: M .: Enlightenment, 224 c.

Yoldoshev, J. G., Usmonov, S., 2004. Effective Pedagogical Technologies: T.:Teacher, 101 c.

Rean, A. A., Kolominsky, Ya. L., 1999. Social Pedagogical Psychology : St. Petersburg, 32 c

Rubinstein, S. L., 2004. Principles and Paths of Psychology Development: M .: RSFSR. PFA 8th edition, 180 c.

Sulaymonova, F., 1997. East and West: T .: Uzbekistan, 415 c.

Slavin, R. E., 1978. Student Teams and Comparison Among Equals: Effects on Academic Performance and Student Attitudes.: *Journal of Educational Psychology*, vol. 70. - P. 532-538. c.

Khoshimov, K., Nishonova, S., Inomova, M., Hasanov, R., 1996. History of Pedagogy: T.: Teacher, 314 c.

Khoshimov, K., Nishonova, S., Inomova, M., Hasanov, R., 1996. History of Pedagogy: T.: Teacher, 488 c

Tsukerman, G. A., 1992. Collaborative Learning Activity as the Basis for Developing Learning to Learn Skills: Author's abstract of Doctoral Dissertation in Psychology. 39 c.

Dziuban, C., Moskal, P., Hartman, J., 2016. Adapting to learn, learning to adapt. EDUCAUSE Research.

Selwyn, N., 2016. Is Technology Good for Education? Cambridge UK: Polity Press; p. 178.

Prinsloo, P, Slade, S., 2017. An elephant in the learning analytics room – the obligation to act. In: Proceedings of the Seventh International Learning Analytics & Knowledge Conference. 2017:46-55.

Urban, M., Děchtěrenko, F., Lukavský, J., Hrabalová, V., Svacha, F., Brom, C., Urban, K., 2024.ChatGPT improves creative problem-solving performance in university students: An experimental study. Computers and Education. № 215.

Showcases of Innovative Applications in Teaching Translation

Yelena Aripova[1][1], Yana Arustamyan[2][2]
[1]Westminster International University in Tashkent, Uzbekistan
[2]National University of Uzbekistan, *Uzbekistan*
ya.arustamyan79@gmail.com

Keywords: Artificial Intelligence, Higher Education, Personalized Learning, Teaching Methodologies, Learning Theories, Diagnosing, Decomposing, and Reframing, Teaching Translation.

Abstract: The adoption of Artificial Intelligence (AI) in educational environments signifies a juncture change to the digital mode of learning within higher education. This paper investigates the functioning effects of integrating AI technologies within higher education, which include a focus on having a personalized interface and experience as well as a way of enhancing pedagogy and addressing learning and assessment-based challenges. The analysis of drastic learning theories including behaviorism, cognitivism, and constructivism reveals their fundamental role that AI plays for their integration in education and educational practices. Also, revelations about transformational education and knowledge creation show how AI has a vital role to play for these processes. Given the above, the present article is designed to conduct a critical analysis of the implications of AI integration in the translation classes at the Department of Translation Studies and Comparative Linguistics at the National University of Uzbekistan from foundational theories perspective and develop an efficient translation teaching course strategy. Therefore, the paper presents the opportunities for implementing AI in the teaching translation classroom checked by the principles of constructivism, behaviorism, and cognitivism to enhance language learning.

1 INTRODUCTION

The appropriateness of Artificial Intelligence (AI) in learning environment, AI in education, marks the next significant move in the growth horizon of higher education. The provisions, which hint at a further shift towards digital learning environments, are presenting more and more perspectives that could be beneficial to educational delivery. In this paper, the main focus is on how AI, or its subsets, will transit higher education through ideas for self-learning, education policy, and long-standing issues to instruction and university assessment. It is in the traditional learning theories like behaviourism, constructivism, cognitivism that the application of Artificial Intelligence in instruction can be founded. Patterned from the perspective of the learner with each theory, they describe the student's role in their learning process. There is an essential history of the roles learning theories of connectionist instruction in Artificial Intelligence and substantial perspectives gained from learning theories concerning the connectionist instructions. Technological evolution is closely related to pedagogical innovation, as we have observed before. Integral to knowledge teaching and learning processes, therefore, a university assessment is at the forefront of the essential these ideas. Most obviously, Artificial Intelligence can be founded in theory on traditional education that integrates learning. Learning involves several basic theories. Firstly, there is constructivism. A perspective on Artificial Intelligence that describes it as a conscious entity, constructs the learner's world and awareness. From their experiences, learners make aware decisions. The assistance can be provided mainly to enhance constructivist learning by giving learners information on their understanding.

Another useful theory is cognitivism, which focuses on cognitive processes, especially the role of intelligence, memory, knowledge, and problem-solving in thinking. (Ertmer and Newby, 2013) Cognitivism also helps to explore the role of AI in

[1] https://orcid.org/0009-0009-8406-6667
[2] https://orcid.org/0000-0003-1528-7537

such complex cognitive processes. Firstly, AI can process large amounts of data and establish patterns and ideas that assist in creating learning content based on the cognitive processes of understanding and remembering. Secondly, it can be utilized in creating simulations and models that help learners develop excellent problem-solving skills. Transformative learning theory may also offer a profound understanding of AI integration in higher education as it is about fully changing one's frame of reference. (Gruetzemacher and Whittlestone, 2022) With AI, learners from various parts of the globe get access to unlimited resources and a wide range of perspectives that enable them to reflect critically on their ideas and values. It is essential because knowledge is created through questioning and expanding what people believe and accept as true from a young age. AI plays a critical role in supporting knowledge creation processes in higher education. The use of AI assists in aggregating and analyzing different information, making learning fun, and enabling it to promote for new knowledge and ideas. It also facilitates the building of a collaborative and inquiry-based learning where the students interact through dialogs and come up with new ideas. The achievement and integration of AI in learning fit into the traditional learning theories. However, their relation and integration help develop the traditional learning theories to new levels to grow as technology grows. Thus, AI's contribution to learning has helped develop learners' quality of knowledge and access levels at the higher level.

A Student - Centered Approach to Learning

Student engagement, personalized learning pathways, and adapted learning approaches – overwhelmingly effective with the help of AI technologies – are the areas prompting the learning-centered approach in higher education. This means that the new teaching approach needs to make students much more independent within the educational process itself, which will, at the same time, be much more oriented to the needs, wishes, and goals of students. The AI tools and platforms can become self-directed and independent in that they study student learning patterns to give recommendations, adjust learning courses, and change support where necessary, all in an effort to enhance learning outcomes together with experience (Zawacki-Richter et al., 2019). This use of AI is surely leading to a pedagogy approach, nature of student-centered, since it increases substantially the autonomy of the learners over the learning pathways. Being analytics-driven guarantees the way of providing possibilities for the adjustment of the learning content, pacing, and even way of conducting learning activities in real-time. This is where adaptivity comes in: AI can learn through monitoring both the learner profile and his performance information in order to be able to uniquely tailor each learning experience to achieve the highest possible engagement and understanding (Baker and Smith, 2019).

Evaluating Current Learning Opportunities

This part of the spectrum is one of the most important frontiers that higher education has been reaping benefits from using AI to increase learning opportunities, especially in cases where it is adopted by online and hybrid models. These kind of learning opportunities have developed a trend to this era of education, which is that dimensionally interactive and individually customized to open the field to the student, and not vice versa. AI can be noticed to afford personalized learning environments, AI-powered tutors, and chatbots that present direct instant feedback to students free of charge. This coupled element has the potential of enhancing the above but has to be counter-weighed with potential risks. Numerous studies claim AI can present learning outcomes developments holistically. According to the research by Li and Ma (2020), the proposition that the fields of AI can improve student engagement and accordingly retention integration, therefore, "when students have adaptive learning systems, they are more than willing to stay around longer. Several positive developments associated with AI that can be positively be linked with learning achievement through formative assessment and feedback" (He et al., 2020). The domain of the human factor in education comes with bigger challenges to the respective domains of privacy of data and that of the digital divide (Weller et al., 2020). This scope only outlines the human-centric approach over AI and, consequently, the risks of the external threats to private information should then more or less be considered destructively. The dualism of AI represents more critical sophistication in the usage of form in the later application for AI to learn. A point that also needs to be noted is the fact that the research intersubjectivity in the field found much more research still needs to be executed on the matter, because the dialogue on the integration will stay open and cannot be limited, given the complexities of the field. This is also undoubtedly true for the context in question since Acar (2023) approaches the formulation angle of using the education AI method, clearly bringing out how emphasis on precise problem formulation becomes the prerequisite to problem acquisition. There is a critical underemphasizing when hiring an AI tool to frame a concrete usage phase for the development of active direction of learning opportunities.

2 PROBLEM FORMULATION

Acar (2023) in the Harvard Business Review, points out that many times, at the level of learning contexts or professional fields, the core of many problems is not the lack of solution but poorly comprehended problems before attacking it. Problem formulation is defined as the capability of a person to recognize, analyze, and delineate problems clearly. This is considered a weak point across the world, and it identifies an important area of development in educational environments. He illustrates a common problem for students in the definition phase: Students are likely to have difficulties coming to grips with what questions they could possibly ask regarding the topic that has been given. He points out that herein lies a place where generative AI tools will greatly assist the student in critically appraising their research problem. Here, the example of how ChatGPT can be used, through problem decomposition in essay questions, students might get the key concepts and interrelations by utilizing AI. The following is the description suggested by Acar (2023). This process involves (**Figure 1**):

Figure 1: AI implementation stages.

Diagnosis means to find the root of a problem and lay bases for sustainable solutions. Decomposition means to break down the problem into smaller, more manageable pieces. Reframing means the shift in perspective toward a problem in a creative manner to come up with new, innovative solutions.

This, therefore, makes the approach appropriate to be implemented in teaching English translation course to students of the National University in Tashkent, which will allow teachers to make the process easier and more practical. The Diagnosing, Decomposing, and Reframing (DDR) approach is hence illustrative in this classroom situations.

Constructivism and AI in Translation Education Constructivist learning theory argues that that learner constructs information from experiences and reflections. Thus, in the context of the translation course, AI can improve learners' experiences since it creates an interactive platform for learners to play with the available text can range from legislation to fiction. For instance, during translation, AI tools can enable learners to input translated words, sentences and even paragraphs; then the AI system will compare the translation with a plethora of professional translated databases and then the feedback is given. In this case, students are prepared to engage in reflect for thought and play with the complex and contextual nature of language in learned examples. It helps them understand how an effective translation is done. Behaviorism and AI-Driven Repetition Behaviorism asserts learning as a product of repetition and reinforcement. Indeed, an AI tool language earning applications with spaced repetitive algorithms may suit the translation course well to support students in learning and retrieving various target languages vocabulary terms and popular idioms. AI would then present translation quizzes at optimal intervals to solidify the translation vocabulary. For this case, the accurate translations can be positively reinforced by immediate feedback while the inaccurate translations are presented back to students to correct the word selection until the habit is formed. As regards cognitivism, here it focuses on the processing involved in language. To process the statements made, we would assume that one requires language that is "cognitive enough" in context and familiar to the culture they come from and questions that require some exercises that are otherwise given in this translation AI application. Some of the tasks that the AI applicable would have been challenging include the translation of idiomatic expression and cultural reference; hence one is required to think critically of how to proceed with this assignment to get the right translation. The AI is to control the task such that it adjusts to a point where it becomes cognitive enough according to the learner.

3 STUDENT-INFORMED TRANSLATION SIMULATION

Students work with a text presentation AI to translate texts across domains. The AI interacts with students, offering instantaneous advice and corrections during translation as the social practice of the tool, providing learners with a "learning by doing" experience.

Vocabulary practice through a series of drills: Students get a series of daily drills in the morning according to their levels and the amount they need to have caught up. Spaced repetition enables the students to have long-term memory of the translation-specific words.

Another variant to use simulations in the classroom is to exploit different Computer-Assisted Tools (CATs), which further graduates may use in their real-life situations. Here are some simulation programs and platforms commonly used training and simulating tasks:

1.SDL Trados Studio. This is a popular CAT that also offers features translation memory, terminology management, and project management. It is widely used in the industry and often integrated into translation training programs.

2. MemoQ. MemoQ is another CAT tool that provides a platform for translation memory, terminology management, and collaborative translation projects. It is used in professional settings and is also incorporated into translation education and simulation programs.

3. Wordfast. Wordfast is a suite of translation tools that includes Wordfast Classic, Pro, and Anywhere. These tools are utilized for different types of translation projects and are also used in educational programs for training and simulation purposes.

4. OmegaT. OmegaT is a free and open-source translation memory application that is also utilized in training programs and educational settings for simulating translation tasks.

5. Across. Across is a language translation software providing a range of translation management tools. It is used in professional settings and is also integrated into translation education for simulation and training purposes.

6. XTM Cloud. XTM Cloud is a web-based translation management system with features for translation memory, terminology management, and project management. It is used both in professional translation and incorporated into translation training programs.

These programs and platforms are commonly utilized in both professional and educational settings to provide students with hands-on experience and simulation of real-world translation tasks. They help to bridge the gap between theoretical knowledge and practical application in the field of translation.

In our showcase we used OmegaT CAT in order to create a real-life environment for collaborative translation, which also provided good opportunities for students to make own conclusions regarding advantages and disadvantages of this tool. Therefore, learners become not only passive performers of the provided instructions, but mostly make their own decisions and come to the conclusions independently.

4 COLLABORATION WITH PEERS

Furthermore, students collaborate with peers throughout the program in projects such as finding and sharing AI resources, collaborative translation where they get group feedback from the AI system, and building a learning environment in which they use constructive learning. Therefore, throughout the course, teaching involves AI is not merely a backing process with interaction and customization; it matches the theoretical foundation for which kids can learn best. It could be a very useful aid to the successful education of competent translators; it promotes the cognitive, behavioral, and constructivist learning of the translation skills through AI so that the challengers of the profession can be faced multi-dimensionally. During this paper's development, we have learned a lot of details about Al integration in educational technologies – support in personalized ease of learning through adaptive strategies and in ethical questions concerning human interaction subtleties in a digital learning form on the heads. Therefore, the role of Al is to create more opportunities for group learning, a learning landscape responsive to a particular case, with possibilities according to an educational approach, making learning more open and affordable.

Nevertheless, the way for AI in education has just been paved by the practitioners. While rapid technological change offers new opportunities, it also poses serious threats. However, it is clear that additional research is needed. First of all, it does not seem possible to visualize very clearly that the ultimate arch would be harmed in the long run. There are simply too many unknowns and knowledge collecting needs to be done. The way the most essential needs would be better understood is with very systematic research about how exactly are these technologies used to advance the educational goal. Data privacy and security remain major concerns, and it should be a concern that must be kept vigilant by educators and those they educate. There is also the area of developing inclusive AI systems, which bridges the gap so that the winnings of technological advancement are available to everyone. Again, the process must happen exactly like this as educators and learners' needs remain up-to-date, and so should these be supporting technologies. It is meant to be a process as it is essential to restate a disparity in learning experiences that are most social, most effective, and more available to attain the full potential of AI.

Therefore, the use of AI in higher education presents an opportunity to revolutionize the field of learning. Through utilizing the capabilities AI provides, while also addressing its challenges with caution and insight, an inspiring and ethical pathway for the use of AI in education is possible. The path to achieving this goal is exciting and, at times, daunting. Moreover, it is essential to unite educators, technologists, and policymakers in the collaborative effort to harness the potential of AI in the domain of education. The case study illustrates evidently the incorporation of AI in higher education, not only as a technology but also as a means through which pedagogies can advance. The understanding of the problem formulation is essential for all parties involved to realize the best that the AI technologies have to offer at any given learning experience. Moreover, its application transcends the impact it has on an individual and reflects the relevance of AI in developing the twenty first century academic and professional skills. The facets it embraces do not only enhance the understanding and desire to pursue the topics by students.

5 CONCLUSION

In conclusion, integrating AI into higher education demonstrates the potential to reshape the learning terrain. Realizing the full promise of AI without falling into its pitfalls, in a wise, forward-looking, and accountable manner, may well open direct opportunities to the future where technology helps harness both transformational and ethical learning. In other words, the developing story tempts with a trajectory so labyrinthine it will need the joint efforts of educators, technologists, and policymakers if the transformative potential of AI for the future of learning is to be fully realized. The first one: this case study will indicate that the integration of AI in institutions of higher learning does not stop at yet another technology tool in assisting to solve the pedagogical problem but that it acts as a catalyst for the pedagogical revolution. The case study has also addressed the need for educators to understand the problem at an elementary level if they have to realize AI’s maximum benefits to learning spheres. Finally, the present case study implies the breadth to which the individual experiences of learning were given prominence instead of the breadth to which applications of AI in the development of academic and professional training competencies were covered. This not only gets students into and participating with what can often be somewhat dry research topics but also shows how AI is transforming the world of learning. This kind of penetration into the material with AI assistance in the identification of the problem will develop the students' thinking level and capability of problem-solving at a far higher or elevated level than it would have developed for them simply by reading the material.

REFERENCES

Acar, A., 2023. The importance of problem formulation in AI integration in education. *Harvard Business Review*. (Accessed: 25 March 2024).

Baker, R.S., Smith, L.F., 2019. Using Learning Analytics to Predict (and Improve) Student Success: A Faculty Perspective *Journal of Interactive Online Learning*, 17(1), pp. 1-15.

Ertmer, P. A., Newby, T. J., 2013. Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, 26(2), 43-71.

Gruetzemacher, R., Whittlestone, J., 2022. The transformative potential of artificial intelligence. Futures, 135, pp.1-11.

He, J., Bailey, J., Rubinstein, B.I.P., 2020. Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development. *International Journal of Artificial Intelligence in Education*, 30(1), pp. 1-24.

Li, X., Ma, E., 2020. Integrating artificial intelligence into online education: Examining its impact on teaching and learning'. *British Journal of Educational Technology*, 51(3), pp. 601-618.

Weller, M., Van Ameijde, J., Cross, S., 2020. Learning analytics and ethical issues: A framework for understanding. *British Journal of Educational Technology*, 51(4), pp. 903-919.

Zawacki-Richter, O., Marín, V.I., Bond, M., Gouverneur, F., 2019. Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, 16, Article 39.

Research of Nature-Based Solutions to Improve the Biocapacity of Cities and Increase Sustainable Development

Aleksandr Kononov[1], Elena Pavlova[2], Evgenii Iushkov[3]
ITMO University, Kronversky Avenue 49, Saint Petersburg, Russia
411558@niuitmo.ru, eapavlova@itmo.ru, Eevgeny1998@gmail.com

Keywords: Nature-based solutions, biocapacity, sustainable development.

Abstract: With the rapid growth of the urban environment and an increase in the number of citizens, the issues of environmental sustainability and conservation of the naturaleenvironment in cities are becoming increasingly relevant. The research of nature-oriented solutions to improve the bio-capacity of cities and increase sustainable development is an important topic that attracts the attention of researchers, urban architects, and the public. Nature-oriented approaches include the integration of green areas, the use of natural water resources, consideration of ecosystem needs in construction, as well as other innovative methods. The aim of these studies is to create sustainable urban development strategies that reduce the environmental impact, improve the quality of life of citizens and preserve biodiversity in the urban environment.

1 INTRODUCTION

In recent decades, humanity has faced growing environmental challenges, such as climate change, loss of biodiversity, environmental pollution, depletion of natural resources, and others. Solving these problems requires collective efforts and science-based decision-making. The current vector of urban development is to maintain a balance between bio-intensity and the ecological footprint of the population, these two indicators, that correlate with each other and are aimed at maintaining sustainable development, green transformation, and economic growth, as evidenced by the Sustainable Development Goals, adopted by the UN on September 25, 2015 (Gabbi, Matthias, Patrizi, Federico, Bastianoni, 2021).

Today, sustainable development is acquiring new trends related to the economy, ecology, and social institutions. To understand the whole picture of the world, we need a universal indicator that will reflect the relationship of many elements on the part of humanity and nature. This integral indicator can be biointensity.

2 BIO-CAPACITY AS AN INDICATOR OF SUSTAINABLE ECOSYSTEM DEVELOPMENT

The concept of bio-capacity is related to the assessment of the consumption of natural resources and the analysis of their sustainability. Bio-capacity determines the ability of an ecosystem to restore the resources needed to meet the needs of humanity and absorb the waste that human activities leave behind.

The use of natural resources and the production of waste that exceeds the bio-capacity of an ecosystem can lead to environmental degradation, resource depletion, and other environmental problems.

When we talk about bio-intensity, we mean several key types of land use, such as arable land, pastures, forest areas, built-up areas, and fishing areas. These territories are currently undergoing a global change, during уменьшается which the stock of bio-productive territories decreases, which in the future can lead to economic instability not only of the local territory, but also of a larger area (Sowińska-Świerkosz, García, 2022). To maintain and further

[1] https://orcid.org/0009-0001-2753-8180
[2] https://orcid.org/0000-0001-6492-7102
[3] https://orcid.org/0009-0005-2488-0422

increase the bio-intensity, it is necessary to properly manage the resources and the study area. To calculate the bio-intensity, there is a certain method, which implies that the bio-intensity (BC) of the study area is the total indicator of various types of land use:

$$\mathrm{BC} = \mathrm{A} * \mathrm{YF} * \mathrm{EQF}, \quad (1)$$

where BC is the bio-capacity, A is the available area of the studied land use type, YF is the yield coefficient, and EQF is the equivalence coefficient for the considered land use type in the country.

The yield coefficient, in turn (YF) (2), is calculated as the ratio of the yield of the considered categories of land in the territory to the yield of this category of land in the world.

$$\mathrm{YF} = \frac{\text{crop yields (territories)}}{\text{level culture (world)}} \quad (2)$$

Equivalence Factor (EQF) - is a coefficient for converting the actual acreage for different categories of land in hectares to their global equivalent in global hectares. Equivalence factors for different types of surfaces were taken from the dissertation on the study of bio-productivity (Boev, Burenko, Shvartz, 2017) (Table 1).

Table 1: Equivalence factors for different types of bio-productive surfaces.

Type of bioproductive land surface	EF
Arable	2.51
Pasture	0.46
Forest	1.26
Fishing land	0.37
Built up land	2.51

Global hectare (gga) is a conventional unit that characterizes a hectare of bio-productive area or water area with an average global indicator of bio-productivity for a year of research. The global hectare is a composite unit for calculating the "ecological footprint" and bio-intensity (Boeva Shvartsev Knizhnikov Voropaev , 2014).

The global experience of using this methodology shows that this method has a number of limitations. The key indicator is the complexity of collecting reliable statistical information, which varies, differs, and sometimes even is not available in different sources. Such information is: the area of pasture and arable land, studied at the local level, data on the average yield of pastures and agricultural crops. crops, as well as information on fishing grounds.

An analysis of the consumption of natural resources and the impact of human activities on ecosystems allows you to determine the level of environmental sustainability and take measures to improve the situation. And the bio-capacity calculation can help determine the acceptable level of resource consumption and waste generation to support the sustainable functioning of the ecosystem.

Currently, there is no single strategy for increasing bio-intensity in the world. Improving biological potential requires comprehensive measures, including effective management of natural resources, reduction of waste consumption and production, development of environmentally friendly technologies, conservation of biodiversity, and others. Environmental decision-making based on bio-intensity analysis can create a sustainable framework for development and ensure that the environment is preserved for future generations.

Thus, bio-intensity is an indicator that allows influencing decision-making in the field of sustainable development, allowing you to determine the level of ecosystem sustainability and develop strategies for improving the situation. Taking measures to improve bio-capacity is important for ensuring sustainable development and preserving the environment. Scientific research and an interdisciplinary approach are also important for developing effective strategies to improve biocapacity and make environmentally sound decisions.

3 NATURE-BASED SOLUTIONS TO INCREASE THE BIOLOGICAL POTENTIAL OF CITIES

Modern cities face a number of environmental challenges, including air pollution, deterioration of soil and water quality, and loss of biodiversity. These problems are caused by various factors, including urbanization, industrialization and climate change, and the loss of biocapacity (Luo, Cai, Zeng, Zheng, Lin, 2024). To address these issues, it is necessary to look for nature-oriented solutions that can help improve the biological potential of cities and increase sustainable development.

The concept of natural resource-based solutions (NBS) was first put forward in 2008 by the World Bank. The first research program on nature-based solutions was conducted in 2013 (Sowińska-Świerkosz, García, 2021). The concept solutions as a result of the search for innovative solutions for managing natural systems in such a way as to create a balance between nature and societyом. In other words, receiving from nature not only resources, but also its way of acting, using as many resources as necessary for life and making up for what was used. Thus, it turns out that human communities can develop and implement solutions for a sustainable, resource-efficient, and green economy. For many years, the scientific community could not come to a single consensus on what NBS is. According to the EU report on NBSследует, "the concept of natural solutions embodies new ways of approaching socio-ecological adaptation and sustainability, equally relying on social, environmental and economic areas" (Dumitru, Wendling, 2021). To clarify the conceptual nature of NBS, the IUCN global Standard includes eight criteria that can be used to form a cluster of economically green interventions as NBS actions. These criteria are based on the principles of the concept and on feedback, received from public authorities involved in green policy: (1) solving social problems; (2) scale of intervention in the natural landscape; (3) increased biodiversity; (4) economic viability; (5) ability to manage; (6) equitable ecological and economic balance; (7) adaptive management; (8) relevance in the relevant jurisdictional context.

In practice, e- solutions include such aspects as the creation of green zones, reservoirs, sustainable use of natural resources, the development of environmentally friendly modes of transport and public space (Sowińska-Świerkosz, García, 2022).

One of the most important aspects is the development of urban parks and green areas. Their creation and maintenance contribute to improving air quality, preserving water resources, creating places for recreation and entertainment, and also contributes to the formation of an ecological infrastructure of the city.

In addition, sustainable water resources management is also a key issue. The introduction of methods for collecting and cleaning rainwater, the creation of reservoirs, recreational areas and systems for water reuse allows cities to ensure sustainable use of water resources and improve the environmental situation.

The integration of eco-friendly modes of transport and the development of infrastructure for pedestrians and cyclists also play an important role in improving the biocapacity of cities (Bressane, Hashimoto, 2024). The creation of hiking areas and bike paths will reduce air pollution and create favorable conditions for an active lifestyle of citizens.

To study natureoriented solutions to improve the biointensity of cities, an analysis of existing research and practices in this area was conducted. The main principles and approaches that can contribute to achieving these growth points to improve the bio-intensity of cities were identified.

Today, there are various natural solutions, but for each location where NBS will be implemented, it is necessary to take into account local climatic, economic, and social factors and determine the adaptability of innovations. The territories of many countries may include different climatic zones and urban conditions, and it is impossible not to take into account the fact that a large number of natural solutions are more adaptable to countries with mild climates, where the weather is warmer most of the year and there are more sunny days, based on this, in the opinion of scientific communities, it is necessary to take into account the following features (Hossein, Zarfeshani, Arast, 2024). Local adaptation of environmental solutions in each research area and the possibility of implementing such solutions in relation to the specifics of climatic conditions.

One of the most effective natural solutions for the territories of most countries of the world, and first of all, urban settlements, can be the concept of vertical gardening, which consists in creating and hydroponic vertical gardens aimed at absorbing carbon dioxide, street noise, creating a new format of park areas within the city, and also serve as an important catalyst for improving the quality of urban biodiversity. This approach includes the following ecosystem services (Maksimova, 2020):

- mitigates the effects of global climate change;
- creates conditions for recreation of citizens;
- forms the cultural identity of the city and its individual districts;
- reduces the city's "heat island".
- manages rainwater runoff.
- adjusts the wind speed.
- cleans the air from dust.
- absorbs carbon dioxide and releases oxygen.
- supports the biodiversity of urban animals and plants.

Vertical gardening has been known to the population for a long time, but now this environmentally oriented method is gaining a new trend among architects, environmentalists, and managers of nature-oriented areas. Vertical gardening is becoming more popular every year and is being introduced into urban planning, being a leading trend in urbanization and sustainable development based on natural solutions. For its active implementation in the urban environment, it is necessary to popularize this concept at various hierarchical levels, from local initiative to communicating this idea to the level where urban decisions are made on planning the environmental strategy of regions. The creation of green walls will develop the ecological framework of cities, increase the biodiversity of urban areas, improve the ecological situation, thereby contributing to the increase in the city's bio-potential.

Turning to historical chronicles, we can recall how in ancient times people collected rainwater in various containers, but today, in the context of the increasing influence of climate change and sustainable development, effective water resources management is becoming an increasingly important task. In this regard, the use of rainwater and snow as one of the options for nature-based solutions is an important innovative approach to sustainable water use. Collecting rainwater or snow can be relevant at different times of the year and in many cities due to the country's climatic features. Naturally collected sediments in special containers can be used as a backup water source in case of emergencies оля when water is turned off to the building.

Collecting, storing, and using rainwater and snow has several advantages. First, it helps to reduce the consumption of groundwater and surface water bodies, which helps to conserve water resources and prevent water scarcity. Second, it promotes more efficient use of water for agriculture, industry, and urban water supply systems. Finally, collecting rainwater and snow can reduce the risk of flooding and erosion, which increases the sustainability of water systems.

Successful projects for using rainwater and snow as one of the NBS systems are already underway in various parts of the world. Many countries in Africa and South Asia actively use rainwater collection and storage to provide drinking water and irrigate agricultural land. Similar projects are also being implemented in other regions, including North America and Europe, where combined with solar energy, in particular with solar panels, water is heated in containers with precipitation, such a symbiosis of natural solutions allows you to effectively use natural sources without harming the environment.

When talking about green solutions for cities, we should not forget that historically, many of the cities are located either on rivers or near large bodies of water. Destruction of coastlines is one of the major challenges faced by many countries due to climate change and overexploitation of coastal areas (Souliotis, Voulvoulis, 2024). Nature-based solutions, including the use of live coastlines, have been widely used to address this problem.

Living shorelines are morphological forms created and maintained by vegetation and biological processes. This includes measures such as the restoration of mangroves (for warm countries), the creation of natural coastal formations from vegetation, plant fencing and other natural ways to strengthen the coastline.

Using live coastlines as an NBS can bring a number of benefits. First, they contribute to the conservation of coastal zones and prevent erosion, which threatens biodiversity and economic infrastructure in coastal areas. Second, living shorelines are a natural means of filtering out pollution and depositing salt, which contributes to improving water quality and maintaining ecosystems in the tidal zone (Waylen, Wilkinson, Blackstock, Bourke, 2024). Finally, they provide coastal residents with protection from floods and hurricanes.

Projects to create living coastlines are being successfully implemented in various parts of the world. For example, in some regions of Asia and Africa, mangroves are being actively restored, and green belts and park areas are being laid out in urban suburbs and coastal settlements to protect against natural disasters.

And the use of live shorelines as one of the NBS options demonstrates the potential of this strategy for preserving coastal zones and improving the sustainability of coastal communities. However, to scale this approach and successfully implement it, it is necessary to continue research, develop regulatory standards, and implement appropriate technologies.

4 CONCLUSIONS

Nature-Based Solutions (NBS) is an innovative approach to sustainable development that aims to use natural processes and biodiversity to address the various challenges facing humanity and ecosystems. In recent years, NBS has attracted a lot of attention as an effective way to adapt to climate change, ensure environmental sustainability, increase biological potential and human well-being.

Based on various studies, projects, and experiences with NBS applications in various regions of the world, several conclusions can be drawn about their effectiveness and potential:

1. Improving ecosystem resilience: Biodiversity and natural processes, using NBS, can offer solutions for restoring and strengthening vulnerable ecosystems. For example, restoring mangroves, creating plant baskets to control erosion, and other

methods help prevent ecosystem degradation and preserve their value.

2. Climate change adaptation: The NBS can serve as an effective tool for climate change adaptation. For example, the use of natural reservoirs and green spaces to reduce the risk of flooding and conserve water resources, as well as the creation of residential zones and parks to regulate the temperature in cities.

3. Cost effectiveness: NBSS can offer additional benefits in the form of cost-effectiveness. For example, green spaces and natural filters can help reduce infrastructure maintenance costs, as well as improve public health and environmental quality.

4. Community approach: It is important to note that NBSS can encourage public participation and an opportunity to engage local communities in nature conservation and improving the quality of life.

In general, it can be concluded that nature-based solutions represent an effective and promising approach to solving various environmental and social problems, and also have a positive impact on increasing the bio-intensity of cities, especially where flora and fauna are in a depressed state. Some of these methods are highly adaptable even to the climate features of the Nordic countries, although many of the green solutions are easier to implement in countries with more pleasant and warmer climates. However, for their successful scaling and integration in various fields of activity, it is necessary to continue research, develop regulatory mechanisms, and share international experience to ensure their sustainable implementation in practice.

REFERENCES

Boeva, P. A., Shvartsev, E. A., Knizhnikov, A. Yu., Voropaev, A. I.; under the general editorship of Boeva, P. A., 2014. Ecological Footprint of the subjects of the Russian Federation: World Wildlife Fund, p. 88.

Boev, P. A., Burenko, D. L., Shvartz, E. A., Vakernagel, Matis; under the general editorship of Boev P. A., 2017.Ecological footprint of the constituent entities of the Russian Federation. Main conclusions and recommendations/ World Wildlife Fund (WWF). WWF of Russia, p. 72.

Bressane, A., Hashimoto, F., 2024. Enhancing energy sustainability of building projects through nature-based solutions: A fuzzy-based decision support system.

Dumitru, A., Wendling, L., 2021.Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners. d-G R&I. European Commission, Luxembourg.

IUCN. Global Standard for Nature-based Solutions., 2022. A User-Friendly Framework For the verification, Design and Scaling Up of NbS. (1st Edition), IUCN, Gland, Switzerland.

Gabbi, G., Matthias, M., Patrizi, N., Federico, M., Bastianoni, S., 2021.The biocapacity adjusted economic growth. Developing a new indicator.

Hossein, M., Zarfeshani, A., Arast, M., 2024. Investigation of green roofs effects on reducing of the urban heat islands formation (The case of a municipal district of Tehran City, Iran).

Luo, M., Cai, J., Zeng, Zh., Zheng, Y., Lin, T., 2024. Development and practices of nature-based solutions in China.

Maksimova, O., 2020. RBC trends. What is the ecological framework of a city and why is it needed?

Souliotis, I., Voulvoulis, N., 2024. Operationalising nature-based solutions for the design of water management interventions.

Sowińska-Świerkosz, B., García, J., 2021. A new evaluation framework for nature-based solutions (NBS) projects based on the application of performance questions and the indicators approach.Sci. Total Environ., p. 787.

Sowińska-Świerkosz, B., García, J. 2022. What is Nature-based solutions (NBS)? Setting core ideas for concept clarification.

Science for Environment Policy., 2022. The Solution is in nature. Future Brief 24. Brief Produced for the European Commission DG Environment. Science Communication Unit, UWE Bristol, Bristol .

Waylen, K., Wilkinson, M., Blackstock, K., Bourke, M., 2024. Nature-based solutions and restoration are intertwined but not identical: Highlighting implications for societies and ecosystems.

World Bank, 2008.Climate Change and Adaptation: Nature-Based from the World Bank Portfolio. Biodiversity, SolutionsWashington, DC.

Smartfarm DSS Framework for Decision Support System on City Smart Farm with Deep Neural Network and Case-Based Reasoning

Igor Glukhikh[a], Dmitry Glukhikh[b], Anastasia Maltseva[c] and Viktoriia Shcherbakova[d]
School of Computer Science, University of Tyumen, Volodarskogo 6 Street, Tyumen, Russia
d.i.glukhikh@utmn.ru, stud0000263172@study.utmn.ru

Keywords: Smart farm, automation, neural network models, framework.

Abstract: Smart urban farms have become one of the trends of modern cities and their ecosystems. The trend in the development of such farms is full automation and minimizing human involvement. At the same time, problematic situations that require prompt and competent intervention by specialists, often at the expert level, are not excluded on a smart farm. In particular, this is the occurrence of plant diseases or conditions for them. Such situations do not appear on a daily basis; however, they can critically affect the results of the city farm. In these conditions, it is important to supplement the software and hardware complexes of smart farms with decision support systems. The paper presents a framework for such a system. The framework implies three modes of operation: visual monitoring of plants for disease detection, monitoring of microclimate and nutrient medium parameters, and a question-and-answer system. The proposed architecture has been tested in the implementation of the DSS software prototype. The peculiarity of the framework presented in this work is that it offers an architecture and methodology for creating such DSS, where deep learning and knowledge engineering methods are organically combined the case-based reasoning method, which is effective for inferring solutions.

1 INTRODUCTION

The creation of smart city farm became one of the development trend do modern city and those ecosystems (Virk, Noor, Fiaz, Hussain, Hussain, Rehman, Ahsan, Ma, 2020). Urban farms allow the use of compact urban spaces, public or industrial premises in order to provide residents with food products in the immediate vicinity of their residence. On such farms, horticultural crops, vegetables, mushrooms and other types of products are grown. An important feature of smart urban farms has become their organization in the form of highly automated complexes. Smart farms strive to become autonomous cyber-physical systems that require almost no human involvement in their work. Data collection and management of nutrition, soil, and microclimate parameters on a smart urban farm are performed automatically using special software and hardware complexes (He, Fu, Fang, Sun, Suo, Li, Zhao, Yang, Li, 2022).

However, a high level of automation not only makes it easier to run a business, but also significantly reduces the level of requirements for the competencies of the people who do it. Reducing the bar of professional requirements and the complexity of doing business creates conditions for an increase in the number of urban farms. At the same time, problematic situations that require prompt and competent intervention by specialists, often at the expert level, are not excluded on a smart farm. In particular, this is the occurrence of plant diseases or conditions for them. Such situations do not appear on a daily basis, however, they can critically affect the results of the city farm.

In these conditions, it is important to supplement the software and hardware complexes of smart farms with special systems and services that will help the farm staff in resolving such situations. The

[a] https://orcid.org/0000-0002-0683-6138
[b] https://orcid.org/0000-0002-4839-3064
[c] https://orcid.org/0009-0002-6555-0882
[d] https://orcid.org/0009-0000-1267-5783

experience in creating such systems using artificial intelligence (AI) technologies and methods is already existed in agro engineering.

For example, deep neural networks (DNN), which work as part of video surveillance systems, have already shown their effectiveness in detecting and recognizing plant diseases and pests (Bhujel, Kim, Arulmozhi, Basak, Kim, 2022; Hashan, Islam, Avinash, 2022; Quiroz, Alférez, 2020).

However, when detecting a problem, neural networks do not offer answers to the questions "What and how to do?" to fix this problem. At the next stages of the development of these technologies, the fact of detecting a disease or any other problematic situation needs to be supplemented with the conclusion of decisions about what to do in this situation. Thus, there is an urgent prospect of creating specialized decision support systems for smart farm personnel (SmartFarm DSS).

In this paper, we propose the SmartFarm DSS framework, which combines computer vision neural network technologies and the well-known case-based reasoning (CBR) method in the field of AI to output solutions in problem situations. In our study, experiments were conducted with neural network models to detect diseases of strawberry berries from images of berry bushes grown on an urban farm. In the SmartFarm DSS framework, the process of detecting and recognizing berry diseases is complemented by the collection of data on the microclimate and nutrition of plants. On this basis, a vector of representation of the situation is created, which is used to find analogues in the situational knowledge base. In the same database, solutions recommended for given examples of situations are stored, which will be given to the user.

2 METHOD AND MATERIALS

For prompt decision-making in case of a problematic situation, it is advisable to use the Case-based reasoning method (Aamodt, Plaza, 2001). The CBR method implies creating a database of cases (knowledge base - KB) in the form of <Situation (Sit), Solution (Sol)> pairs, where Sit is the key to finding solutions Sol. When a new Sit_{act} problem situation arises, it is compared with those known in the Sit knowledge base according to the specified rules and criteria. As a result, one Sit* or several {Sit*} situations are retrieved, whose solutions will be recommended to the user. Thus, the decision-making process includes the following steps:

- Identification of the Sit_{act} and the formation of its formal representation;
- Retrieving from the knowledge base of one Sit* or several {Sit*} situations;
- Solution output Sol* ⇔ Sit* or the output of an ordered subset of solutions {Sol*} ⇔ {Sit*}.

When new situations arise for which there are no close analogues in the knowledge base, solutions from a subset of the closest {Sol*} can be used to develop a new solution. After the necessary assessment, a new case with this situation and its solution can be entered into the knowledge base.

In our work, to form a formal representation of the situation, we use the concept of a complex technological object (Glukhikh, Glukhikh, 2021). To characterize each element of a complex object, a vector is used in its parameter space. Bringing these parameters to a general form by moving into the state space, by discretizing or categorizing parameters, allows you to introduce a set of uniform vectors X1, X2, X3, ..., the concatenation of which is a representation of the current situation on a complex object: X = Concat (X1, X2, X3, ...).

Thus, it becomes possible to search the knowledge base both for vector X and for any of its parts X_i.

The following elements of a complex object are highlighted in the basic version of the framework:

- A cultivated products. The representation vector of this element X1 is formed at the output of the neural network for disease detection as $X_1 = Round_H(Sigmoid(F_W(I)))$, where I – input form, tensor with photo images of the cultivated crop; F_W – a trained neural network model for disease detection and recognition; Sigmoid – activation function on the output units of the neural network; $Round_H$ – the rounding function for a given threshold, which outputs "0" when the input level is less than the threshold H and "1" otherwise. Vector X_1 contains as many components as the classes of diseases the neural network is designed for. The components of the vector take a value from the set {0, 1}, where 1 in some position means a conclusion about the presence of the corresponding disease;
- A subsystems of microclimate and plant nutrition. They are represented by vectors X_2, X_3, respectively. The dimension of these vectors is determined by the number of controlled parameters and categories (ranges) for each of them. The incoming data, depending on its value, is converted into the appropriate category (range), which is encoded by its vector component. Thus, the components of these vectors also take values from the set {0, 1}.

For the tasks of detecting and recognizing plant diseases, the work uses pre-trained models of the YOLOv8 family from the Ultralitics developer (Terven, Cordova-Esparza, 2023). It is a complex of modern models based on a common architecture and algorithms that are designed for image and video processing tasks. We are talking about such computer vision tasks as classification, detection (localization of objects in the image and determination of their class), and segmentation (outlining found objects in the image). Accordingly, the developers have provided classes of models YOLOv8-cls, YOLOv8, YOLOv8-seg, each of which has options that vary in complexity and number of parameters. For the tasks of detecting and recognizing diseases of plants (strawberries), we used the YOLOv8s detection model.

To solve the applied problem of detecting diseases of strawberry berries, the YOLOv8s model was further trained on new data. For this purpose, a dataset was assembled, it included well-known examples of images with diseases (Afzaal, Bhattarai, Pandeya, Lee, 2021), supplemented with their own images of strawberry bushes. Own images were obtained from the cultivation modules on a vertical urban farm, which was created on the basis of the agrobiotechnical complex of Tyumen State University. In this work, neural network models were further trained to detect such common diseases of strawberries as angular leaf spot, leaf spot, anthracnose fruit rot, gray mold and powdery mildew fruit.

3 RESULTS

The architecture of the proposed framework is shown in Figure 1. In the knowledge base, the <Sit, Sol> pairs are represented by detailed structures, where the Sit part includes such components as "Disease", "Microclimate conditions", "Nutrition conditions". Each of the components contains a descriptive characteristic and a vector representation for the ability to search and extract on request from the retriever block. The Sol part consists of components such as "Medicines", "Treatment Regimen", "Reference data", as well as additional materials (expert recommendations, regulatory documents, links to additional information resources, etc.).

The KB provides for the inclusion of two types of cases. The first is typical situations that are set by experts at the stage of initial filling of the KB. They contain information about diseases and conditions of their possible occurrence, which are represented by specified sub-ranges of parameters. The second type of cases is examples from practice, which are a special case of generalized situations with specific parameter values. To store and extract additional reference data, maintain statistics on diseases or other undesirable events, as well as to generate reports, interaction with the accounting system module with its own database is additionally provided (not shown in the figure).

When implementing this architecture, the following main modes can be distinguished in the work of DSS:

- The Product monitoring mode. In this mode, images from a controlled space (a site for growing products on a smart farm) are received at the input of the computer vision (CV) module with set time discreteness. The images are processed by the neural networks of the CV module, when an undesirable event is detected – plant diseases, they are classified and, together with the identifier of the location of the bush, are transmitted further to form a description of the situation. The retriever block generates a query to the knowledge base to extract relevant cases. In the initial case, only information about the detected disease (vector X_1) is used for this;

- The Parameter monitoring mode. In this mode, the values of the microclimate parameters (temperature, humidity, carbon dioxide level, lighting power) and nutrition (solution temperature, acidity, composition, watering frequency) are monitored with set time discreteness. Vectorizers convert incoming data into vectors X_2, X_3, which are used to find matches in the database. To calculate the matches, a character–by–character comparison of the input vector with the corresponding vectors in the case structure is used and a selection is made according to the criterion $n/N \rightarrow Max$, where n is the number of matching positions in the vectors, N is their dimension. If the specified threshold is exceeded, the corresponding case is displayed to the user indicating the risk of developing a disease that meets these conditions. The threshold value can be set individually in relation to certain diseases and is stored in the reference data of the case. Significant parameters can also be set here, which are taken into account when calculating the number n. This mode allows you to explore the possibility of diseases. If the existing conditions (climate and/or nutrition) coincide with the conditions of the occurrence of diseases, a corresponding message is generated to the user and other recipients (for example, farm owners). Since plant disease does not occur immediately even when favorable conditions appear for it, this mode allows you to take measures in advance to change these conditions (climate and nutrition parameters) and eliminate the threat of disease;

- The Question-and-Answer mode. This mode allows the user to search for information about diseases, drugs and other data in the database, which is performed using the search query form in the system interface and full-text search mechanisms in the knowledge base.

The proposed architecture has been tested in the implementation of the DSS software prototype. The software implementation is made using the Python programming language and the Flask framework for creating software applications, the CV module is developed using the Ultralitics libraries, as well as TensorFlow and Keras. Additional training of neural network models was performed in the Google Collaboratory environment. The knowledge base consists of json-files stored on disk. To work with them, modules for querying, reading and editing these files have been created, which are implemented using the Json library.

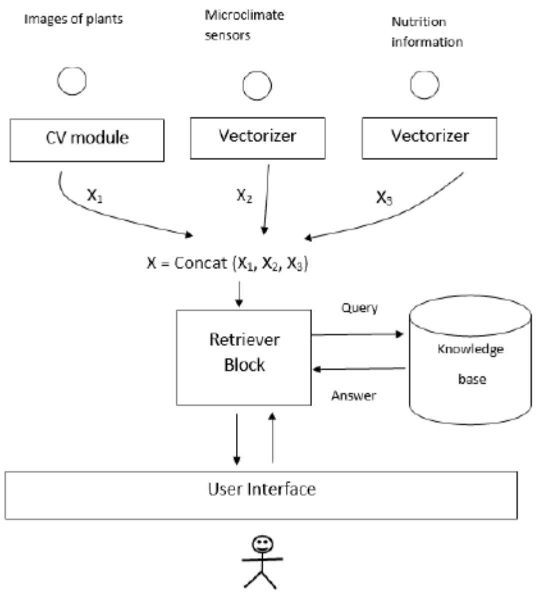


Figure 1: SmartFarm DSS framework.

Depending on the mode ("Monitoring", "Parameter Control", "Questions and Answers"), the retriever generates a request to the desired segment of the knowledge base to extract the cases closest to the request. The cases consist of two parts – Sit (characterization of the problem situation) and Sol (components of the solution to eliminate the problem).

4 DISCUSSION AND CONCLUSION

The proposed architecture can be implemented by various development tools and has scaling capabilities. In particular, the functionality of the CV module can be expanded. In addition to detecting berry diseases, another urgent task will be the detection and recognition of insect pests, models of artificial neural networks of computer vision can also be used to solve it (Peng, Wang, 2022; Li, Zheng, Yang, Li, Sun, Yang, 2021).

Another type of task is related to making business decisions. Thus, the task of assessing the volume and quality of the harvest of products based on observations of the state of cultivated crops is relevant for business (Rizzo, Marcuzzo, Zangari, Gasparetto, Albarelli, 2023; Cho, Kim, Jung, Park, Na, Ihn, Kim, 2023). In terms of machine learning, this task is also formulated as a classification task and is solved using neural network models that will classify berries by degree of maturity and by degree of condition (compliance with product requirements).

The integration of such tasks into a single complex is becoming a promising direction for the creation of intelligent decision support systems at smart farm enterprises (Abbasi, Martinez, Ahmad, 2023). The peculiarity of the framework presented in this work is that it offers an architecture and methodology for creating such DSS, which combines methods of deep learning and knowledge engineering, in particular, the case-based reasoning method effective for decision derivation (Raja, Siddharth, Yuvaraj, Kumar, 2023). This allows us to move from the use of neural networks for the detection and recognition of plant diseases to the next stage of the activity of an agrotechnologist on a smart farm – making decisions to eliminate detected diseases.

This paper does not address the issues of improving the human-machine dialogue in the process of decision-making discussions or when working with DSS in the "Question-Answer" mode. A promising direction for further research and improvement of the proposed architecture is the use of large linguistic models with retrieval augmented generation (RAG) technology (Raja, Siddharth, Yuvaraj, Kumar, 2023; Guo, Qiu, Leroy, Wang, Cohen, 2024). This will expand the capabilities of DSS in question-answer mode, search for additional information and advice users when problem situations are detected. In this regard, we also plan to explore the implementation of the knowledge base using modern vector database technologies, where are used the representation of texts with vectors and mechanisms for semantic search and retrieval of texts (answers to questions) based on vector comparison (Taipalus, 2024).

REFERENCES

Virk, A.L., Noor, M.A., Fiaz, S., Hussain, S., Hussain, H.A., Rehman, M., Ahsan, M., Ma, W., 2020. Smart Farming: An Overview. Smart Village Technology.

Modeling and Optimization in Science and Technologies.
He, L., Fu, L., Fang, W., Sun, X., Suo, R., Li, G., Zhao, G., Yang, R., Li, R., 2022. IoT-based urban agriculture container farm design and implementation for localized produce supply. *Computers and Electronics in Agriculture.*
Bhujel, A., Kim, N.-E., Arulmozhi, E., Basak, J.K., Kim, H.-T., 2022. A Lightweight Attention-Based Convolutional Neural Networks for Tomato Leaf Disease Classification. *Agriculture.*
Hashan, A.M., Islam, R.M.R.U., Avinash, K., 2022. Apple Leaf Disease Classification Using Image Dataset: a Multilayer Convolutional Neural Network Approach. *Informatics and Automation.*
Quiroz, I.A., Alférez, G.H., 2020. Image recognition of Legacy blueberries in a Chilean smart farm through deep learning. *Computers and Electronics in Agriculture.*
Aamodt, A., Plaza, E., 2001. Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches. AI Communications.
Glukhikh, I., Glukhikh, D., 2021. Case-Based Reasoning with an Artificial Neural Network for Decision Support in Situations at Complex Technological Objects of Urban Infrastructure. Applied System Innovation.
Terven, J., Cordova-Esparza, D., 2023. A Comprehensive Review of YOLO: From YOLOv1 and Beyond.
Afzaal, U., Bhattarai, B., Pandeya, Y.R., Lee, J., 2021. An Instance Segmentation Model for Strawberry Diseases Based on Mask R-CNN. Sensors.
Peng, Y., Wang, Y., 2022. CNN and transformer framework for insect pest classification. *Ecological Informatics.*
Li, W., Zheng, T., Yang, Z., Li, M., Sun, C., Yang, X., 2021. Classification and detection of insects from field images using deep learning for smart pest management: A systematic review. *Ecological Informatics.*
Rizzo, M., Marcuzzo, M., Zangari, A., Gasparetto, A., Albarelli, A., 2023. Fruit ripeness classification: A survey. *Artificial Intelligence in Agriculture.*
Cho, S., Kim, T., Jung, D.-H., Park, S.H., Na, Y., Ihn, Y.S., Kim, K., 2023. Plant growth information measurement based on object detection and image fusion using a smart farm robot. *Computers and Electronics in Agriculture.*
Abbasi, R., Martinez, P., Ahmad, R., 2023. Crop diagnostic system: A robust disease detection and management system for leafy green crops grown in an aquaponics facility. *Artificial Intelligence in Agriculture.*
Raja, K.V., Siddharth, R., Yuvaraj, S., Kumar, K.A.R., 2023. An Artificial Intelligence based automated case-based reasoning (CBR) system for severity investigation and root-cause analysis of road accidents – Comparative analysis with the predictions of ChatGPT. *Journal of Engineering Research.*
Guo, Y., Qiu, W., Leroy, G., Wang, S., Cohen, T., 2024. Retrieval augmentation of large language models for lay language generation. *Journal of Biomedical Informatics.*
Taipalus, T., 2024. Vector database management systems: Fundamental concepts, use-cases, and current challenges. *Cognitive Systems Research.*

Continuum of Cities in the Integrative Space of Green Economy

Lyudmila Medvedeva[1,2][a], Vasily Kostin[1][b], Alina Gorbunova[1][c], Sergey Parshev[1][d] and Andrey Fedorov[3][e]

[1]*Volgograd state technical University, Volgograd, Russian Federation*

[2]*All-Russian Research Institute for Hydraulic Engineering and Land Reclamation* them A.N. Kostyakov, *Volgograd, Russian Federation*

[3]*Kotelnikovo, Volgograd region. Russian Federation*

milena.medvedeva2012@ya.ru, vek@volpi.ru alinavictory@mail. ru, Savarg@yandex.ru, kgp.volganet@mail.ru

Keywords: Space-time continuum, small towns, economic and mathematical modeling, rural areas, investments, development potential.

Abstract: Small towns constitute the framework of rural areas and play an important role in development of the green economy. Proximity to agricultural production and natural resources make them the “engine” for applying of green technologies. However, a significant part of Russian small towns continues to be in a depressed state because of the imperfect legislation, weakness of local authorities, and lack of necessary investments. The mathematical tools and the construction of a three-dimensional matrix made it possible to determine the competitive status of a small town, optimize investment flows. It was shown that involvement of personalized triggers increased the significance of small towns at the regional level. The strategies developed by the government should create conditions for the development of green and smart cities on the platform of small towns, ensure their interaction with megacities and rural settlements. Small towns located in rural areas have a special space-time continuum, consolidated society and personalized responsibility of the authorities. The green economy should be developed in the following vector: small towns - innovation - production. The purpose of the study was to substantiate the space-time continuum of small towns, increase their competitive status in development of smart and green technologies and attraction of investments.

1 INTRODUCTION

A small town is a temporary form of existence of Homo sapiens or a historically established form of social life with its own laws of existence. It is not easy to determine the place of a small town in the development of the national green economy. There are two approaches in the science. The first one is fundamental. It determines the main approaches to investigation of an object. The second approach is practical. It offers specific solutions in the field of green technologies (Strategies, Zubarevich, 2019, Ovchinnikov, 2023).

Academic economist Louis Wirth believed that “there was no reason to characterize a city based on its size (population number)”, and that it was necessary to introduce “other characteristics, for example: building density, social inhomogeneity of individuals” (Wirt, 1969). Since the first mentions of aggregated settlements “on well-habitable lands” in the 1st millennium B.C., small towns, like other organizational forms, have gone through a rather complex path in its development. With each new formation, ideas about a city and processes taking place in it expanded, but all attempts to find a unified approach to city development were unavailing.

Scientific theories of cities based on the “iron will of the sovereign” (E. Meyer), guild agreement (O.

[a] https://orcid.org/0000-0002-3650-2083
[b] https://orcid.org/0000-0002-2959-5039
[c] https://orcid.org/0009-0000-3705-9071
[d] https://orcid.org/0009-0005-7570-6459
[e] https://orcid.org/0000-0002-8935-7780

Gierke), military function, development of trade routes, did not reveal the whole essence of the occurring changes (Medvedeva, 2019). According to the UN methodology, cities are the settlements with a population number more than 20 thousand people. According to Russian legislation, a city is a settlement accounting 12 thousand residents not engaged in agricultural activities. According to the typology proposed by E. Pertsik, cities are divided depending on five main characteristics: economical-geographical location, dominant economic function, degree of participation in the territorial division of labor, architectural concept, and genesis of development (Pertsik, 1999).

At the first sight, a meta-analysis of the research literature confirms the conclusion that a small town is an intermediate link between megacities and rural areas, and it "seems to be invisible" in the economic space (Chernysh, Markin, 2021). Undoubtedly, the number of population and area of a small town is fewer. Small towns are functionally uniform. However, if you look at the map of the Europe, you will notice that it is completely covered with a network of small towns located in rural areas, at the crossings of transport and trade routes. On the one hand, small towns are characterized by decline in economic life and outflow of population. However, on the other hand, many of them have managed to find their niche, diversify the economy, take a strong place in local and tourist markets, and enter the general mainstream of green economy development (Smirnov, Bezverbny, 2022).

Most of Russia's small towns continue to stagnate. The reason of this is the imperfection of federal legislation, which determines the conditions for economic activity and management, and does not make the economy attractive for investments. In the 90s of the 20th century, the Ministry of Regional Development introduced a criterion for the number of population in small towns - 50 thousands. With the years, taking into account the demographic situation, in a number of regions this threshold was exceeded. Now small provincial towns are considered as settlements with a population number of 100 thousand people.

Administrative and territorial transformations have always been more significant than demographic and migration ones. Sometimes, in the evening, a citizen was a resident of one province, and waking up in the morning, he found he was a citizen of another administrative-territorial unit. For some small towns such metamorphoses gave the greenlight to prosperity. At the same time, other towns leaved to survive for account of government "alms" (Uskova, Sekushina, 2021).

If we take into account that the green economy is a completely expected and integral stage in the development of human civilization, the interest in the processes occurring in different types of cities is quite predictable. In the last decade, in the number of the EU countries and in the USA, elderly people strongly look toward living in the large cities. On the contrary, families with children move to small suburban settlements associated with the rural way of life (Greenblatt, 2020, Catherine, 2022, Medvedev, Melikhov, Frolova, 2020).

The reason of this phenomenon is quite understandable: good roads and infrastructure, affordable healthcare and education, proximity to nature and better ecological situation give small towns a "greenlight" for a new life. Small towns increasingly become the centers of economic life in rural areas. Russian social-political discourse regarding small towns comes down to two positions:

- small towns are the most important elements in spatial development, with governmental goal- setting;
- small towns are the points of stagnation and unreasonable budget spending, with a predetermined destiny "to disappear from the map of Russia."

To propose vectors for the development of small towns, it is necessary to have an idea of their place in the national economy. In terms of population, small towns are settlements with a population of up to 50 thousand people, with a unidirectional economic profile. In terms of population density, small towns are settlements without clear determination - from 0.3 to 173.1 people per unit of area. In terms of specialization, small towns are one factory towns, scientific towns, closed administrative towns, historical and cultural centers (Ovchinnikov, 2023). In foreign publications, the term of "shrinking city" is used in relation to small towns. It emphasizes their strong dependence on large cities (Uskova, Sekushina, 2021).

Small towns have its own advantages: live communication with nature, well-established communication links, "calm" lifestyle, an established mental and cultural way of life, which can be described as the "Russian spirit". Common problems of small towns include: low level of competitiveness, technological underdevelopment of production, unfavorable demographic situation, outdated housing resources, deterioration of engineering infrastructure and transport network, problems with the availability of high-quality medical and educational services. Introduction of digital technologies allowed to smooth some problems in small towns. Development of marketplaces made it possible to saturate the market with goods and services. Local authorities have begun to show interest in concepts focused on the introduction of green and smart technologies. A smart city is considered as a management entity directed on complex of decisions for promotion of digital technologies. It is not difficult to identify a system of global challenges caused by the emergence of a Smart city and of the course towards a Human Smart city (.Ledneva, 2019, Sizov, Plotnikov, 2023). At his time, T. Bakici determined a smart city as a high-tech and intensively developing city integrating people, information and urban infrastructure for creation of competitive economy through the use of new technologies. Introduction of digital technologies allowed to develop models - Smart Cities 1.0, 2.0 and 3.0. In smart cities, population should be provided with the very services that are highly-demanded. Also, smart city should give equal opportunities for everyone.

The purpose of the study was to substantiate the space-time continuum of small towns, increase their competitive status in the development of smart and green technologies and attraction of investments.

2 MATERIALS AND METHODS

The research methodology was created on the base of academic papers of Russian and foreign scientists and the author's long-term observations. The competitive status of a small town in the development of a green economy is calculated using international (EUROPOLIS Database, Large Cities Statistical Project, Structural Change of the European City System) and Russian (Urban Environment Quality Index) methods (Ledneva, 2019).

The economy of a small town, as a complex of potentials, can be represented by calculated indicators. The trajectory of small towns development can be described by formulas (Sizov, Plotnikov, 2023). Let's denote: $\boldsymbol{S_i}(t)$ – a property characterizing the i -th indicator of the potential of a small town in the t -th given period of time. The total number of such properties is N, i.e. $i \in N$. Let's denote: $U_k(S_j(t)), j \in M_k \subset N, k \in K$ - the value of the *k-th* indicator characterizing the current state of the potential of a small town, and U_k^F - its target value. We use assessment of potential as indicators. In the first case: $U_k(S_j(t)) \equiv S_j(t)$; in the second case to form $U_k(S_j(t))$ we use properties belonging to the multitude M_k consisting of a set of indicators (indices) N. The strategy that determines the development of a small city is associated with attracting investment in the projects (Siptits, 2007):

$$\nu_\theta(R_\theta(t)) \Rightarrow \begin{pmatrix} \varphi_1^\theta(R(t)) \\ \varphi_2^\theta(R(t)) \\ \cdots \\ \varphi_j^\theta(R(t)) \\ \varphi_{n_\theta}^\theta(R(t)) \end{pmatrix}, \theta \in \Pi, j = [1, n_\theta] \quad (1)$$

where $\nu_\theta(R_\theta(t))$ is the vector-function of the θ-th investment project,

P – total number of investment projects,

$\varphi_j^\theta(R(t))$ – change of j - index of small-town potential as a consequence of the implementation of *the* θ -th investment project,

n_θ– the number of indicators of the potential of a small city that are influenced by N - th investment project. The efficiency obtained from the implementation of an investment project can be written by a system of equations:

$$S_i(t+1) = S_i(t) + G_i(S_m(t)) + \sum_{\theta=1}^{\Pi} \varphi_i^\theta(R(t)), m \in M, \subset N, i \in N \quad (2)$$

$$S_i(0) = S_{i0}$$

Change of the value of the i -th indicator of potential is a consequence of two interrelated reasons: self-development of the system $G_i(S_m(t))$ and controlling influence of the project $\sum_{\theta=1}^{\Pi} \varphi_i^\theta(R(t))$(Siptits, 2007, Rogachev, 2022).

Investments for the implementation of the projects can be obtained from public and private sources. To increase investment potential, it becomes advisable to distribute cash flows within the city (Sizov, 2022).

Organizations registered in the tax authorities of a small town and in nearby rural areas are divided into groups:

X_0 – industrial and agricultural;

X_1 - fund-creating;

X_2 – consumer.

The capabilities of each group are specified in the form of linearly homogeneous production functions:

$$Xi = Fi\ (Ki, Li), \quad (3)$$

where i is the index of the group of organizations, i = 0, 1, 2;

Xi – output of products and services by the *i-th* group of organizations;

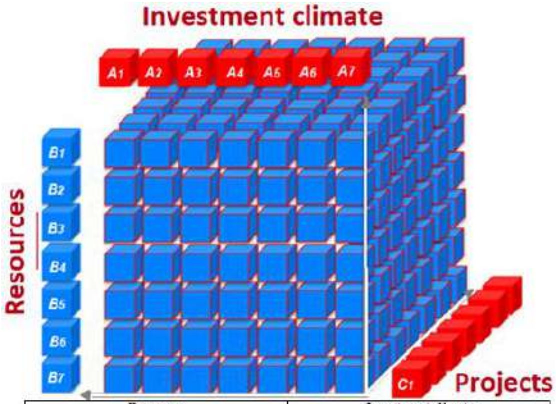
Ii – investments in the *i-th* group of organizations;

Li – number of employees in the *i-th* group of organizations;

Ki – basic production assets.

The following assumptions were made for constructing the mathematical model: the technological structure does not change; labor resources L change with production growth;

investment lag is absent; wear coefficients of basic production assets – μ_i, direct material costs a_i are conditionally constant (Figure 1).



Resources	Investment climate
B_1 – Markets (economic complexes)	A_1 – Spatial development
B_2 – Institutions of power	A_2 – Investment development
B_3 – Human capital	A_3 – Smart Economy
B_4 – Innovation and information	A_4 – Agricultural development
B_5 – Natural resources	A_5 – Development of industries
B_6 – Territories	A_6 – Development of land reclamation
B_7 – Investments and financial capital	A_7 – Development of housing and communal services, roadsnt of land reclamation
Investment projects	
C_1 – C1 – Improvement project	
C_2 – Housing construction	
C_3 – SME Infrastructure	
C_4 – Transport Park	
C_5 – Construction of a stadium	
C_6 – Construction of an irrigation system	
C_7 – Shopping complex	

Figure 1: Scheme of investment flows in the economy of a small city.

Using *the Statistica 13* program, the efficiency indicators of investment flows were calculated for an urban settlement - the small town of Kotelnikovo, the Volgograd region. Calculations are shown that it is reasonable to direct 28% of investments to the industrial-agrarian group, 45% to the fund-forming group, and 27% to the consumer group. Such distribution will ensure economic growth of 3.1%.

The system reflects the basic idea - the participation of a small town in interregional and global competition.

3 RESEARCH RESULTS

Small town management aims to increase competitiveness of the industry branches in the green economy. The level of competitiveness can be determined by the means of three-dimensional matrix. Each strategic goal is represented in resources, institutional foundations, and priority projects. The key factors of a "green strategy" used to choose a city model are related to team formation, development of the strategy, and responsibility for the result (Figure 2,3).

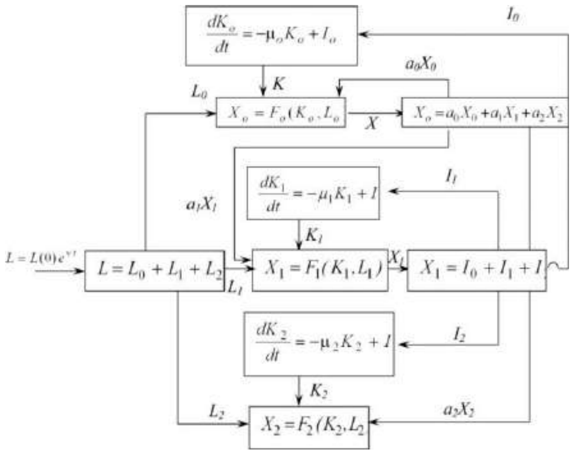


Figure 2: Matrix of three-dimensional projection of the development of a small city along the green economy vector.

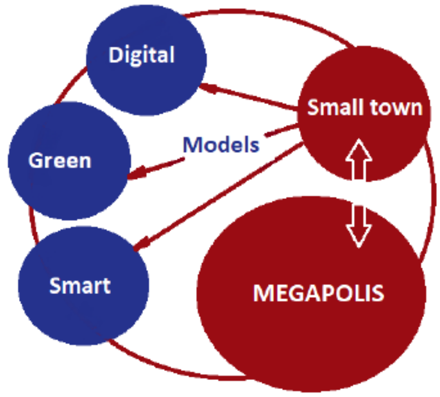


Figure 3: Selection of a small city model based on its competitiveness.

On January 1, 2022, the Volgograd region consisted of 466 municipal structures, including 32 municipal districts and 399 rural settlements. The total number of populations was 2 449 781 people. Population density was 21.70 people per km^2. The proportion of urban population was 78.59%.

The urban-type settlement of Kotelnikovo is the small town of the Volgograd region. The economy of Kotelnikovo is on the rise (Kotelnikovo, 2024).

The town-forming enterprise is PJSC EuroChem - VolgaKaliy. The enterprise is engaged in the extraction and production of mineral fertilizers. It is planned to construct a greenhouse complex, a brick factory, an auto sales dealership, a hotel complex, and a stadium.

Dynamics of development of a small town in Figures 4.

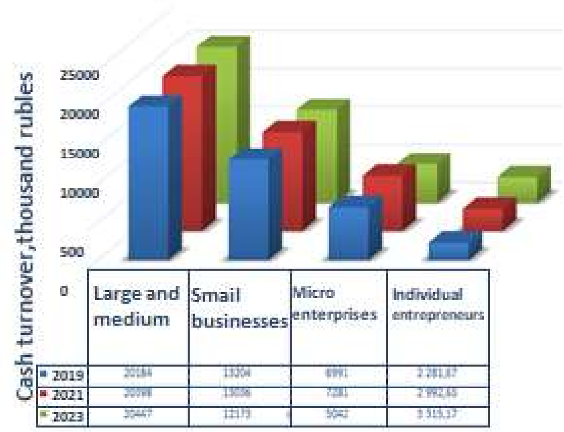


Figure 4: Dynamics of economic development of the urban settlement of Kotelnikovo, Volgograd region.

The strategic goal is to enter the green economy by improving the quality of life of every local resident. The successive implementation of the tasks allowed to attract investments amounting 103 million rubles for the project "Upgrading of the Aksayskaya Dubrava Park". EuroChem -VolgaKaliy LLC was the co-investor (Figure 5).

Figure 5: Project "Aksai oak grove", Kotelnikovo.

When predicting the space-time continuum of small cities on the green economy site, it is necessary to take into account the territorial division of labor and natural and climatic conditions (Sullivan, Ryser, Halseth, 2014, Veselova, Khatskelevich, Ezhova, 2018, Alverti, Themistocleous, 2018 Oliveira, 2019). Table 1 and Figure 6 show the proposed specialization of municipal districts of the Volgograd region of Russia.

Table 1: The direction of development of small towns located in rural areas of the Volgograd region.

Natural area	*Focus*	*Efficiency*	*Priority*
Steppe zone	Grain production, livestock farming	Profitability ≈ 60%	Economic diversification
Dry steppe zone with dark chestnut and chestnut soils	Grain production, meat – dairy farming, vegetable growing, fruit growing	Profitability ≈ 10 - 50%	Irrigated agriculture, raw material processing, services
Semi-desert zone	Irrigated grain production, beef cattle breeding, sheep breeding	Profitability ≈ 15 - 25%	Irrigated agriculture, raw material processing, services

Figure 6: Map of the functional potential of the Volgograd region according to the priorities for the development of the green economy.

Dedicated municipal areas:

- The first group is areas with a multifunctional economy, favorable conditions for the development of agriculture and processing of raw materials: Gorodishchensky, Kalachevsky, Svetloyarsky, Sredneakhtubinsky:

- The second group is areas with socio-demographic restrictions in the development of agriculture and processing of raw materials:

Danilovsky, Zhirnovsky, Rudnyansky, Elansky, Kotovsky;

- The third group is areas with favorable socio-economic conditions and high agricultural specialization: Alekseevsky, Kikvidzensky, Kletsky, Novoanninsky, Uryupinsky;

- The fourth group is areas with a stable socio-demographic situation and potential for production development: Mikhailovsky, Frolovsky, Ilovlinsky and Olkhovsky;

- The fifth group is areas with socio-demographic restrictions in the development of agriculture and an average level of processing of raw materials: Surovikinsky, Chernyshkovsky;

- The sixth group is areas with restrictions in agricultural production and potential for the development of production and mining: Kotelnikovsky, Oktyabrsky;

- The seventh group is areas with natural and climatic restrictions, with average potential for irrigated agriculture: Palassovsky, Staropoltavsky.

4 CONCLUSIONS

Small towns play an important role in the development of the national economy. A significant part of small towns continues to be in a depressed state. The reasons of this situation are systemic. They depend on both external (the imperfect legislation) and internal (lack of investments) factors. The discussed draft law “On the General Principles of Local Self-government Organizing in the Integrated System of Public Authority” offers to replace the existing management system with a three-level one: district - region - federation. So it removes small towns from the strategic space of the country in general. It is necessary to understand that small towns allow to diversify the economy of rural areas and to saturate local markets with high quality products and services.

REFERENCES

Strategies for spatial development of the Russian Federation for the period until 2025.” – URL: https://docs.cntd.ru (date of access: 17.03.2024).

Zubarevich, N., 2019. Spatial development strategy: priorities and tools. *Economic Issues.* V. 1. pp. 135 - 145.

Ovchinnikov, O., 2023. Development of small cities in Russia: problems and solutions. *Development of territories*. V. 4. pp. 85 -97.

Wirt, L., 1969. Urbanism, as a way of life. In. R. Sennet. Appleton Century Grofts New York.

Medvedeva, L., 2019. Strategic consortium: “green” and “smart” cities - the future of Russia. *Trends and development prospects.*

Pertsik, E., 1999. Cities of the world: Geography of world urbanization. *International relations.*

Chernysh, F., Markin, V., 2021. Ttowns of Russia: new challenges, social problems and prospects. FNISC RAS.

Smirnov, O., Bezverbny, V., 2022. Development potential of sectors of the economy of small towns in Russia: modern trends. *Society and power,* V. 1. pp. 62 -74.

Uskova, T., Sekushina, I., 2021. Strategic priorities for the development of small and medium-sized cities. *Economic and social changes: facts, trends, forecast,* V. 14. pp. 56 - 70.

Greenblatt, A., 2020. Wired country: With the right investments in technology, rural communities could use this moment to remake their futures. One small town shows how. *Government Technology.* V. 33. pp. 30-37.

Catherine, W., 2022. Economic Development of Small Towns and Rural Areas: A Case Study of Success Strategies. SPNHA Review.

Medvedev, A., Melikhov, V., Frolova, M., 2020. World development actors - green and smart middle cities. Human and Technological Progress Towards the Socio-Economic Paradigm of the Future. Economics and Law. Berlin.

Ledneva, O., 2019. Adapted system of indicators for assessing the sustainability of small-town development for the UN sustainable development goals. *Economics and Entrepreneurship.* V. 12. pp. 521-526.

Sizov, Yu.., Plotnikov, A., 2023. Factorial and economic-mathematical assessment of the labor potential of rural areas. *Scientific works of the VEO of Russia.* V. 244. pp. 277-301.

Siptits, S., 2007. Mathematical model of sustainable development of rural areas. Nikon readings.

Rogachev, A., 2022. Using cognitive and economic-mathematical modeling to assess the spatial and economic potential of rural areas and small towns. *Drucker Bulletin*/ V. 4. pp. 190-205.

Sizov, Yu., 2022. Using cognitive mathematical apparatus to determine the continuum of small cities. *Scientific works of VEO.* V. 238. pp. 294-317.

Sullivan, L., Ryser, L., Halseth, G., 2014. Recognizing change, recognizing rural: The new rural economy and towards a new model of rural service. *Journal of Rural and Community Development.* V. 9. pp. 219 - 245.

Official website of the Administration of the urban settlement of Kotelnikovo. – Access mode: https://akgp.ru/ (date of access: 03.04.2024).

Veselova, A., Khatskelevich, A., Ezhova, L., 2018. Prospects for creating “smart cities” in Russia: systematization of problems and directions for their solution. Bulletin of Perm University. V. 13. pp. 75-86.

Alverti, M., Themistocleous, K., 2018. Human Centric Approach on the Analysis of the Smart City Concept: the case study of the Limassol city in Cyprus, Adv. Geosci. V. 45. pp. 305 -320.

Oliveira, A., 2019. Human Smart Cities. A Vision for world-wide Urban Living Lab collaboration. .

Meta-Industrial Spaces: Conceptual Model for Sustainable Development within the Virtual Environment

Kizilova Svetlana Anatolievna[a]
Moscow Architectural Institute (State Academy), 11/4 Rozhdestvenka st., 1-4, Moscow, Russian Federation
s.kizilova@markhi.ru

Keywords: virtual architecture, metaverse, conceptual model, sustainable architecture, prefabricated architecture

Abstract: The article focuses on the phenomenon of *meta-industrial space*: the multiple metaverses, which is gaining popularity due to the increase in digital interactions. The main philosophical approaches to understanding the phenomenon from the perspective of ontology are identified: *objective, semiotic,* and *componential*. Within the framework of epistemology, problems of reflection are considered: the problem of preserving architectural traditions, fixing and conserving historical heritage, testing the inclusion of new objects in the existing environment, the problem of regulating the amount of communications, drawing attention to environmental issues. Due to conceptual developments based on philosophical research, a new virtual sustainability is being formed in the field of metaverse architecture.

1 INTRODUCTION

The development of digital technologies and the increase in network interactions determines the emergence of the phenomenon of a virtual home as a separate category of architectural discourse.

The term *metaverse* first appeared in "Snow Crash" fiction novel by Neal Stephenson in 1992, and described a virtual reality in the form of a black spherical planet. The only road along which virtual housing is located, the Street, passes through the Metaverse for more than 65,536 km. By connecting to the Metaverse in the form of avatars, users can interact unlimitedly in cyberspace.

Interest in the term has increased with Mark Zuckerberg's Connect video presentation on October 28, 2021 announcing Meta's intention to create a digital universe for work, leisure and communication that can be accessed using virtual reality glasses (López-Díez, 2021).

Metaverse phenomenon researcher M. Ball gives the following definition for this term: "A large-scale interoperable network of three-dimensional virtual worlds, visualized in real time, in which a virtually unlimited number of simultaneous users can receive a synchronous and persistent experience with a sense of personal presence and with continuity of data, such as identity, history, rights, objects, communications and payments" (Ball, 2023). Unlike the Internet, which developed within scientific laboratories and the universities, the metaverse was originally founded as a method of commercial interactions aimed at collecting data, advertising, and selling virtual objects and real estate.

However, currently the metaverse is beginning to acquire a sociocultural meaning, in which the rules of new interactions in cyberspace are manifested, based on transparency, equality, accessibility and inclusivity (Zallio, Clarkson, 2022). According to O.N. Gurov (2022) the development of cultural values for the metaverse will allow the formation of a humane digital environment in the face of possible future technosphere and the anthroposphere confluence.

The metaverses pose a challenge through the emergence of new speculative architecture of virtual environments, for which requirements have not yet been imposed from the design perspective. The professional design community is currently on the cusp of developing these demands, which will require greater engagement so that the ideals for the created metaverse objects become humanistic rather than predominantly commercial (Rodkin, 2023).

This study is a continuation of scientific research on the topic of the formation of reserve space for

[a] https://orcid.org/0000-0001-5551-4162

human habitation, but in the meta-industrial digital era.

In the historical and genetic path of the reserve dwelling, characteristic stages can be traced (Kizilova, 2023), namely:

- Pre-industrial;
- Industrial;
- Post-industrial;
- Meta-industrial.

The structural code of the first three categories bore specific material features, but with the introduction of augmented and virtual reality tools, a transition to a radically new, meta-stage in the formation of a *home* concept that exists in a certain non-material space, within the pluralism of metauniverses, became possible.

Recent research in the field of home virtualization notes that the material component of the home will decrease, becoming a tiny capsule or prefabricated house, while the virtual component will prevail (Eftaxiopoulos, García, 2023).

2 META-SPACE AS A BASIS FOR CONCEPTUAL MODELING

Meta-space is the object of active design search in the field of architecture. In September 2023, the First Architectural Biennale took place, bringing together more than 60 virtual pavilions based on the Decentraland and W3rlds metaverse platform (Figure 1), where a variety of virtual pavilions from architectural studios and media artists were presented (Kuznetsova, 2023).

Figure 1: Architecture Biennale Presence of the Future. Source: https://archi.ru/russia/98985/sny-o-vselennoi?ysclid=lusr7f3uc1954729376.

Diverse in shape and structure, the pavilions are assembled within the framework of a fictitious digital master plan of the exhibition. Simultaneously with the representation of the brand of workshops in the digital space, the creators reflect on philosophical categories: the role of the architect in the formation of the metaverse, the ambiguity of the human mind, the “digital trace” of a person in virtual reality (Figure 2) and preserving the memory of civilization through the possibilities of digital technologies.

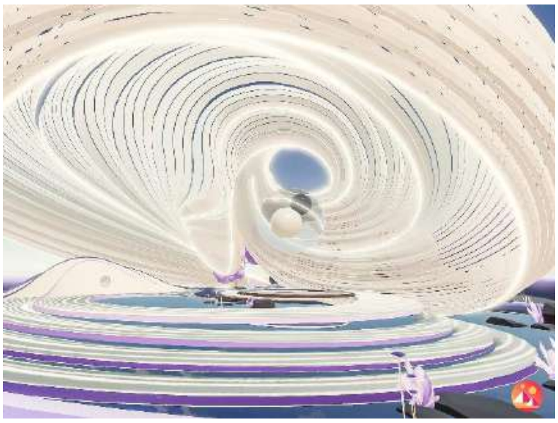


Figure 2: *Your Digital-Footprint*, pavilion by Mariana Cabugueira. Source: https://archi.ru/russia/98985/sny-o-vselennoi?ysclid=lusr7f3uc1954729376.

Among the exhibition sights, a pavilion symbolizing a virtual home was presented. Sintez Architects created the “Shelter” project: a virtual space that reproduces images from the memories of the past, where you can achieve total privacy in the digital environment.

3 THROUGH PHILOSOPHICAL REFLECTION TO PRACTICAL SOLUTIONS

The philosophical foundations of housing in virtual reality can be considered both from the ontological and epistemological point of view.

3.1 Ontological Approaches to the Formation of the Conceptual Space of the Metaverse

From the ontological perspective, the central question is the discourse about the nature of the virtual world and whether it is real, meaning the systems of hierarchies and interactions within it are significant.

Philosopher and theorist D. Chalmers states that value systems that are formed in a virtual context influence external systems in the external world, and for the human mind they are unambiguous (Chalmers, 2021).

From an ontological perspective, the phenomenon of meta-industrial housing has the following interpretations:

- Objective;
- Semiotic;
- Componential.

Within the framework of the objective interpretation, the metaverse appears as a certain form of reality generated by digital technologies. In the object-oriented ontology of G. Harman (2021), the phenomenon of meta-industrial housing can be considered as an object.

Continuing the line of the semiotic approach to understanding of the world (R. Barthes, J. Derrida, J. Baudrillard, Y.M. Lotman), a meta-industrial home can act as an image, a copy of a fragment of the real world. In a semiotic interpretation, a structuralist approach is possible. Since a significant part of the virtual space is represented by textual information or is associated with it, the phenomenon of meta-industrial housing can be considered as text. The pragmatic approach implies that behind the sign there is not only a text, but any object, reaction or impression. A fractal approach is also possible, meaning the sign and its representation are constantly changing and influence each other (Shaev, 2016).

The componential interpretation considers the metauniverse as a model, and meta-industrial housing as its component or an independent model.

Modeling allows not to produce copies of the existing objects and neither extrapolate certain trends into the future, but to simulate and test processes and events.

3.2 From Reflective Modeling in Meta-Space to Sustainability

Since the Metaverse turns out to be both an object of research and a tool of cognition (Segal, Kostikova, 2022), the processes of reflection of a new space from the viewpoint of the architecture philosophy become relevant.

A number of projects in the virtual space of metaverses are devoted to these problems.

3.2.1 Understanding the Accumulated Experience of Architecture

The problem of studying the acquired experience of world architecture in the absence of physical restrictions and fixed environmental characteristics is conceptualized in the space of metaverses.

Through the project of a villa located in a digital fluid landscape, the architect Luis Fernandez, together with MetaMundo, synthesized the experience of classical architecture, modernism and virtual reality. As physical characteristics such as humidity, lighting, and temperature become irrelevant, immersive experience and perception of form become important. The project architecture traces the approaches of Frank Lloyd Wright, Mies van der Rohe and the classic Greek order (Figure 3).

The problem of preserving the features of traditional house's architecture in a metauniverse is conceptualized in the Visual manifesto of Andrés Reisinger. The dwelling appears as a pure form, radically open to the surrounding context, but still using traditional construction techniques.

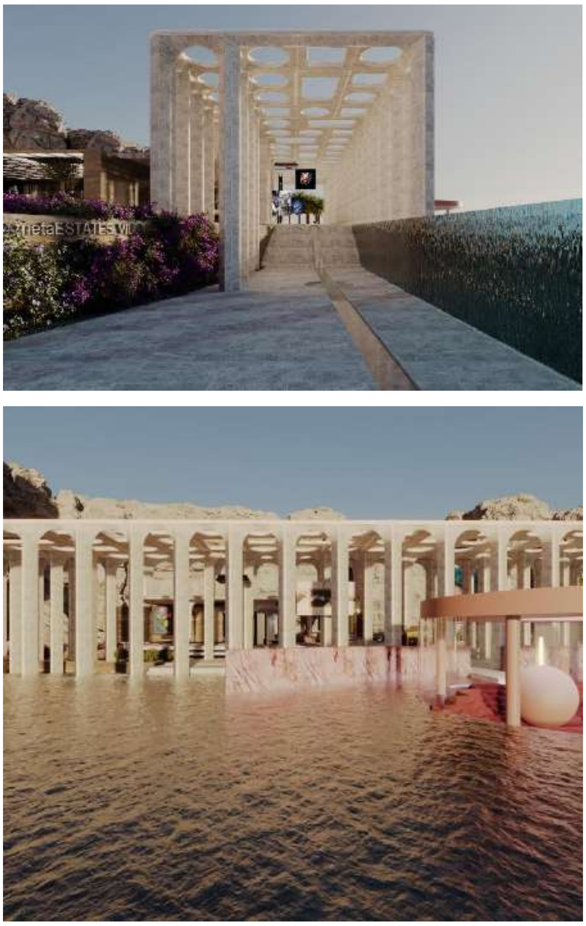


Figure 3: Virtual villa by L. Fernandez and MetaMundo. Source: https://www.archdaily.com/988739/metamundos-3d-nft-villa-opens-questions-about-the-function-of-architecture-in-the-metaverse.

3.2.2 Preservation of the Heritage of Traditional Architecture

The problem of recording lost architectural heritage can be solved by creating copies of historical material objects in hyperspace.

The landmark project of Japanese metabolic architecture, Kisho Kurokawa's Nakagin Tower, which was demolished in April 2022, was transferred into virtual space through digital archiving (Figure 4).

Figure 4: Digital twin of Nakagin Tower created by Gluon. Source: https://www.archdaily.com/986843/gluon-preserves-the-now-dismantled-nakagin-capsule-tower-building-in-the-metaverse.

Originally conceived as a metabolic structure with replaceable elements, the building gradually fell into disrepair due to problems with the water supply infrastructure. The replacement capsules were preserved as museum exhibits.

The Gluon company took more than 20 thousand photos and carried out laser scanning to create a 3D digital copy of the building. Thus, the tower received a digital twin. It is envisioned that users of the metaverse will be able to revisit the building as avatars in the virtual world (Florian, 2022).

Currently, models of the largest cities (Shanghai, London, Singapore, Rotterdam, Stockholm) including infrastructure are stored as digital twins. They represent more data than a typical 3D city model, including semantic data, real-time sensor data, physical models, and simulations (Ketzler et al., 2020). Digital twins will make it possible not only to preserve architectural heritage, but also to test the inclusion of new objects in the environment.

The SOLIDS project, developed by Francisco Alarcon (FAR), is designed in a similar way, where new inclusions of generative architecture are placed in the urban fabric at the level of virtual reality (Figure 5). Based on several dozen archetypes, the algorithm creates new high-rise and compact buildings, united by a common fantasy style, but unique depending on the location and responding to the existing landscape.

Figure 5: Projects of generative structures SOLIDS by FAR. Source: https://www.archdaily.com/990862/i-believe-that-architecture-is-never-finished-in-conversation-with-far-creator-of-the-first-generative-project-for-the-metaverse.

This leads to the next opportunity and current problem.

3.2.3 Communications in Virtual Space: Limitless Communication *vs* Isolation

Currently, virtual space is mostly considered as an information and communication environment in which processes of continuous cultural exchange occur (Saprykina, 2022). The problem of providing unlimited communication, which can be achieved in the virtual space of the metaverse, has both positive and negative sides.

In order to establish unlimited communications, the world's leading architectural studios are creating vast virtual spaces from individual buildings to urban planning concepts. Thus, Zaha Hadid Architects –

ZHA designed the cyber city *Liberland Metaverse* (Figure 6), in which urban self-government is encouraged, and users can buy sites and access them in the form of digital representations. The digital city was designed on a real site on the Danube river, which will allow, if necessary, to implement its physical analogue in the future.

In his interview with ArchDaily, P. Schumacher, head of ZHA, notes: "I predict a mixed reality and a cyber-urban fusion. If this is true, it is again important to design real and virtual spaces together, as a continuum" (Kolata, 2022). Liberland Metaverse is realized as a limitless space of opportunities and communications, "an open platform, based on freely circulating open source insights and technologies" (Stouhi, 2022).

Figure 6: Liberland Metaverse by Zaha Hadid Architects. Source: https://www.archdaily.com/978522/zaha-hadid-architects-designs-cyber-urban-metaverse-city.

As a counterpoint to the theme of unlimited communication, new virtual architecture concepts emerge in isolated, fantasy locations and contexts, where a rethinking of the material world's limitations takes place.

Thus, the *Mirage* house by architect Alexis Christodolou paints the image of an isolated villa in the desert, floating on a single support that looks deliberately unstable and detached. Andrés Reisinger's *Winter House* is set in a fantasy snow-covered landscape, offering an immersive experience of privacy and connection with nature.

3.2.4 Drawing Attention to Environmental Issues

By creating meta-industrial housing, attention is drawn to environmental problems and the adaptation of residential facilities to natural conditions.

The creators of the *Make Room for Us* project, Six N. Five, propose building a house as a biomorphic structure, adapting to the context, but to the virtual one, as a reminder of the fragility of the natural world (Figure 7).

Figure 7: Biomorphic dwelling that adapts to the landscape by Six N. Five. Source: https://www.archdaily.com/985957/daniel-arsham-and-andres-reisinger-among-acclaimed-designers-of-newly-launched-metaverse-real-estate-development.

4 DISCUSSION

As a result of the study, the following topical problems were identified that are being considered in the context of the functioning of metaverses:

- Rethinking and reflection of the world's architecture experience;
- Conservation of historical architectural heritage;
- Testing the inclusion of new objects in the real urban fabric;
- Regulation of communicative interactions within cyberspace;
- Drawing attention to real world environmental problems.

5 CONCLUSION

Within the space of metaverses, there is a gradual formation of new requirements for the construction of virtual architectural objects. The starting point for practical searches is the scope of existential philosophical questions: reflection on the surrounding reality and the attempts to overcome the limitations of the material world through the formation of virtual space. New conceptual models allow processes to be effectively tested and the actual environmental impact of construction to be minimized. The opportunities provided by the metaverse as a platform for experimental research correlate with the global strategy of sustainability, and therefore represent fertile ground for architectural research.

ACKNOWLEDGEMENTS

The research was supported by the Russian Science Foundation grant № 24-28-00960, https://rscf.ru/project/24-28-00960/ .

REFERENCES

López-Díez, J., 2021. Metaverse: Year One. Mark Zuckerberg's video keynote on Meta (October 2021) in the context of previous and prospective studies on metaverses. In *Pensar la Publicidad*. 15(2). pp. 299–303.

Ball, M. Metaverse: How it changes our world. Moscow: Alpina Publisher, 2023. 362 p.

Zallio, M., Clarkson, P.J., 2022. Designing the metaverse: A study on Inclusion, Diversity, Equity, Accessibility and Safety for digital immersive environments. In *Telematics and Informatics*. 75(1). pp. 101909.

Gurov, O.N., 2022. Metaverse – Flight from Dusk to Darkness? In *The Art and Science of Television*. 18(1). pp. 11–46.

Rodkin, P.E, 2023. "Good design" in the Metaverse: Toward a problem statement. In *Technical Aesthetics and Design Research*. 5(2). pp. 5–13.

Kizilova, S.A., 2023. Architectural layout typologies for the sustainable reserve housing organization. In *E3S Web of Conferences.* 460. pp. 10021.

Eftaxiopoulos, G., García M.Á., 2023. Infinite but Tiny: Towards a Hybrid Architecture of Dwelling. In *Delft Architecture Theory Journal*. 17 (32). pp. 91–112.

Kuznetsova, A., 2023. Dreams about Metaverse. Archi.ru. https://archi.ru/russia/98985/sny-o-vselennoi?ysclid=lusr7f3uc1954729376

Chalmers, D.J., 2021. *Reality+ Virtual Worlds and the Problems of Philisophy*. W. W. Norton & Company, Inc., New York.

Harman, G. Immaterialism: Objects and Social Theory, 2016. Polity. 140 p.

Shaev, Yu. M., 2016. Fractal Semiotics and Methodology to Study Virtual Space. In *Gramota*. 2 (64). pp. 208–210.

Segal, A., Kostikova A.A., 2022. Philosophical problems of the Metaverse. How real is the Virtual World and how Virtual is the real one? In *Artificial Societies*. 17 (3).

Florian, M.-C., 2020. Gluon Preserves the Now-Dismantled Nakagin Capsule Tower Building in the Metaverse. ArchDaily. https://www.archdaily.com/986843/gluon-preserves-the-now-dismantled-nakagin-capsule-tower-building-in-the-metaverse

Ketzler, B., Naserentin, V., Latino, F., Zangelidis, C., Thuvander, L., Logg, A., 2020. Digital twins for cities: A state of the art review. In *Built Environment*, 46(4), 547-573.

Saprykina, N.A., Saprykin, I.A., 2019. Formation of a Communicative Space as an Alternative to the Interaction of the Private and Public Spheres. In *IOP Conference Series: Earth and Environmental Science*. 988. pp. 052009.

Kolata, S., 2022. The Metaverse as Opportunity for Architects: An Interview with Patrik Schumacher. ArchDaily. https://www.archdaily.com/980196/the-metaverse-as-opportunity-for-architects-an-interview-with-patrik-schumacher

Stouhi, D., 2022. Zaha Hadid Architects Designs Liberland, a "Cyber-Urban" Metaverse City. ArchDaily. https://www.archdaily.com/978522/zaha-hadid-architects-designs-cyber-urban-metaverse-city

Theoretical Prerequisites for the Creation of Handwriting Research in Criminalistics

Sergey Shvets[a]
Department of Criminalistics, Kuban State Agrarian University, Kalinina 13 Street, Krasnodar, Russia
asfalea@yandex.ru

Keywords: Handwriting, Criminalistics, Forensic Science, Physiology of Handwriting.

Abstract: Handwriting expertise is the most difficult one in criminalistics. Despite the significant recent development of information technology and technical means, handwriting research is still a difficult task. The available computer programs do not allow to make decisions automatically. This is largely explained by the fact that the field of researches of handwriting movements remains not fully studied. This article is devoted to theoretical issues of the physiology of handwriting movements, which can be used as the basis for modelling automated handwriting recognition systems.

1 INTRODUCTION

The problem of researching handwritten notes, for example, in the investigation of economic crimes, remains relevant (Shvets et al., 2018). Currently, various attempts are being made to automate handwriting research, but the theoretical foundations of handwriting movements are still insufficiently explored (Dziechciaruk, 2023). This article considers modern views on the problem of motion control in the implementation of the act of writing as the basis for digital handwriting research.

As is known, both the theory of forensic handwriting expertise and modern dissertation researches in the field of handwriting are based on the level theory of movement construction by N.A. Bernstein. However, professor Bernstein created his theory in the middle of the 20th century, so it makes sense to consider issues related to motion control from the point of view of modern scientific researches, since what has been discovered in physiology can expand our knowledge in the field of handwriting-forming movements and, accordingly, contribute to the development of forensic handwriting examination.

The fundamental principles of N.A. Bernstein's theory can be formulated as follows (Bernstein, 1947):

1. The system that controls the movements of a biological being is a hierarchical structure consisting of different levels.
2. There is feedback between the "lower" and "upper" levels of the system, which allows you to adjust the executed command.
3. The inevitable loss of time during the transmission of information in feedback systems indicates that motion control, along with feedback systems, should be built using proactive correction systems.
4. The number of degrees of freedom of biological systems is always excessive, and the process of motion control should be considered as overcoming the uncertainty of solving a motor problem caused by an excessive number of degrees of freedom.

N.A. Bernstein built his theory based on the concept of a "black box", i.e. a certain system, the structure of which is unknown, but the functioning of which can be studied by sending a signal to the input of the system and fixing the result at the output. For the purposes of our research, we will take as a basis the three–level scheme for the implementation of arbitrary movements by M.L. Latash, also based on the concept of a "black box". This scheme can be represented as "Making of decision - construction of movement – implementation of movement " (Latash, 1993).

The above scheme is useful because it does not reflect the organization of the central nervous system

[a] https://orcid.org/0000-0002-2160-778X

that controls arbitrary movements, but allows us to discuss issues related to the organization of movement of biological beings as a whole.

The content of the "making of decision" level of this scheme still remains a mystery to modern science, and although numerous studies have been conducted by various scientists concerning the role of certain brain structures in organizing of movement, the thought process associated with the adoption of certain volitional commands has not yet been fully completed studied.

The content of the level of "realization of movement " of the above scheme is determined by the physiological and biomechanical parameters of the system. The biomechanical parameters of the implementation of handwriting movements are considered in sufficient details in the forensic literature (Mantsvetova, 1997).

2 MATERIALS AND METHODS

In the meantime, we will focus on the second level of M.L. Latash's scheme. This level can be represented as a kind of device for transcoding the decision to perform a movement into some control signals for the lower level. A model of such coding, a kind of motion control language, was proposed back in the 60s of the last century by A.G. Feldman (1966). This model, known as the equilibrium point hypothesis or λ-model, is based on the idea of central control of only one variable for each muscle (λ is a threshold value of reflex tonic tension).

A.G. Feldman suggested that the control of the movements of a kinematic link with a single-articular joint can be described with the help of two variables: r and c. These variables have a direct correspondence to known physiological concepts: mutual reverse activation and coactivation. These variables can also be correlated with the characteristics of the joint: position (r) and angle of placement (c).

Since any movement takes place both in space and in time, it makes sense to consider the change in the values of the variables r and c in time, i.e. to consider the functions of time r(t) and c(t). And since, by definition, the variable r is the central control signal, the motion itself can be described as:

$$r(t)=r_0+ \omega t, \tag{1}$$

where r_0 is the initial value of r at time t=0, and ω is a constant.

The position of the kinematic link in space changes over a period of time Δt, and the variable r takes on a new value. If, during the movement of the distal part of the kinematic link, some external force is applied to it ($r(t)=r_1$), then

$$r_2=r_1+\omega \Delta t. \tag{2}$$

Thus, we come to the concept of a "virtual trajectory".

The assumption that there is some kind of an ideal concept characterizing arbitrary movement appeared in physiology quite a long time ago. It is worth mentioning the "engram of action" by N.A. Bernstein or the "virtual trajectory" by N. Hogan (1984). These two concepts reflect two approaches to the theory of control of arbitrary movements. An engram of action is a pre–planned sequence of complex motor acts, a virtual trajectory is a kind of proactive movement "plotting a course" right at the moment of movement. But in both cases, the change in the trajectory of motion under external influence is associated with a change in the value of the control variable in time (i.e., a change in r(t)). Hence, the virtual trajectory is an ideal curve of motion along which the distal end of the kinematic link would be moved without external influence.

Movement during the act of writing always occurs under the influence of external forces, and, above all, this act is associated with overcoming the friction force within two systems: “writing device – paper” and “hand – paper”.

3 RESULTS

The conducted research has established that the virtual trajectory is predominantly forms an N-shaped curve (Gottlieb, 2010). When the real and virtual trajectories are applied to the same coordinate plane, the following picture appears. In the initial phase of movement, the virtual trajectory is ahead of the real trajectory, since the movement of the limb is forced to overcome the forces of acceleration resistance. As soon as the moving limb gains a certain speed, the virtual trajectory changes its direction to the opposite, lagging behind the movement of the real trajectory. And finally, at the end of the movement, both trajectories meet again.

Since the nature of the trajectory of movement is determined by the physical characteristics of a particular biological object, the amount of deviation of the actual trajectory of movement from the virtual trajectory is individual. This value (and in fact these are several values characterizing the movement of the distal end of the kinematic link such as amplitude, trajectory shape and phase shift) could be used in forensic handwriting studies as another parameter characterizing the performer's motor system.

As is known, in modern criminalistics, the definition of a motor system that implements handwriting movements is inextricably linked to the concept of an individual and dynamically stable writing program. In our opinion, the very concept of "program" in relation to the organization of the movement requires clarification. On the one hand, a program is a certain sequence of control signals that arises or already exists in certain structures of the human brain, thanks to which the implementation of a particular movement is carried out.

On the other hand, the very concept of a " program of movement " is currently not as unambiguous in physiology as it was commonly believed half a century ago.

It is necessary to recall that the term "program" in relation to the implementation of movements was proposed by Professor N.A. Bernstein and is associated with the concepts of "synergy" and "engram" that were proposed by him as well.

According to Bernstein, synergy is a temporary sequence of control signals transmitted to muscle groups, as a result of which simple coordinated motor acts are possible. These motor acts are a kind of elementary actions, the combination of which allows to build more complex movements. An engram is a kind of abstract model of movements, the sequence of which can be represented as a program for the implementation of motor acts. According to Bernstein, there are basic engrams corresponding to certain synergies. Higher-level engrams are built on the basis of basic engrams.

However, there is still no clear answer to how engrams are formed. Attempts have been made to associate the engram with a model of muscle activation, i.e. to represent the engram as a sequence of different values of muscle tension. Initially, this interpretation of motion programming was criticized, because with such an approach, the engram of motion should consist of an infinite number of options, since motion is built and carried out under the influence of various external factors.

Even N.A. Bernstein, conducting research on movements when performing highly automated motor acts (cutting metal with a chisel), found out that, despite the fact that the trajectories of movement of the impact part of the object (hammer) approximately coincide, the trajectories of movement of the joints of the hand performing the impact movement differ significantly. Therefore, it is not the repetition of the same movement (the execution of the same engram), but the execution of the movement taking into account different external conditions.

At the end of the last century, a new approach to this problem arose in the physiology of movements (the idea of dynamic construction of a motion model) (Kelso, 1984). It has been suggested that motion control is based on the laws of dynamics of nonequilibrium systems. With this approach, movement is a self–organizing process that manifests itself as a coordination-stable structure with repetitive characteristics. The construction of movement depends not only on the task of the motor act, but also on the initial state of the system implementing the movement. The transition of a system from one equilibrium state to another equilibrium state is possible along an infinite number of trajectories.

When performing the same motor task repeatedly, while maintaining the initial conditions, the variation in the trajectories of movement of both joints and the working point of the limb remains significant. Within the framework of the theory of "programs" of movement, such a variety of implementations seems meaningless, indeed, why use different sequences of joint movements each time when repeating the same movement, if there is already a program that ensures the performance of a specific task?

From the point of view of the theory of dynamic motion construction, the answer to this question is as follows: the motion control system is in a non-equilibrium state, i.e. in a state of constant fluctuation (Shoner, 2011). Thus, even if the initial conditions of the system are reproduced with perfect accuracy with multiple repetitions of motion, then the trajectories of the realization of this motion will still differ, since the system itself is in a non-equilibrium state and, therefore, by definition it is impossible to reproduce the initially identical conditions.

All of the above applies to handwriting movements. Since the conditions for performing writing movements (the so-called "usual conditions") differ a little from each other, and every time the task of performing a handwriting object is solved anew, it is realized in approximately the same way, which creates the illusion of reflexivity of performing letters and their elements. Although any individual who does not have knowledge of handwriting analyses knows that it is impossible to reproduce letters and their elements in exactly the same way. The variability of handwriting from the standpoint of the dynamic construction of movements can also be explained by the nonequilibrium of the handwriting-forming system. The non-reproducibility of the absolute sameness of the handwriting object is a characteristic of the handwriting-forming system itself. In addition, the absolute coincidence of the geometric shape of a handwritten object (for example, a signature) is a sign indicating its forgery.

4 DISCUSSION

Among other things, speaking about the variation of handwriting, one more interesting aspect should be mentioned. Variation of handwriting is understood, first of all, as modifications of handwriting features, i.e. changes in the attributes of letters. But a handwritten letter is a trace of movement of the colorising element of the writing device fixed on the paper. But, as it is known from the course of physics, motion is characterized by the values of velocity (v), time (t) and distance (s). Consequently, modifications in the writing of the letter can be expressed by changes in the parameters of speed, time and distance. And since these quantities are interrelated, only two of them can change independently, while the third quantity is the result of the interaction of two other quantities and is determined mathematically. Thus, the variation of handwriting can be described through a change in two physical characteristics of movement. In this case, the following 3 options are possible.

1. The change in the values of v and t with unchanged s. In this case, an increase in speed (the new value is v_1) will lead to a decrease in time (the new value is t_1) spent on executing the same letter, and the ratio is true:

$$v/v_1=t_1/t=\alpha, \tag{3}$$

where α is a constant, and $\alpha <1$.

The nonequilibrium state of the system of handwriting movements obviously ensures the reproduction of the trajectory with some (greater or lesser) deviations. The error of such deviation (Δs) is the sum of errors in the control of speed (dv) and time (dt) characteristics:

$$\Delta s=dv+dt, \tag{4}$$

and, accordingly:

$$\Delta s_1=dv_1+dt_1=dv/\alpha+d\alpha t. \tag{5}$$

As we noted, as the speed increases, the error of reproducing the trajectory increases with the increasing of speed. As the speed decreases, the trajectory playback error decreases.

Similarly, it can be shown that with an increase in the time spent on writing a letter, the reproduction error decreases, with a decrease in time, the reproduction error increases.

Thus, we have obtained a mathematical expression of the regularity of increasing the variation of handwriting with increasing writing speed (decreasing the execution time of the graphic element), and reducing the variation of handwriting with decreasing writing speed (increasing the execution time of the graphic element).

2. The change in the values of s and v at constant t.

3. The change in the values of s and t with v unchanged.

Variants 2 and 3 represent a special case of a manuscript execution – in the absence of visual control, when the trajectory of movements during the execution of letters is subject to significant changes. Under such writing conditions, the handwriting situation itself contributes to an increase in handwriting variation. However, in this case it is not a variation as such, but the effect of confounding factors on handwriting movements, which should include the biomechanical properties of the executive system itself.

In this regard, it is necessary to pay attention to the work of physiologist T. Flash (1987), who tried to experimentally find out why, when trying to perform a rectilinear movement in space with his hand, the working end of this kinematic chain (arm) moves from the starting point to the end point along a trajectory that is not an absolute straight line. It is always inevitable that deviations from a straight trajectory occur in the course of movements. According to Flash, such deviation can be explained by the fact that the kinematic links forming the human arm have different mechanical properties at different points of the trajectory, i.e. different inertial characteristics that depend not only on the design of the executive system, but also on the position of the elements of this system relative to each other and on the position of the system itself in space.

Conducting researches on the movement of a human hand in a horizontal plane caused by the influence of an external force, Flash found that the working end of such a kinematic chain easily shifts in one direction, but moves very slightly in the other direction. When changing the initial coordinates of the placement of the working end of the kinematic chain of the arm, there is also a change in the ratio of force and direction of displacement.

As a result of the experiments, Flash identified the so–called "ellipses of inflexibility " (or in terms of mechanics - "ellipses of rigidity"), showing a significant difference in the inertial characteristics of a human hand when it moves in different directions.

4 CONCLUSIONS

Thus, from the modern point of view of studies of movements of multi-link kinematic chains, the implementation of handwriting movements occurs as follows: the central nervous system sets the coordinates of the end point of movement of the working part of the kinematic chain, the executive system moves the working part to a given coordinate with some delay in relation to the formed initial image, at the same time the biomechanical, anatomical properties of the executive system itself prevent rectilinear movement. The movement of the working part takes place in a given direction, but along an elliptical trajectory determined by the rigidity dependence of the system.

REFERENCES

Bernstein, N., 1947. *About the Construction of Movements*. Moscow.

Dziechciaruk, J., 2023. Interpretation of differences in a comparative analysis of handwriting. *Problems of Forensic Sciences (Z Zagadnień Nauk Sądowych), 34,* 133-141.

Feldman, A., 1966. Functional tuning of the nervous system with control of movement or maintenance of a steady posture. *Biophysics, 11,* 565-578.

Flash, T., 1987. The Control of Hand Equilibrium Trajectories in Multi-Joint Arm Movement. *Biological Cybernetics, 57,* 96-102.

Gottlieb, G., 2010. Organizing principles for single joint movements. *Journal of Neurophysiology, 63,* 154-158.

Hogan, N., 1984. An organizational principle for a class of voluntary movements. *Neuroscience, 4,* 232.

Kelso, J., 1984. Phase transitions and critical behavior in human bimanual coordination. *American Journal of Physiology, 246,* 83-92.

Latash, M., 1993. *Control of Human Movement,* Chicago.

Mantsvetova, A., 1997. *Theoretical Foundations of Forensic Handwriting,* Moscow.

Shoner, G., 2011. A dynamic theory of coordination of discrete movement. *Biological Cybernetics, 63,* 487-491.

Shvets, S., Zelensky, V., Korchagin, A., Kuemzhieva, S., 2018. Tactics of interrogation with participation of interpreter during investigation of economic crimes. *Espacios, Vol.39 (Number 42),* 34.

Intellectual Property Protection in Mobile Applications for Dietary Supplement Intake Control: Legal Aspects and Strategies

Mariya Sogrishina[1], Alexandr Stashishin[2] and Pavlova Elena Alexandrovna[3]
ITMO University, Saint-Petersburg, Russia
marya-97-97@mail.ru, alex.stashishin@gmail.com, eapavlova@itmo.ru

Keywords: intellectual property, legislation, patent, industrial design, trademark, computer program.

Abstract: Intellectual work is one of the hardest. From a legal point of view, the results of creative, scientific, research or industrial activities are objects of intellectual property. Despite the fact that a number of problems remain in Russian legislation in the field of intellectual property protection, the unresolved nature of which in modern conditions harms Russia as a whole, as well as its citizens and entrepreneurs. At the same time, modern technologies are developing, which affects both the ways of creating the results of intellectual activity and their use, as well as the methods of legal protection of its results. The Russian state protects the results of intellectual labor from illegal use by individuals and legal entities (Part four, Section VII of the Civil Code). Violators of the law are brought to administrative and criminal responsibility.

1 INTRODUCTION

Intellectual property is the results of intellectual activity and equated means of individualization of entrepreneurs and legal entities, goods, works, services and enterprises that are protected by law.

It can be perceived as a set of rights of the author or other copyright holder, allowing them to dispose of these intangible objects, prohibit and allow their use by third parties.

A mobile application is the result of intellectual activity, as well as an invention or an author's work.

Development rights can be protected in several ways:

– Register the name and logo of the application as a trademark. Other developers will not be entitled to use this mark without written consent (in the form of a license agreement or an alienation agreement). You can also not use someone else's registered logo in advertising or on a website or on social networks to attract users. In case of violation of trademark rights, you can go to court and collect compensation up to 5 million rubles or more.

– Register the program code with Rospatent. Registration is made in the form of deposit, since the listing of computer programs is protected by copyright as a literary work. This practice has been adopted in all States that support the International Berne Convention (more than 170 participating countries). You can attach audio-visual displays (videos, drawn images) to the listing, which arise as a result of executing program commands.

– Register a device with embedded software as an invention or utility model.

The unique design of the mobile application can be registered as an industrial design. At the same time, a state patent is also issued.

Trademark registration for a mobile application is carried out in several stages:

1) Checking the name or logo for the absence of matches with previously registered marks. We check not only a complete match, but also a partial one. The two designations may differ in detail, but if they give the consumer the same overall impression, then they become competing. The mark that was registered earlier has the advantage.

2) We issue an application on Rospatent letterheads. We specify information about the copyright holder of the trademark, the priority of the designation, the classes according to the international

[1] https://orcid.org/0009-0000-2325-8782
[2] https://orcid.org/0009-0009-4147-6359
[3] https://orcid.org/0000-0001-6492-7102

classifier of the International Standard for which this mark will be used, unprotected elements of the designation and other information. There can be only one image in the application, color or black and white.

3) We pay state fees for the examination. The amount of state duties directly depends on how many classes of the MCTU are assigned in the application.

4) Sending a set of documents to Rospatent.

After registration of the application, its two-level verification is carried out:

Formal examination is the verification of compliance with the rules of registration of documents.

Substantive examination is the verification of a trademark for compliance with the requirements of Rospatent regulations. There are more than two dozen reasons for refusal of registration, so it is recommended to always make a preliminary check of the designation before submitting an application.

We present to your attention the ICTU class for the project "mobile application for the control of dietary supplements and FDI "IRecipe"

Class No.9 – Scientific, research, navigation, geodetic, photographic, cinematographic, audiovisual, optical, weighing, measuring, signaling, detection, testing, rescue and training devices and instruments; devices and instruments for transmission, distribution, transformation, accumulation, regulation or control of distribution or consumption of electricity; apparatus and tools for recording, transmitting, reproducing, or processing sound, images, or data; recorded or downloadable media, software, clean media for recording and storing digital or analog information; mechanisms for prepaid devices; cash registers, counting devices; computers and computer peripherals; diving suits, masks, earplugs, gloves for divers, nose clips for divers and swimmers, breathing apparatus for underwater diving swimming; fire extinguishing equipment.

Class No. 44 - Medical services; veterinary services; hygiene and cosmetics services for humans and animals; services in the field of agriculture, aquaculture, horticulture and forestry.

The original name of the project, as well as the intended trademark name, was "MyDoctor". However, in the course of the analysis, already registered in the open databases of FIPS and Linmark, already registered data were found (Figures 1 and 2).

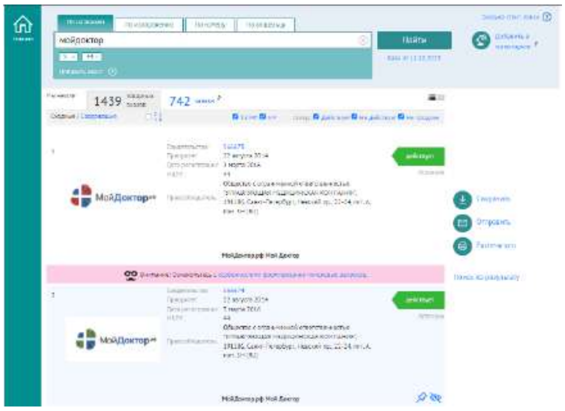


Figure 1: Open database of registered trademarks of Linmark MyDoctor.

Based on the data obtained, we see that in the open database there is already a registered trademark, which belongs to an organization located in St. Petersburg, LLC «Managing Medical Organization».

Figure 2: Open database of registered trademarks of FIPS «MyDoctor».

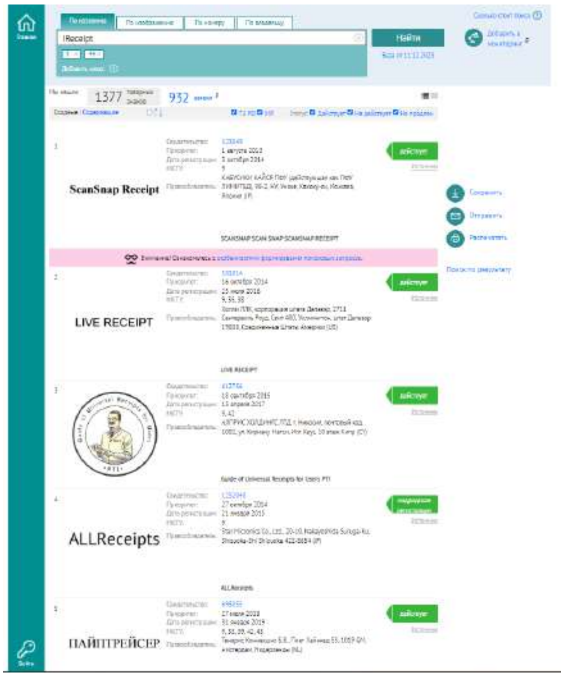
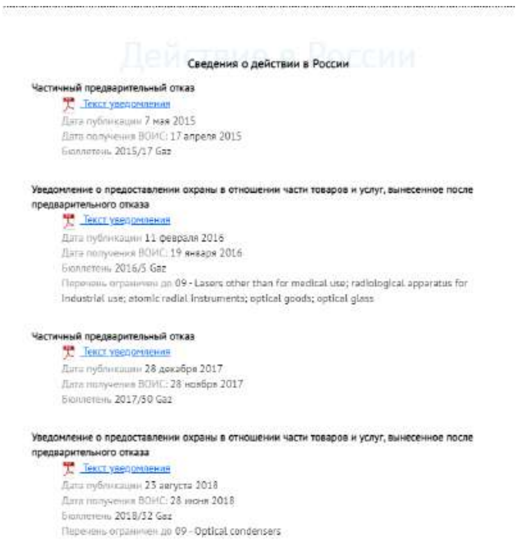


Figure 3: Open database of registration data about the Linmark « IRecipe ».

Having analyzed the open database of FIPS registered trademarks from the last two bulletins, unfortunately, no registered trademarks were found that have the status of valid or discontinued. In this regard, it was decided to rename the mobile application – «IRecipe» (Fig. 3).

Note that the main difference between a trademark is its validity period. The certificate is issued for 10 years, but it can be extended an unlimited number of times for the same period (clause 2 of Article 1491 of the Civil Code of the Russian Federation). It is recommended to apply for an extension one year before the expiration of the designation.


Сведения о действии в России

Частичный предварительный отказ
Текст уведомления
Дата публикации 7 мая 2015
Дата получения ВОИС: 17 апреля 2015
Бюллетень 2015/17 Gaz

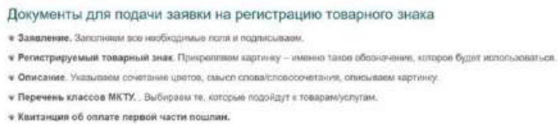
Уведомление о предоставлении охраны в отношении части товаров и услуг, вынесенное после предварительного отказа
Текст уведомления
Дата публикации 11 февраля 2016
Дата получения ВОИС: 19 января 2016
Бюллетень 2016/5 Gaz
Перечень ограничен до 09 - Lasers other than for medical use; radiological apparatus for industrial use; atomic radial instruments; optical goods; optical glass

Частичный предварительный отказ
Текст уведомления
Дата публикации 28 декабря 2017
Дата получения ВОИС: 28 ноября 2017
Бюллетень 2017/50 Gaz

Уведомление о предоставлении охраны в отношении части товаров и услуг, вынесенное после предварительного отказа
Текст уведомления
Дата публикации 23 августа 2018
Дата получения ВОИС: 28 июня 2018
Бюллетень 2018/32 Gaz
Перечень ограничен до 09 - Optical condensers

Figure 4: List of registration «recipe», «rept», «recipe».

We analyze other useful information (Fig. 4), for example, «recipe», «rept», «recipe». Lasers not intended for medical purposes; radiological equipment for industrial purposes; atomic beam device; optical products; optical glass; optical capacitors.


Документы для подачи заявки на регистрацию товарного знака

- **Заявление.** Заполняем все необходимые поля и подписываем.
- **Регистрируемый товарный знак.** Прикрепляем картинку – именно такое обозначение, которое будет использоваться.
- **Описание.** Указываем сочетание цветов, смысл слова/словосочетания, описываем картинку.
- **Перечень классов МКТУ.** . Выбираем те, которые подойдут к товарам/услугам.
- **Квитанция об оплате первой части пошлин.**

Figure 5: List of documents for filing for trademark registration.

So far, only individual entrepreneurs or legal entities can register a trademark (Article 1478 of the Civil Code of the Russian Federation). But since June 28, 2023, this opportunity has also appeared for individuals. The necessary documents for filing for trademark registration are shown in Figure 4.

Considering the protection of image components from copying, it is worth noting that this is quite natural, and the registration of application icons (pictograms) as trademarks is a trend phenomenon and is often used for umbrella brand protection.

In the context of software, an icon is an element of the graphical user interface; a small image, an icon that serves to identify a file, program, application, and serves to launch/activate it.

It should be noted that in order to obtain registration as a trademark, the pictogram should not fall under the scope of Article 1483 of the Civil Code, which contains a list of grounds for refusal of state registration of a trademark. The most common refusals are with references to paragraphs 1 and 3 of this article — we will study them in more detail.

As a rule, pictograms do not contain verbal elements. In a general sense, a pictogram is a stylized and easily recognizable graphic image of an object, simplified in order to facilitate visual perception. The pictogram enhances the characteristic features of the depicted object, «cutting off» excess and conveying its very essence. Examples of such pictograms are icons indicating a medical facility (a bowl with a snake), a hospital (a red cross), a taxi (checkers), an entrance to the parking lot (the letter P), a toilet (a pair of schematic men or letters WC), an indication that the product does not contain sugar (crossed out cubes in a circle).

Such pictograms cannot be registered as trademarks on the basis of clause 1 of Article 1483 of the Civil Code, as they do not have a distinctive ability. If the icon consists only of elements:

1) entered into general use to designate goods of a certain type;

2) being generally accepted symbols and terms;

3) characterizing goods, including indicating their type, quality, quantity, property, purpose, value, as well as the time, place and method of their production or sale;

4) representing a form of goods that is determined solely or mainly by the property or purpose of the goods, then it falls under paragraph 1 of Article 1483 of the Civil Code of the Russian Federation and cannot be registered as a trademark. Based on the above, the icon of the mobile application for searching nearby pharmacies, which depicts, for example, a green cross or a bowl with a snake, cannot be registered as a trademark — you need to be creative.

The lack of distinguishing ability can also be said in the case when the icon is a simple geometric shape: a circle, a polygon, an oval.

Based on the identified features during development, we will create our own icon for the project mobile application for the control of dietary supplements and food intake «IRecipe» (Figure 6).

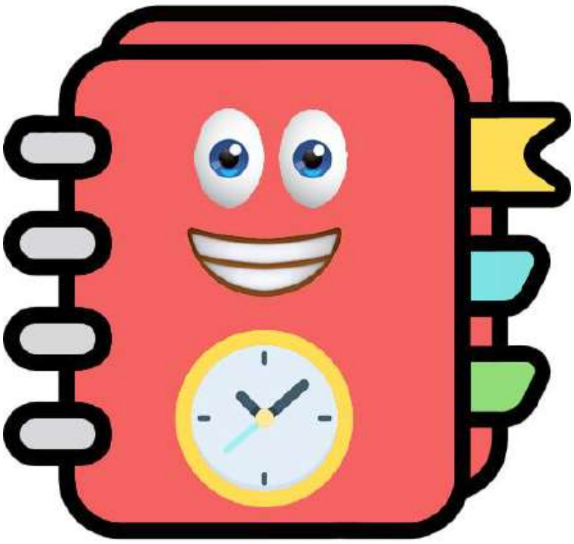


Figure 6: Icon for the mobile application « IRecipe ».

Another way to protect the right to develop is to deposit the program code – transfer a copy of it to Rospatent for storage. Registration takes place in a simple application procedure – the examination of the department checks only the correctness of filling out documents, the analysis of the software's operability is not performed. The applicant is issued a state certificate of deposit confirming the fact that the rights to the program have arisen at this point in time. It can be used as a confirmation of rights in controversial situations.

Examples of deposit items are:

A customer base for cross-promotions between business owners. A single discount card for consumers;

News feed, reading news on source sites, news announcements;

Control of the schedule of admission of users (patients of doctors), a database of prescriptions and the well-being of patients of a medical organization.

An entry about the software will be entered into the open state register only in the volume of the abstract. The full set of documents is stored in the depository.

When depositing programs, it should be borne in mind that the law protects only the external expression of the author's work – the code itself, and not the functionality of the software, i.e. it is protection against direct copying. The certificate provides protection throughout the life of the author + 70 years after his death, as well as for other objects of copyright.

Protection of the mobile application design, interface, icons, fonts and other elements can also be protected by a patent. In this case, an application for registration of an industrial design is issued. This type of intellectual property exists for the legal protection of design solutions.

Next, let's look at protecting the design of a mobile application. This method applies to industrial designs, the procedure for processing documents to Rospatent is similar: to do this, you need to file an application, pay state fees and send a package of documents to the patent office. One of the advantages of such protection is that several design options or GUI windows can be specified in the application at once. Thus, you can save on fees without paying them for each design separately (Figure 7).

On the other hand, an industrial design, like an invention, must have global novelty, that is, it must be checked against all major databases of patent documentation. Otherwise, the examination will refuse registration.

The average duration of obtaining a design patent is 5-6 months (according to the regulations, the maximum examination period is 1 year. The patent is issued for a period of 5 years, but it can be extended by submitting an application to Rospatent and paying the fee. An extension is granted for another 5 years, but the total period of legal protection cannot exceed 25 years.

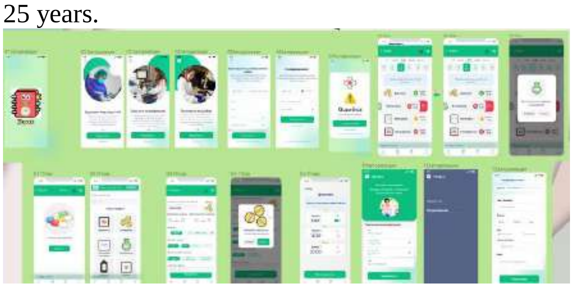


Figure 7: Protection of the design of a mobile application as an industrial design.

The patent law of a mobile application gives stronger legal protection to IT development, as it protects not only from direct copying, but also from imitation. If a competitor uses all the main features of the invention (or utility model) described in the patent, then he will violate the exclusive rights.

Another way to protect a mobile application may be to register a patent for an algorithm, that is, a way to solve a specific problem.

The scope of rights granted to the developer is determined by the content of the claims or utility model. Stricter requirements are imposed on the patent application, and the examination at Rospatent often lasts more than a year. The development itself must be new on a global scale, that is, verification is carried out against all publicly available sources published in any language.

The patent for the invention will be issued for a period of 20 years, and for a utility model – for 10 years, without the possibility of extension. Every year, state fees must be paid to Rospatent for maintaining the patent in force. Just as for trademarks, the right to a patent may be granted to other persons on the basis of a license agreement or an alienation agreement.

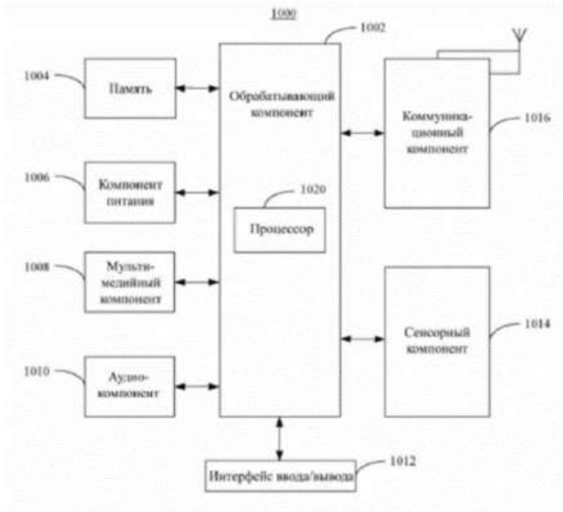


Figure 8: A fragment of the description of the patent of the mobile application.

2 RESULTS OF RESEARCH

Thus, obtaining security documents (certificates and patents) for individual elements of a mobile application gives the following advantages to its owner:

Legal protection against illegal copying.

Registration of the program in Rospatent makes it possible to include it in the unified register of the Ministry of Communications.

The opportunity to participate in tenders for the supply of software for government agencies, benefits for IT companies.

3 CONCLUSION

Thus, the mobile application «IRecipe» will have the following functionality: Android platform compatibility; scheduling of appointments taking into account: time of day, dosage, appointment plan, reception features and the ability to download or share the received schedule; the ability to conduct online consultations and make an appointment with a specialist; the ability to add medical records; sending push and audio messages notifications; the ability to use educational materials: first aid; lessons on balanced nutrition; recipes; nutrition recommendations; analysis of physical activity and meal schedule.

REFERENCES

GOST R 15.011-2022 System of product development and commissioning [Electronic resource] URL: https://www.tsu.ru/upload/medialibrary/199/82clbsd5be722uh4ya5ljt2dlb9ag9re/GOST-R-15.011_2022.pdf?ysclid=lqocuqm83h624454946 (Accessed 12/18/2023)

Trademark database [Electronic resource] URL: https://linkmark.ru/request/b3hvQkFrZk5MNjhtM2dKR0tYOFovZz09 ?new=1 (Accessed 12/25/2023)

Database of the Federal Institute of Intellectual Property [Electronic resource] URL: https://fips.ru/iiss/search.xhtml (Accessed 12/24/2023)

Nikolaev, A.S., 2022. Patent analytics: an educational and methodological manual. Petersburg: ITMO University, 98 p.

Charyeva, O.A., 2022. INTELLECTUAL PROPERTY. IN SITU. 2022. NO.12.

Intellectual Property and the Protection of Apps in the European UnionHelen Gubby, Jos Klaus, Kees van Noortwijk [Electronic resource] URL: https://ejlt.org/index.php/ejlt/article/view/713/1020 (date of application: 14.04.2024).

Intellectual property and patent prospecting as a basis for knowledge and innovation – a study on mobile information technologies and virtual processes of communication and management [Electronic resource] URL: https://www.sciencedirect.com/science/article/pii/S1809203916311160 (date of application: 14.04.2024).

A Survey of Intellectual Property Rights Protection in Big Data Applications [Electronic resource] URL: https://www.mdpi.com/1999-4893/15/11/418 (date of application: 14.04.2024).

Mobile Intellectual Property Marketplace Model for Commercialization of Intellectual Property Rights [Electronic resource] URL: https://ieeexplore.ieee.org/abstract/document/10118835 (date of application: 14.04.2024).

Intellectual property rights, strategic technology agreements and market structure: The case of GSM [Electronic resource] URL: https://www.sciencedirect.com/science/article/abs/pii/S0048733301001895 (date of application: 14.04.2024).

Problems of Adaptation of Foreign Students in the Space of a Smart Urban Environment

Elena Yurievna Turner[1], Tatyana Nikolaevna Nikitina[2] and Nadezhda Vasilyevna Rychkova[3]
Department of management and entrepreneurship, Institute of Innovation Management, Kazan National Research Technological University, Kazan, Republic of Tatarstan, Russian Federation
elurmax@mail.ru, nita101@mail.ru, nadvas2@rambler.ru

Keywords: "smart city", foreign students, adaptation, forms of adaptation, problems of adaptation.

Abstract: Based on the analysis of scientific sources of Russian and foreign researchers, the main trends in the study of the smart urban environment, difficulties in the implementation of the "Smart City" concept are revealed. Variants and forms of adaptation of foreign youth to the conditions of urban space, new socio-cultural conditions and educational environment (physiological, psychological, social, cultural, linguistic, etc.) are determined. The article presents the results of a survey of foreign students of Kazan universities in the areas of training "Management"and "Economics". The respondents' needs for knowledge, attitude to Internet sources, knowledge and use of information technologies in the urban environment, participation of foreign students in the public life of the city, communications with Russians and Tatars, etc. are determined. The difficulties experienced by foreign students in the new urban conditions were revealed: a change in lifestyle, loss of contact with loved ones, the organization of everyday life, the language barrier, etc.

1 INTRODUCTION

Between 2050 and 2060, the world's population will reach 10 billion people. As the population grows cities grow, and migration flows increase. With the growth of the population, the use of infrastructure, energy consumption and environmental pollution also increase, the issues of adaptation of the population to life in new urban conditions, intercultural communication and issues of conflict resolution caused by the residence of different ethnic groups in the same territory are raised.

Digitalization makes the population of a smart city more and more dependent on the operation of intelligent applications and the ability of their active users. This, in turn, provides adaptation mechanisms. On the one hand, there is an improvement in the quality of life of the urban population, and on the other hand, there are acute issues of adaptation not only in society and in the urban space, but also in the context of the digital development of the city, which requires initial knowledge of digital technologies.

The problem of adaptation of foreign citizens to living and studying in Russia today is of particular importance in connection with the recent events in Crocus City Hall. Russia leaves its borders open for citizens from the countries of the Commonwealth of Independent States. Arrival on a study or work visa for different purposes is accompanied by the creation of special conditions for stay. First of all, it is the inclusion in the adaptation processes of technologies that facilitate the entry of migrants into the socio-cultural space of the host region.

Statistics show that over the past 15 years, the number of international students in Russia has doubled. In 2019, 298 thousand foreign students studied in Russia, in 2020 - 315 thousand, in 2021 - 324 thousand.

Modern cities are intellectual centers that ensure the priority of information and non-material parameters of urban development (urban software) over traditional material elements (urban hardware), turning them into 'smart cities'. Efficient use of natural resources, transport mobility and information and communication technologies of the urban

[1] https://orcid.org/0000-0002-0246-2300
[2] https://orcid.org/0000-0002-0722-2381
[3] https:// orcid.org/0000-0001-9789-4597

economy, priority formation of human and social capital, improvement of the quality of life, as well as the participation of citizens in urban management allow cities to become competitive, but at the same time create new challenges for the adaptation of the newcomer population to new values and living conditions (Ganin, Ganin, 2014).

It is necessary to rethink the problem of adaptation of foreign youth to life in a big city. Living in a metropolis is a risky, stressful factor for visitors, causing states of anxiety and loneliness. The article analyzes the problem of adaptation of foreign youth to life in a large city.

2 RESEARCH METHODOLOGY

Modern cities, including the city of Kazan, strive to build an environment in accordance with the Smart City concept. It is not only about the adaptation of young people to the conditions of a large city, but also to the conditions of a smart urban environment. The information base for the study of the process of adaptation of foreign youth in the space of a smart urban environment was the results of previous research, which made it possible to form an idea of the structure of the 'Smart City', the problems of adaptation to the educational environment of the university, the socio-cultural conditions of the urban environment, etc. The unit of the sample was foreign students of the Kazan university in the areas of training 'Management' and 'Economics'. Number of respondents was 398 foreign students.

3 RESULTS OF THE STUDY

A review of the scientific literature on the problem of forming a smart urban environment demonstrates the main distinctive features of a modern city in the context of digitalization. The smart urban environment is designed to ensure a decent quality of life through the introduction of innovative technologies in the urban space, to form technologies for the ecological and rational use of urban life systems (Argunova, 2016). The Smart City concept reflects the interconnected system of communication and information technologies and the Internet of Things (IoT). This greatly simplifies the management of the city's internal processes.

The object of scientific research is the Concept of 'Smart City'. In general, the scientific world has formed an idea of the elements of a smart urban space. Their goal is to ensure a high quality of life and create favorable conditions for the development of various categories of the population, including the migrant population (Pivkina, 2019). The basis of the Smart City Concept is the following areas: smart economy, smart mobility, smart management.

Smart City is developing new services for the use of primary services in the areas of housing and utilities, ecology, public transport and medicine. In a smart urban environment, there are opportunities to aggregate 'big data' in order to improve the quality of state and municipal services (Makarenko, Loginovskaya, 2018).

A significant number of scientific sources are devoted to the study of the adaptation of foreign youth. First of all, the issues of adaptation to an unfamiliar socio-cultural space, new forms and types of educational activities, the language of communication, everyday and climatic conditions are considered. Adaptation of foreign students is defined as a complex multifactorial process of adaptation to the educational environment of a university, including educational, didactic, linguistic, professional, socio-psychological, socio-cultural, domestic and climatic aspects. Studies show that it is difficult to adapt to new conditions during the first two years of study at the university, while the tendency to maintain one's traditions and habits remains. Therefore, migration to regions with similar ethnic and religious characteristics remains preferable. A large city provides peace and security, and a large city has a well-developed law enforcement system.

According to scientists, the main problem area is the lack of skills for independent farming, difficulties in organizing food and difficulties in professional adaptation, adaptation to the peculiarities of the chosen profession, mastering professional knowledge, skills and abilities, difficulties associated with insufficient language training (Schelkova, 2019).

Adaptation to the conditions of urban space and new socio-cultural conditions is subjective. The individual adapts by using internal resources to overcome difficulties in the process of adaptation (Vitkovskaya, Trotsuk, 2003).

There are several forms of adaptation: physiological, psychological, social, cultural, etc. Forms of adaptation are superimposed on the factor of a smart urban space, some of them are overcome faster, others cause difficulties of a new order. Climate change leads to difficulties in physiological adaptation as a change in the biological mechanisms of regulation of vital activity in order to maintain a favorable physical well-being. Problems in the field of psychological adaptation intensify, the level of anxiety increases, and an unfamiliar space determines the emotional mood.

A smart urban space creates difficulties in reconciling the conditions of the social environment and human capabilities, expectations and needs. Due to the fact that students learn in groups, their personal adaptation (getting used to new conditions of the external environment) is directly related to their position in the team, and the individual, the group and the environment actively influence each other. Adaptation in the educational process means the restructuring of the personality within the framework of inclusion in a new social role of a foreign student. Cultural adaptation as the development of cultural values and features of living in order to form a comfortable standard of living is determined by the features of a smart urban space. Adaptation barriers to living in the new conditions of a smart urban space are overcome faster and can become the basis for other forms of adaptation and overcoming adaptation barriers in education and communication space.

Other forms of adaptation are associated with the language barrier, which is defined as primary. Motivation to overcome the language barrier is a prerequisite. The formation of the right motivation allows you to start overcoming the socio-cultural barrier, which consists in mastering the culture of the country. This helps to overcome communication and psychological barriers.

Sociological studies show that it is most difficult for foreign students to get used to changed weather conditions, living conditions in a dormitory and the need to communicate in Russian. Then there are the difficulties of getting used to a different way of life, the attitude of others, the absence of relatives and the peculiarities of Russian cuisine (Vitkovskaya, Trotsuk, 2003).

Language adaptation and overcoming the language barrier is one of the most difficult tasks of adaptation of foreign students in Russia. Poor command of the Russian language makes it difficult for some foreign students to communicate in everyday life and master the studied specialty, and may persist in some foreign students until the last year of study. Significant difficulties in the assimilation of knowledge also arise due to the fact that educational programs and courses are often not adapted for foreign students (Klyushnikova, 2018).

Students arriving in Russia from different regions of the world experience stress from the first days associated with a high level of intellectual load, emotional and mental stress, everyday problems, social and age restructuring of the personality, a sharp change in climatic and geographical conditions, changes in biorhythms and a different diet. Students of the Near and Middle East are characterized by neuroses (Vitkovskaya, Trotsuk, 2003).

There are also difficulties associated with orientation in the urban environment, the rhythm of life, and the use of public transport. Social barriers arise in the area of the ability to express one's point of view clearly, compliance with rules and laws, and attendance at public events (Vasil'eva, Abramova, Volkova, Dmitrienko, Kovalenko, 2020).

In the process of adaptation, problems of behavior in free time may also arise. What is customary for a foreign citizen in his homeland can cause a negative reaction from the local population. Lack of daily supervision from loved ones can lead to deviant behavior. Everyday difficulties are noted, which are primarily associated with the lack of skills of independence, decision-making and problem solving. Many people have trouble comparing prices and costs. Self-sufficiency in the sphere of budget allocation, self-sufficiency, and self-service also indicate the difficulties of adapting to the complex conditions of the new urban space (Klyushnikova, 2018).

A smart urban environment creates employment opportunities for foreign youth. Job search is facilitated by the digitalization of the labor market and communications with employers. Developed infrastructure provides new jobs, and low-skilled labor is in demand in a metropolis.

A smart urban space creates conditions for intercultural communication as an interaction of cultures and tolerance in a smart urban environment. The formation of a culture of interethnic communication and intercultural integration is possible if the city provides a space for intercultural communication.

The analysis of foreign literature reflects the main trends in the study of the smart urban environment. First, issues related to environmental performance, climate change and the development of healthy urban ecosystems are explored. The urban population is growing rapidly, which is a major obstacle to the creation of an environmentally friendly environment. Particular attention is paid to the distribution and use of land; mobility and transport; building standards; supply and disposal. Attention is paid to the development of cities, both industrial centers and business centers, industrial relations, innovation and market flexibility (Ahvenniemi, Huovila, Pinto-Seppa, Airaksinen, 2017; Zenkteler, Darchen, Mateo-Babiano, Baffour, 2022; Bastanchuri-López, De Pablos-Heredero, 2022).

Another important element of a smart city is smart mobility, including transport, information and communication technologies.

As a result, a smart city solves the problem of sustainable development. Sustainable development meets the needs of the present generation without the possibility that future generations will jeopardize the satisfaction of future generations' own needs. Sustainable development is divided into three components: environmental sustainability (taking into account biodiversity, the natural environment, cultural and landscape zones, and general climate protection); economic sustainability; social sustainability (health protection and social stability) (De Guimarães, Severo, Junior, Da Costa, Salmoria, 2020; Farkas, Hoyk, de Morais, Chomos, 2023; Chen, Guo, Wang, Tsai, Wang, Wang, 2020; Betagan, 2011).

Among the difficulties that arise in the implementation of the Smart City Concept, we note the following:

1. Excessive concentration of technologies within a single urban space and shortcomings in the real perception of the scale of technology by the visiting population
2. Social inequality in the availability of gadgets, in the use of digital technologies in the urban space
3. Development of urban infrastructure and investment in the construction of new districts and facilities, division of the city into new and old districts, this affects the social stratification of citizens
4. The lack of digital competencies among newcomers, digital illiteracy, and the lack of social ties create conditions for marginalization.

4 RESULTS OF A SURVEY OF STUDENTS OF THE UNIVERSITY

Results of a survey of students of the university of Kazan on the topic 'Adaptation of foreign youth in the space of a smart urban environment' the majority of international students (85.4%) came to study from the Commonwealth of Independent countries. Answering the question 'Has the quality of life in the city of Kazan changed in comparison with your hometown?' more than half of the students answered that the quality of life has improved, for 16.7% of respondents it has not changed. Respondents were asked to name the difficulties they experience in the urban environment.

The responses were distributed as follows. The greatest difficulties are caused by lifestyle changes (63.8%), loss of contact with loved ones (29.8%) and difficulties related to nutrition (23.4%) (Table 1).

Table 1: Difficulties in moving to a new environment.

Difficulties	% of answers
A lot has changed, we can say that the lifestyle has changed	63.8%
Geographically and territorially difficult to navigate in the new urban environment, there are many roads, difficulties in moving around the city	27.7%
Difficulties in shopping	17%
Anxiety due to a large number of people on the street, in the urban space	0%
Difficulties in organizing everyday life, Change of diet	23.4%
Changed the image and style of clothing, it is difficult to get used to a new style of clothing in the urban space	10.6%
Difficulties in communication, I do not speak Russian well, I cannot communicate with locals	12.8%
Acceleration of the rhythm of life	12.8%
Difficulties in mastering new urban practices (payment for housing and communal services, mobile payment, mobile banking)	19.1%
Difficulties related to employment	10,6%
It is difficult to get acquainted with a new language environment, communicate only with representatives of my ethnic group	4,3%
Difficulties in understanding humor and jokes in the new language environment	6.4%
Difficulties in mastering and observing Russian rules and laws	6.4%
Difficulties in planning one's free time, spending leisure time	12.8%
Lack of communication with loved ones	29.8%

Of scientific and educational interest is the issue of communication between newcomers and the local population. To the question: 'Do you communicate with representatives of Russian or Tatar ethnic groups?' 43.8% of respondents said that they have good friends among the local population, but 14.6% rarely communicate with them.

The next group of questions concerned the knowledge of modern technologies and the availability of adaptive mechanisms for life in the urban space. 'Do you have enough knowledge of information technology to live in the city?' The majority (70% of respondents) are active Internet users, so it is not an effort for this group to use information technologies in an urban environment. Respondents actively use knowledge of information technology to build a personal profile in social networks (85%), mobile payment systems (84%), download Yandex maps (79%), actively use mobile directories, and plot public transport routes in applications (85.4%).

A third of respondents (27.1%) wanted to gain additional knowledge and undergo training. This group can become potential clients of educational institutions.

Another group of questions concerned the respondents' participation in the public life of the city. The majority (83.3%) take an active part in city events. The activity mainly swings from visiting city festivals, going to shopping centers, but unfortunately does not imply their activity when visiting cultural events and cultural and leisure institutions.

Respondents get up-to-date information about the city's infrastructure using Yandex maps (77.1%). At the same time, respondents work with applications in Russian (97.9%). All respondents have a personal email and a third of respondents often (35.4%) actively use food delivery services, 25% of respondents do not use them, 39.6% of respondents rarely use them.

Answering the question 'Have you searched for the necessary information on the Internet about the city, customs, traditions of the peoples living there?', we state that only a third of the respondents were interested in information about the customs and traditions of the peoples living in our region.

Table 2 illustrates the knowledge requests/needs of young people.

Table 2: Knowledge needs.

Knowledge	% of respondents
History and culture of Russia	57.4%
Leisure opportunities in the city	38.3%
Fundamentals of the legislation of the Russian Federation and international law	25.5%
Etiquette and rules of conduct in public places, shops, food, medical care, transport, etc.	12.8%
Russian language training. Testing of different levels to obtain certificates	34%
Resolution of intercultural conflicts	19.1%
Psychological barriers and ways to overcome them	4.3%
Acquaintance with the internal regulations of the university	23.4%
List and calendar of necessary actions upon arrival and in the process of training	6.4%
Acquaintance with the interactive possibilities of remote communication via the Internet (ask a question, chat) and with the electronic dean's office system	21.3%
Opportunities for additional training at the university 38.3%	38.3%

Knowledge about the history and culture of Russia (57.4%), university education opportunities (38.3%), and leisure opportunities in the city (38.3%) are in demand. Students are not interested in knowledge about overcoming psychological barriers (4.3%) and about the procedure for collecting and submitting documents, the share of relocation and (6.4%).

5 DISCUSSION OF THE RESULTS

The results of the survey showed a high level of formation of adaptation mechanisms. Respondents adapt well to living in an urban environment, and the skills of an Internet user are a factor in the adaptation of young people. Convenient and understandable services, universal for different countries, become guides to a new urban space, organized taking into account the smart environment.

1. The study showed that information technology is a factor in the adaptation of newcomers to living in an urban environment.

2. Knowledge about the history and culture of Russia is becoming in demand. It is important how and where young people spend their leisure time.

3. The creation of an interactive course on Internet platforms for the adaptation of foreign youth, containing information about the key points of the smart urban space, technologies of the smart urban

environment is relevant. This is information of a legal, country, historical, cultural, linguistic and reference nature. Interactive classes should be conducted in the native language, the printed version should be provided to young people in their native language and duplicated in the Russian language.

4. A low percentage of answers about the ability to overcome psychological barriers may mean closeness and unwillingness to recognize a problem in oneself, so we consider it necessary to develop a supportive resource in the native language to solve socio-psychological problems and overcome psychological barriers associated with adaptation in urban space.

5. The difficulties of adaptation in a smart urban environment can be divided into three groups:

A) difficulties of the socio-cultural space

B) difficulties of the information and communication space

C) language barrier.

6 CONCLUSIONS

Knowledge of the features of the smart urban environment makes it possible to create forecasts of the adaptation process in new conditions for foreign youth. The task for public authorities is to organize urban space taking into account the needs of the visiting population, to create urban information resources and interactive urban space adapted for use by the non-indigenous population. Adapting to cultural differences, communicating with representatives of the host culture, assimilating norms and rules is also possible only with the use of digital technologies of a smart urban environment.

The adaptation of foreign youth in a smart urban environment is associated with overcoming psychophysiological, educational, cognitive, communication barriers and overcoming them, socio-cultural difficulties, ensuring safety and life, financial difficulties and problems of self-realization, employment due to the digitalization of the urban environment.

The problems of adaptation are related to the inclusion of the individual in the new socio-cultural reality, which determines the main stable interactions. Therefore, the process of adaptation to the conditions of a smart urban environment should be purposeful and organized, accompanied by the processes of digital socio-cultural transmission of norms and rules for living in new conditions. Adaptation involves adaptation not only to a new socio-cultural environment, new rules of behavior and norms of living in a metropolis, but also adaptation to new values shared by citizens and associated with the perception of urban space.

REFERENCES

Export of Russian educational services. Statistical Collection. Issue 10. Moscow: Ministry of Science and Higher Education, Pushkin State Institute of Linguistics, 2020, 557 p.

The number of international students in Russia has increased by 26 thousand in three years (18.01.2022). Official website of the Ministry of Education and Science of the Russian Federation. URL: https://minobrnauki.gov.ru/presscenter/news/mezhdunarodnoe-sotrudnichestvo/46158/ (accessed: 01.04.2024).

Ganin, O.B., Ganin, I.O., 2014. Smart City. *Prospects and Development Trends.* N1. -pp.124 -135

Argunova, M.V., 2016. Model of the «Smart». City as a Manifestation of a New Technological Way. *Science and School.* N 3. - pp. 14-23.

Smart City - Concept, Technologies, Development Prospects. - https://robo-sapiens.ru/stati/umnyiy-gorod.

Pivkina, N.V., 2019. Smart cities as a new standard of quality of life of the population. *Bulletin of the Financial University.* N 4.

Makarenko, K.V., Loginovskaya, V.O., 2018. Smart City. *Standards, Problems, Development Prospects*. NO 1. pp. 75-89.

Schelkova, T. V., 2019. Features of social adaptation of foreign students to new conditions of life and study at the university -pp.36-40.

Vitkovskaya, M.I., Trotsuk, I.V., 2003. Adaptation of Foreign Students to the Conditions of Life and Study in Russia (on the Example of RUD www.dsmu.edu.ua/files/MUC/Psihologicheskie_Issledovaniya.doc 1N). "Vestnik RUDN. "Sociology" series. Moscow.

Klyushnikova, E.V., 2018. Problems of adaptation of foreign students in Russia. *Pedagogy and Psychology Series.* Issue 1. pp. 133-140.

Vasil'eva, S.L., Abramova, A.A., Volkova, M.G., Dmitrienko, N.A., Kovalenko, N.S., 2020. Socio-Cultural Adaptation of Foreign Students in the Siberian Region. VOL. 10, N. 4. pp. 4212-4222.

Ahvenniemi, H., Huovila, A., Pinto-Seppa, I., Airaksinen, M., 2017. What is the difference between sustainable and smart cities? Cities 60, 234-245.

Zenkteler, M., Darchen, S., Mateo-Babiano, I., Baffour, B., 2022. Working from Home in Cities: Finding the Right Urban Planning Solution.

Futures 135, 102494. Intellectualization of management decisions in a large city and ensuring viable conditions.

Bastanchuri-López, M.T., De Pablos-Heredero, C., 2022. Bibliometric analysis of smart cities related to land use. Earth 11 (12), 2132.

De Guimarães, J.C.F., Severo, E.A., Junior, L.A.F., Da Costa, W.P.L.B., Salmoria, F.T., 2020. Governance and Quality of Life in Smart Cities: Towards the Sustainable Development Goals. J. Clean. Cont. 253, 119926.

Farkas, J. Z., Hoyk, E., de Morais, M.B., Chomos, G., 2023. A Systematic Review of Urban Green Space Research Over the Past 30 Years: A Bibliometric Analysis. Heliion 9(2), e13406.

Chen, Yu, Guo, F., Wang, J., Tsai, W., Wang, K., Wang, K., 2020. Projection of China's population based on provinces and grids according to general socioeconomic trajectories from 2010 to 2100. Sci. Data 7(1), 83.

Betagan, L., 2011. Smart Cities and Sustainable Development Models. Inf. Econ. 15 (3), pp. 80-87.

Multifactor Monitoring of the Smart Cities Water Framework as Information Basis for Sustainable Development

Asiya Galeeva [1][a], Nafisa Mingazova [2][b], Iskander Gilmanshin [3][c], Nedim Ozdemir [4][d] and Rustem Galeev [5][e]

[1]*Institute of Electric Power and Electronics, Kazan State Power Engineering University, 51, Krasnoselskaya str., Kazan, Russian Federation*

[2]*Department of Environmental Management and Water Use, Kazan Federal University, 18, Kremlevskaya str., Kazan, Russian Federation*

[3]*Institute of Automation and Electronic Instrumentation, Kazan National Research Technical University named after A. N. Tupolev – KAI, 10, K.Marx str., Kazan, Russian Federation*

[4]*Faculty Of Fisheries, Mugla Sıtkı Kocman University, Kötekli Mahallesi, Mugla, Turkie*

[5] *Medical Engineering Department, Fashion and Design Kazan National Research Technological University, 68 Karl Marx str., Kazan, Russian Federation*

asiyaaleeva@yandex.ru, nmingas@mail.ru, is-er@yandex.ru, ata.dadaoz@gmail.com, grd377@gmail.com

Keywords: urbanization, ecology, smart city, water ecosystem, ecological framework, city development strategy, sustainable development, environmental strategy.

Abstract: The work is devoted to the current problem of urbanization of cities. Conceptual provisions for monitoring the condition of natural objects in a smart city are proposed. The author's methodology for assessing the effectiveness of sustainable development strategies for smart cities is presented using the example of the dynamically developing agglomeration of Kazan. A highly effective natural multiplier for assessing the state of water bodies is proposed - ichthyoproductivity as a function of the objective state of zooplankton and zoobenthos. The results of long-term monitoring studies of the objective state of water bodies in the dynamically developing agglomeration of Kazan are presented. Based on the data obtained, an assessment of ichthyoproductivity was carried out and a conclusion was made about the effectiveness of the implementation of the city's environmental strategy in general and water protection measures in particular.

1 INTRODUCTION

The global trend towards urbanization of territories determines the need for a qualitative change in the principles of constructing urban development strategies, especially in terms of the methodological, informational and organizational foundations of environmental activities. As it turned out, the vast majority of citizens consider the concept of "Smart city" as the main tool for eco-urbanization and the creation of a new type of urban ecosystem based on the principles of sustainable development and a rational approach to the formation of urban space, taking into account the environmental factor.

Urbanization refers to the process of population migrating from rural areas to cities, resulting in an increase in population and the construction of new cities and infrastructure. In turn, the "Smart city" concept implies the use of modern technologies and information systems to improve the lives of citizens, increase the efficiency of urban infrastructure and ensure sustainable development. Thus, smart cities are cities that integrate various science-based methods and digital solutions to improve the quality of life of citizens, reduce negative environmental

[a] https://orcid.org/0000-0001-6248-6374
[b] https://orcid.org/0000-0002-8360-7005
[c] https://orcid.org/0000-0001-9766-0598
[d] https://orcid.org/0000-0001-7410-6113
[e] https://orcid.org/0009-0008-9240-5158

impacts, improve safety and manage resources. As part of the “Smart city” concept, technologies such as data analytics, multifactor analysis, artificial intelligence, sensors, Big data, IoT, cloud computing, and many others are used. In other words, modern “Smart cities” are global ecosystems that unite closely interconnected ecological, recreational, sociocultural, architectural, engineering, industrial, transport, energy, and household frameworks.

Smart cities can offer a number of advantages, such as creating a favorable ecosystem for the life and development of citizens, preserving the biodiversity of the territory’s ecosystem, energy saving, increasing the level of education, health and safety, which means urbanization and the “Smart city” concept play an important role in the modern development of cities and improving the quality of life of its residents.

The environmental strategy of smart cities involves the use of modern technologies and innovations to improve the state of the environment and reduce the negative impact of human activity on the ecosystem.

The main principles of the environmental strategy of smart cities include:

- Application of artificial intelligence and big data analytics to monitor and predict the state of the environment and take effective measures to protect it.
- Development of green technologies and solutions, including increasing the share of renewable energy sources in urban infrastructure.
- Use of energy efficient technologies and solutions to reduce energy consumption and greenhouse gas emissions.
- Reducing air pollution, creating comfortable and safe conditions for residents through the use of smart energy, transport and infrastructure management systems.

The environmental strategy of smart cities contributes to the creation of a sustainable and environmentally friendly urban space, which, in turn, improves the quality of life of its residents and helps preserve the environment for future generations.

When forming an environmental strategy, it is important to choose the right information basis and methodology for monitoring the state of the environment. Architectural and planning solutions can and should take into account not only the factors of insolation and air purity; the urban area must remain a comfortable habitat for a wide range of living organisms inhabiting a given location, including ichthyofauna.

It is important to note that the proximity of water bodies has traditionally attracted people. Water is the most important factor in quality of life. Water bodies serve as a source of nutrition, a recreational area, and a natural biofilter. As a result, they are among the first to experience the full range of anthropogenic pressure. But water bodies are the natural habitat of aquatic biological resources. The key components of aquatic biological resources are zooplankton, zoobenthos and ichthyofauna. The quantitative and qualitative indicators of ichthyofauna directly depend on the quality of the habitat and food supply. In turn, the food supply of water bodies primarily experiences stress from human proximity. The oppressive factors are the well-known dust, hydrocarbons, water-soluble pollutants, various fractions of industrial and household waste, heavy metals and toxic chemicals, which are widely present in the city. The second echelon is the factors of disruption of trophic links and gross interference in the ecosystem (Alimov, A., 2001). During the research conducted under the guidance of Doctor of Biological Sciences, Professor of Kazan University Mingazova N.M. long-term monitoring studies of water bodies in the city of Kazan and the Republic of Tatarstan and regions of the Russian Federation have established that it is advisable to consider ichthyoproductivity as a function of the object as one of the key integral indicators of the quality of a water body.

2 MATERIALS AND METHODS

Fundamental materials for the work were data from inventory studies of 175 lakes in Kazan, environmental passports of these ecosystems developed as part of the inventory and certification of water bodies in Kazan (2007-2010), as well as individual reports on the condition of water bodies within the framework of municipal contracts with MKU "Committee for External Improvement of the City of Kazan" and economic agreements (2010-2023) (Mingazova, N., Derevenskaya, O., Palagushkina, O., 2014). Hydrobiological samples were taken at each reservoir from 2-4 stations. Control stations were selected for research. Sampling of zooplankton and zoobenthos was carried out and processed in accordance with generally accepted hydrobiological methods (Vshivkova, T., Ivanenko, N., Yakimenko, L., 2019, Shchepovskikh, A., 2006, Kutikova, L., Starobogatova, Ya., 1977, Tsalolikhina, S., 1994).

2.1 Zooplankton

Zooplankton is an integral part of lake ecosystems, a key food resource for ichthyofaunal (Derevenskaya, O., 2015, Mingazova, N., Derevenskaya, O., Palagushkina, O., 2008). During the study using databases, the qualitative composition was analyzed, statistical processing of the quantitative composition of zooplankton in lake ecosystems in Kazan was carried out, and an assessment was made of possible fish production based on zooplankton biomass.

Analysis of species composition showed the presence of 204 species of zooplankton, of which the taxa Rotifera include 84 species (41% of the total number of species), Cladocera – 64 species (31%), Copepoda – 56 species (28%). The qualitative composition of zooplankton includes 34 families, seven orders and two classes of rotifers and crustaceans (Fig. 1).

During the analysis, the prevalence of the following representatives of Rotifera (Rotifera) was noted. Among Cladocera crustaceans, the highest occurrence is: Chydorus sphaericus (O.F. Muller), Bosmina longirostris (O.F. Muller), Simocephalus vetulus (O.F. Muller), Daphnia longispina O.F. Muller, Daphnia cucullata Sars, Scapholeberis mucronata (O.F. Muller). Of the copepods (Copepoda), the most frequently found are: Eucyclops serrulatus (Fischer), Mesocyclops leuckarti (Claus), Thermocyclops oithonoides (Sars).

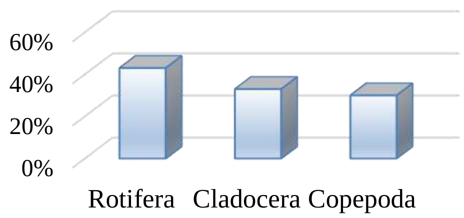


Figure 1: Distribution of zooplankton taxa in the studied area.

The occurrence of zooplankton species in the lakes of Kazan is presented in Table 1. The identified number of zooplankton species in the lakes ranged from 1 species (Lake-marsh complex in the village of Lagerny) to 85 species (Lake Sredny Kaban).

Table 1: Taxonomic composition of zooplankton in lakes of Kazan (according to dominant and rare species for 46 lakes studied in summer).

Taxon / Predominantly occurring species	Occurrence
Rotifera	
Keratella quadrata (Muller)	27%
Brachionus angularis (Gosse)	19%
Cladocera	
Chydorus sphaericus (O.F. Muller)	47%
Bosmina longirostris (O.F. Muller)	26%
Copepoda	
Eucyclops serrulatus (Fischer)	29%
Mesocyclops leuckarti (Claus)	28%

The analyzed lakes are very diverse in terms of the abundance and biomass of zooplankton. According to quantitative characteristics, the average value of zooplankton abundance is 181 thousand specimens/m^3, the average value of zooplankton biomass is 2.32 g/m^3 (Table 2). The poorest lake in this regard is. Rotanovoe (number of zooplankton – 0.4 thousand specimens/m3 and biomass – 0.0004 g/m^3). The highest abundance was found in the lake. Peschanoye (2120 thousand specimens/m^3), and the highest zooplankton biomass is in lake. Bead (37.70 g/m^3).

As part of the study, an assessment of zooplankton biomass was carried out from the point of view of the food supply of ichthyofauna (Kitaev, S., 2007). To estimate possible fish production based on zooplankton biomass, a regression equation was used (1):

$$Y=4.408*X^{0.698}, \quad (1)$$

where Y, kg/ha – fish production;
X, g/m^3 – zooplankton biomass.

Calculations of fish productivity based on zooplankton biomass for lake ecosystems in Kazan are shown in Table 24; the average fish productivity of all studied lakes was 5.68 kg/ha. The lake turned out to be the most highly productive per unit area. Businka (55.53 kg/ha), the least productive lake. Rotan (0.02 kg/ha).

Table 2: Number, biomass and estimated fish productivity based on zooplankton biomass in lakes in Kazan.

№	Number (ind./m²)	Biomass (g/m²)	Fish products activity, kg/ha
1	396	37,7	55,53
2	49	18,5	33,79
3	588	10,2	22,3
4	2120	8,36	19,41
5	243	4,1	11,8
6	86,2	2,9	9,27
7	52	2,67	8,75
8	66	2,6	8,59
9	204	2,2	7,64
10	24	1,77	6,57

11	41	1,7	6,38
12	1310	1,6	6,12
13	124	1,56	6,01
14	277	1,3	5,29
15	104	1,2	5,01
16	101	1,2	5,01
17	37,3	0,86	3,97
18	82	0,7	3,44
19	18,6	0,63	3,2
20	50,2	0,59	3,08
21	24,9	0,5	2,72
22	781	0,5	2,72
23	72	0,5	2,72
24	338	0,48	2,64
25	65	0,37	2,21
26	226	0,32	1,99
27	69	0,24	1,63
28	49	0,16	1,25
29	8,47	0,15	1,17
30	65	0,15	1,17

All studied lakes by zooplankton biomass in accordance with the division of I.N. Sorokin, can be divided into 4 groups: I – with biomass less than 1 g/m^3, II – with biomass from 1 to 5 g/m^3, III – with biomass from 5 to 10 g/m^3 and IV – with biomass more than 10 g/m^3 m^3 (Table 3). 64% of the studied lakes are included in group I with low zooplankton biomass (very low productivity), i.e. They are classified as low-nutrient in terms of bioresources.

The qualitative composition of zooplankton in the lakes of Kazan shows a significant anthropogenic impact on aquatic ecosystems (the most common species of zooplankton are species that inhabit mainly eutrophic and polluted lake ecosystems).

Table 3: Groups of lake ecosystems in Kazan by zooplankton biomass.

Number of lakes	% of lakes	Biomass (g/m^3)
I (very low productivity)		
30	64 %	less 1
II (low productivity)		
12	25 %	1 - 5
III (medium productive)		
1	2 %	5 - 10
IV (highly productive)		
3	9%	more 10

According to quantitative characteristics, the average value of zooplankton abundance is 181 thousand specimens/m^3, the average value of zooplankton biomass is 2.32 g/m^3. Most of the studied lakes belong to the group with low plankton biomass (poor food or very low productivity, in terms of bioresources). The possible average fish production based on zooplankton biomass was 5.68 kg/ha.

2.2 Zoobenthos

Zoobenthos is an important part of the food supply of fish resources; assessment of potential fish productivity based on zoobenthos can be carried out to analyze promising ichthyoproducts, as well as for measures for restoration and improvement of fish biological resources (Nabeeva, E., 2010).

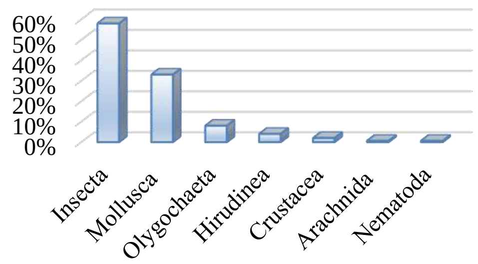


Figure 2: Distribution of taxa within the qualitative composition of zoobenthos in lake ecosystems of Kazan.

Based on the analysis of the database on hydrobiological indicators, 163 species of organisms from seven taxonomic groups of benthic aquatic invertebrates were identified, of which insects (Insecta) - 91 species (56%), mollusks (Mollusca) - 51 species (31%), oligochaetes (Olygochaeta)) – 11 species (7%), leeches (Hirudinea) – 6 species (4%), crustaceans (Crustacea) – 2 species (1.2%), arachnids (Arachnida) – 1 species (0.6%) and nematodes (Nematoda) – 1 species (0.6%) (Fig. 2).

The predominant group in terms of species composition in the zoobenthic community of lake ecosystems of Kazan is Insects (species of beetles Hydroporus, chironomids Chironomus plumosus, Polypedilum nubeculosum, mayflies Cloen dipterum, hemiptera Corixa sp.). Among the Mollusca group, the dominant species were Planorbis planorbis and Anisus spirorbis. Among the oligochaetes, the most common were Limnodrilus hofmeisteri, Tubifex tubifex, among leeches - Erpobdella octoculata, among crustaceans - Asellus aquaticus. The occurrence of macrozoobenthos species (by dominant species and rare species) in the lakes of Kazan is presented in Table 4. Complete information on the number of zoobenthos species found in all studied lakes in the regions of Kazan is presented.

In the lake ecosystems of Kazan, rare species listed in the Red Book of the Republic of Tatarstan were discovered: Ranatra linearis (Ranatra rod-shaped, living in Lake V. Kaban) and Nepa cinerea (aquatic scorpion, living in Lake V. Kaban), Argironeta aquatica L. (silver spider, living in lake - oxbow No. 2 of the Kazanka River, Sovetsky district).

The identified number of zoobenthos species in the lakes ranged from 1 species (Lake Shosseynoye) to 14 species (Lake Sredny Kaban).

According to quantitative characteristics, the average value of zoobenthos abundance in lake ecosystems in Kazan is 287 specimens/m3, the average value of zoobenthos biomass is 2.84 g/m3 (Table 5). Lake is the poorest in terms of zoobenthos abundance. Kharovoe (12 specimens/m2) and biomass – lake. Eastern (0.04 g/m2). The highest abundance of zoobenthos was found in lake. Verkhniy Kaban (2800 ind./m2), and the highest biomass is near lake. Medium Boar (16.2 g/m2).

Table 4: Taxonomic composition of zoobenthos in lakes of Kazan (by dominant and rare species for 31 studied during the summer period of the lake).

Taxonomic group	Species
Olygochaeta	*Limnodrilus hofmeisteri* (Claparède, 1862)
	Tubifex tubifex (Müller, 1774)
Leeches (Hirudinea)	*Erpobdella octoculata* (Linnaeus, 1758)
Shellfish (Mollusca)	*Planorbis planorbis* (Linnaeus, 1758)
	Anisus spirorbis (Linnaeus, 1758)
Insects (Insecta)	*Chironomus plumosus* (Linnaeus, 1758)
	Polypedilum nubeculosum (Meigen, 1804)
	Hydroporus (Clairville, 1806)
	Cloen dipterum (Linnaeus, 1758)
	Corixa dentipes (Thomson, 1869)
	Coenagrion armatum (Charpentier, 1840)
	Ischnura elegans (Vander Linden, 1820)
	Mistacides niger (Linnaeus, 1758)
	Nymphula stagnata (Donovan, 1806)
	Elophila nymphaeta (Linnaeus, 1758)
Arachnids (Arachnida)	*Argyroneta aquatica* (Clerck, 1757)
Crustaceans (Crustacea)	*Asellus aquaticus* (Linnaeus, 1758)

All studied lakes can be divided into 4 groups according to zoobenthos biomass: I – with biomass less than 1 g/m2, II – with biomass from 1 to 5 g/m2, III – with biomass from 5 to 10 g/m2, IV – with biomass more than 10 g/m2 (Table 4).

Lakes of group IV, as reservoirs with high and very high biomass of zoobenthos, are highly food-rich and make up 10% of the studied lakes (in terms of bioresources). 58% of the studied lakes are included in group I with very low biomass (very low productivity) and 19% are in group II with low biomass of zoobenthos (low productivity), respectively, low-forage. Group III of lakes - medium-feeding (medium-productive), makes up 13% of the studied lakes. Thus, most of the studied lakes in Kazan (58%) are very low-productive (i.e., low-nutrient in terms of biological resources).

To calculate the possible production of benthophages based on zoobenthos biomass, the formula was used (2):

$$P_{benthophages} = 0.2P_{bent}. \tag{2}$$

where P is fish productivity, kg/ha;
P_{bent} - benthos biomass, kg/ha.

Calculations of fish productivity based on zoobenthos biomass for lake ecosystems in Kazan are shown in Table 5; the average fish productivity of all studied lakes was 5.68 kg/ha. The lake turned out to be the most highly productive per unit area. Medium Kaban (32.4 kg/ha), the least productive lake in terms of biological resources. Eastern (0.08 kg/ha).

Table 5: Number, biomass and estimated fish productivity based on zoobenthos biomass of lakes in Kazan.

№	Number (ind./m²)	Biomass (g/m²)	Fish products activity, kg/ha
1	250	16,2	32,4
2	192	15	30
3	24	15	30
4	1575	7,95	15,9
5	2800	7,07	14,14
6	2050	6,93	13,85
7	375	4,8	9,6
8	37	1,66	3,32
9	88	1,47	2,94
10	150	1,46	2,92
11	12	1,27	2,54
12	38	1,16	2,32
13	350	1,03	2,05
14	75	0,88	1,76
15	72	0,88	1,76
16	112	0,81	1,62
17	112	0,81	1,62
18	100	0,75	1,5

19	13	0,63	1,26
20	50	0,5	1
21	50	0,4	0,8
22	87	0,4	0,8
23	75	0,35	0,7
24	12,5	0,15	0,3
25	25	0,13	0,25
26	89	0,11	0,22
27	12,5	0,11	0,22
28	25	0,09	0,18
29	12	0,06	0,12
30	12,5	0,06	0,12

Thus, in the biocenosis of zoobenthos of lakes on the territory of the city of Kazan, chironomid species are most often found, and the predominant group in terms of species composition is insects. The average value of zoobenthos abundance was 287 specimens/m3, the average value of zoobenthos biomass was 2.84 g/m3, 58% of the studied lakes were included in group I with very low zoobenthos biomass or very low-productive (poor-feeding) (less than 1 g/m2). When calculating possible fish production based on zoobenthos biomass, the average value was 5.68 kg/ha.

Table 6: Groups of lake ecosystems in Kazan by zoobenthos biomass.

Number of lakes	% of lakes	Biomass (g/m^3)
I (very low productivity)		
18	58 %	less 1
II (low productivity)		
6	19 %	1 - 5
III (medium productive)		
4	13 %	5 - 10
IV (highly productive)		
3	10%	more 10

2.3 Ichthyofauna and assessment of fish productivity of lake

Ichthyofauna is the final link in the trophic chain of an aquatic ecosystem, reflecting its state (Abakumov, V., 1992). Based on the analysis of the database on hydrobiological indicators, 15 species were noted in the composition of the ichthyofauna of lake ecosystems in Kazan (Mingazova, N., 2005). All species belong to the class Bony fishes (Osteichthlyes), to 3 orders (Esociformes, Cypriniformes, Perciformes) and 5 families (Ecocidae, Cyprinidae, Balitoridae, Percidae, Eleotriade). The most diverse order is Cypriniformes; 11 species out of all species represented in the lakes of Kazan belong to this order (Table 7).

Table 7: Occurrence of ichthyofauna species in lake ecosystems of Kazan.

№	Species	Occurrence, %
1	*Esox Lucius* L.	16
2	*Rutilus rutilus* L.	32
3	*Scardinius erythrophthalmus* L.	21
4	*Lecaspius delineates*	47
5	*Alburnus alburnus* L.	26
6	*Abramis brama* L.	11
7	*Blicca bjoerkna* L.	11
8	*Tinca tinca* L.	21
9	*Carassius carassius* L.	68
10	*Carassius auratus gibelio* Bloch	32
11	*Ciprinus carpi L.*	42
12	*Barbatulla barbatulla* L.	11
13	*Perca fluviatilis L.*	39
14	*Acerina cernua L.*	5
15	*Percottus glehni* Dybowsky	42

The occurrence of species ranges from complete absence or one (usually a weed species of Amur sleeper) to 11 species in the lake. The highest species diversity (9-11 species) of ichthyofauna was found in oxbow-karst lakes with a depth of more than 10 m - Nizhny, Middle and Upper Kaban. About 5-8 species were found in stagnant karst lakes (Lake Bolshoye Glubokoe, Lebyazhye, Botanichesky). Most of all within the city of Kazan there are lake ecosystems with 1-4 species of ichthyofauna and completely fishless lakes. It should be taken into account that lakes with one species are most often inhabited by the invasive species Amur sleeper, which has a high tolerance to pollution and ecological plasticity; it is considered a “weed” species that negatively affects the aquatic ecosystem and oppresses local aquatic organisms. Rotan reservoirs probably should not be classified as fish-producing and resource lakes.

Summary Table 8 presents data for calculating the ichthyoproductivity of the studied lake ecosystems in Kazan based on regression equations taking into account the biomass of zooplankton and zoobenthos.

Calculations of fish productivity based on zooplankton biomass showed that the average fish productivity of all studied lakes was 5.68 kg/ha, while the most highly productive per unit area was lake. Businka (55.53 kg/ha), the least productive lake. Rotan (0.02 kg/ha).

In terms of zoobenthos biomass, the average fish productivity of all studied lake ecosystems is 5.68 kg/ha; according to this indicator, lake turned out to be the most highly productive per unit area. Middle Kaban (32.4 kg/ha), the least productive lake. Eastern (0.08 kg/ha).

Table 8: Estimated ichthyoproductivity of lake ecosystems in Kazan.

by zooplankton biomass, kg/ha	by zoobenthos biomass, kg/ha	total, kg/ha
minimum		
0,02	0,08	0,10
maximum		
55,53	32,4	87,93
average		
5,68	5,68	11,36

Thus, the overall average ichthyoproductivity of lake ecosystems in Kazan for all two indicators (biomass of zooplankton and zoobenthos) was 11.36 kg/ha.

As a result of analyzing data on fish resources, the city's lakes can be divided into 4 groups (Table 9).

Table 9: Division of lakes in Kazan into groups according to fish resources.

Group	Name
I	fish with rare species (more than 10 species)
II	fish with rich species diversity (4-10 species)
III	fish with background species, low species diversity (1-4 species)
IV	fishless

The background fish species for the lakes of Kazan are golden crucian carp, perch, silver crucian carp and roach, rare species are ruffe, pike, bream, and silver bream.

3 CONCLUSIONS

In general, for a more in-depth analysis and detailed calculations of ichthyoproductivity, it is necessary to conduct a study of the complex state of ichthyocenoses based on a set of geographical, hydrological, morphometric, hydrochemical, hydrochemical, hydrobiological parameters, including the influence of the trophic structure of the ecosystem, a detailed analysis of fish production, and a comparison of different methods and expert assessments.

The proposed methodology for assessing the effectiveness of strategies for the sustainable development of smart cities using the example of the dynamically developing agglomeration of Kazan based on the determination of the natural multiplier for assessing the state of water bodies - ichthyoproductivity as a function of the objective state of zooplankton and zoobenthos - makes it possible to quickly assess the ecological state of water bodies of urban development. Based on the data obtained, an assessment of ichthyoproductivity was carried out and a conclusion was made about the effectiveness of the implementation of the city's environmental strategy in general and water protection measures in particular. The presented results of monitoring studies of water bodies in the Kazan agglomeration revealed the need to take a set of operational measures to maintain and restore the ecological state of the city's water framework.

REFERENCES

Alimov, A., 2001. *Elements of the theory of functioning of aquatic ecosystems*, Nauka. St. Petersburg.

Vshivkova, T., Ivanenko, N., Yakimenko, L., 2019. *Introduction to freshwater biomonitoring*, Publishing house VGUES, Vladivostok.

Kitaev, S., 2007. *Fundamentals of limnology for hydrobiologists and ichthyologists*, Karelian Research Center RAS, Petrozavodsk.

Shchepovskikh, A., 2006. *Red Book of the Republic of Tatarstan. Animals. Plants. Mushrooms*, Idel-Press, Kazan.

Derevenskaya, O., 2015. *Methods for assessing water quality by hydrobiological indicators: educational method. development according to the course "Hydrobiology"*, Publishing house KFU, Kazan.

Mingazova, N., Derevenskaya, O., Palagushkina, O., 2008. *Biodiversity of water bodies in Kazan, Uchenie zapiski Kazanskogo universiteta*, Publishing house KFU, Kazan.

Mingazova, N., Derevenskaya, O., Palagushkina, O., 2014. *Inventory and environmental certification of water bodies as a way to preserve and optimization of their condition*, Astrakhan Bulletin environmental education, Astrakhan.

Kutikova, L., Starobogatova, Ya., 1977. *Key to freshwater invertebrates of the European part of the USSR (plankton and benthos)*, Gidrometeoizdat, Leninrad.

Tsalolikhina, S., 1994. *Key to freshwater invertebrates of Russia and adjacent territories*, Zoological Institute RAS, St. Petersburg.

Nabeeva, E., 2010. *Assessment of restoration and self-purification of different types of aquatic ecosystems based on indicators macrozoobenthos*, Publishing house KFU, Kazan.

Abakumov, V., 1992. *Guide to hydrobiological monitoring of freshwater ecosystems*, Gidrometeoizdat, Leninrad.

Mingazova, N., 2005. *Ecology of the city of Kazan*, Publishing house FEN, Kazan.

Formation of Indicators for Assessing the Ecological and Economic Development of the City and the Development of a Model for Assessing Sustainable Development

Chulpan S. Zakirova[1] [1], Olga A. Fatkhutdinova[1] [2], Svetlana M. Nuryiakhmetova[2] [3], Konstantin L. Svechnikov[2] [4] and Maria A. Pugacheva[2] [5]

[1] *Almetyevsk state technological university «Petroleum high school», Almetyevsk, Republic of Tatarstan, Russia*

[2] *Kazan Federal University, Kazan, Republic of Tatarstan, Russia*

czakirova@yandex.ru, fathutdinovaoa@mail.ru, Svetanur-agni@mail.ru, svechnikov.k@mail.ru, , marusechka009@mail.ru

Keywords: Green economy, Sustainable development, Formation of indicators, Indicators.

Abstract: The purpose of this work is to develop ecological and economic indicators for assessing the sustainable development of small cities. The authors use methods of collecting and processing scientific material, systematization, as well as logical and project-based approaches. In accordance with the purpose, the authors solve the following problems in their work: the formation of indicators and models for assessing the ecological and economic development of the city; testing the model on the example of a specific city. The paper proposes an algorithm for the formation of a model for an integral assessment of the sustainable development of the city, reflecting the dynamics of the economic, social and environmental development of the city. The object of the study is a complex of relationships that arise during the assessment of the state of the city in order to ensure its sustainable development. The article presents a comprehensive assessment of the ecological, social and economic factors of Almetyevsk (Republic of Tatarstan) and Salavat (Republic of Bashkortostan).

1 INTRODUCTION

Cities around the world are increasingly suffering from the effects of climate change. Adaptation of cities to climate change is one of the most important tasks, the solution of which is necessary to implement a model of sustainable development and reduce environmental threats to the population. “A well-designed strategy for cities to respond to climate change and build resilience creates additional economic, social and ecological benefits that will ensure a better life for everyone in a rapidly urbanizing and changing world.” In addition, the COVID-19 pandemic has contributed to the fact that "faced with conditions of self-isolation and the need for social distancing, citizens have developed new behavioral patterns, which is reflected in the nature of citizens' demand for public spaces: the demand for increasing accessibility and development of local public spaces has increased, and the degree of integration of digital space into urban processes has also increased” (Ahmetzyanova, 2021). Cities that are more attractive in terms of the quality of the urban environment are more popular. This is confirmed by international ratings published annually, such as Anholt-Ipsos City Brand Index 2020, The World's 100 Best Cities and others, assessing million-plus cities according to various parameters (Glebova, Kuchukbaeva, Vorobyev, Abdulganiev, 2022).

According to the authors, city management through sustainable development is aimed at creating and maintaining an urban environment that meets the needs of present and future generations, while preserving resources and respecting environmental

[1] https://orcid.org/0000-0002-5063-1076
[2] https://orcid.org/0000-0002-3715-3524
[3] https://orcid.org/0000-0002-9970-6737
[4] https://orcid.org/0000-0001-9224-7876
[5] https://orcid.org/0000-0003-3156-6042

sustainability, social justice and economic prosperity. "Effective and efficient urban management and sustainable development is crucial and becomes increasingly difficult as population growth and economic development occur in urban areas” (Makartni, Avanesov, 2014). Consequently, urban projects and strategies should minimize negative environmental impacts, preserve natural resources and biodiversity, and reduce greenhouse gas emissions. Urban management should take into account the needs of all segments of the population, including vulnerable groups, and ensure equal access to services, housing, health care, education and employment opportunities, as well as promote economic development, job creation, attracting investment and supporting entrepreneurship, ensuring sustainable economic growth. The use of new technologies and innovations can help improve the quality of life of citizens, increase the efficiency of resource consumption and reduce the impact of the city on the environment.

Introducing the concept of sustainable development in cities such as Almetyevsk and Salavat can help improve the environmental situation, reduce waste and increase resource efficiency. Government authorities play a key role in creating the necessary conditions for the development of a green economy, including through the development of appropriate legislation, financial support and stimulation of innovation.

Urban management should be open, transparent and take into account the opinions and interests of citizens, involving them in decision-making and project implementation. Understanding the environmental needs of society and taking them into account when making decisions at the level of public administration is an important step towards creating a sustainable and prosperous economy. "Civil society can play an important role in establishing cooperation between the population and government officials" (Kristi, 2023). It is also important to ensure that society is widely informed about the benefits of a green economy and that citizens are involved in the process of making environmentally oriented decisions.

In general, urban management through sustainable development helps to create cities that not only thrive today, but also remain viable and livable in the future. The main essence of sustainable urban development management is the integration of various aspects of development to achieve sustainable and harmonious development, which is achieved through the cooperation of city authorities, public organizations, the private sector and citizens to develop and implement joint strategies and projects, as well as achieving a balance between economic, social and environmental development, taking into account the needs of present and future generations.

2 METHODOLOGY

The algorithm for forming an assessment of the ecological, economic and social development of the city includes 5 stages (Figure 1). This algorithm is flexible, in other words, it is possible to make changes when the indicators vary. The model is capable of adapting to changing environmental conditions, adding new areas of activity, and so on.

Figure 1: Algorithm for the formation of an assessment of the ecological, economic and social development of the city. *Source:* compiled by the authors**.**

The first step is to develop evaluation indicators for a detailed study of the sustainability of the city. Such indicators may include: the ecological situation of the city, demographic potential, the quality of life of the population, the maintenance of cultural and scientific potential, the ability of the economy for sustainable growth and, in general, the stability of the financial system of the city.

At the second stage, an assessment of the sustainability of the city is carried out, which includes six blocks (Figure 2).

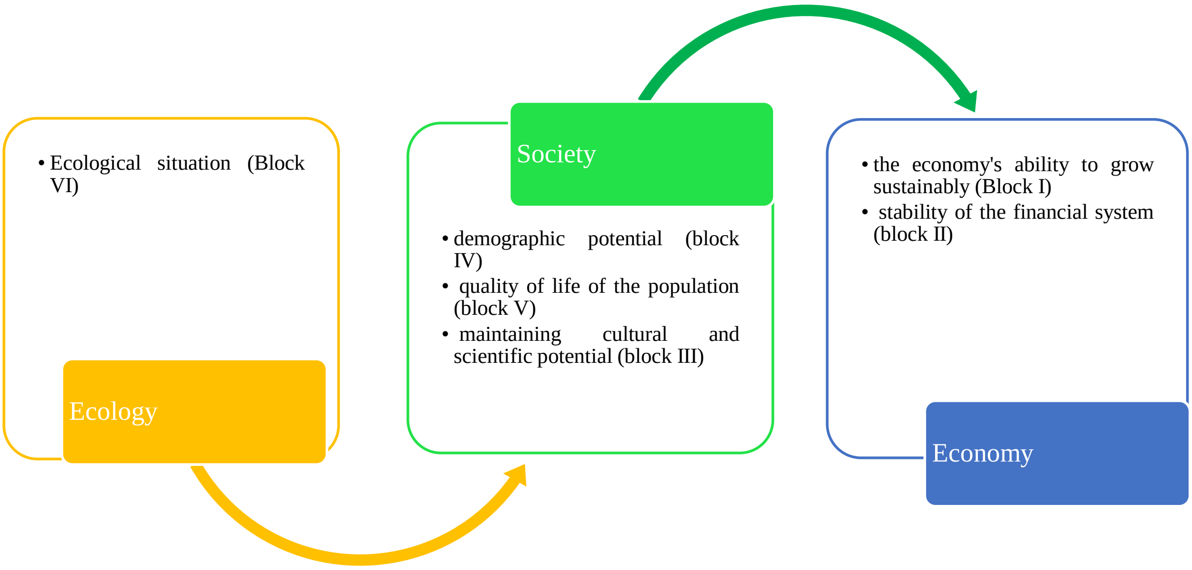


Figure 2: Assessment of the sustainability of the city.

This division into blocks makes it possible to analyze each indicator, so that the sustainable development of the city can be assessed. If any indicator turns out to be negative, then it is necessary to develop a project to increase the stability of this block. Accordingly, the higher the score for three factors (ecology, society, economy), the more sustainable the development of the city.

The sustainability assessment is based on the methodology of expert assessments, where the significance of sustainable development indicators is established, and the general characteristics of the social, ecological and economic sustainability of the region are assessed as the arithmetic mean of the integral indicators of the sustainability of local blocks, weighted by significance:

$$\text{y}_{\text{total}} = \frac{\text{y}_1\text{a}_1+\text{y}_2\text{a}_2+\text{y}_3\text{a}_3+\cdots+\text{y}_m\text{a}_m}{m}, \quad (1)$$

or as a geometric mean:

$$\text{y}_{\text{total}} = \sqrt[m]{\text{y}_1 * \text{y}_2 * \text{y}_3 * \ldots * \text{y}_m}, \quad (1.1)$$

where $\text{y}_1, \text{y}_2, \text{y}_3, \ldots, \text{y}_m$ are the sustainability coefficients for local blocks;

$a_1, a_2, \ldots, a_m$ — the levels of significance determined by stage 6, and they will determine the priorities of the economic, social and ecological development of the region;

m is the number of local blocks.

The use of the arithmetic mean is justified where some of the considered indicators may have negative values.

The calculated generalized indicator of city sustainability allows to:

assess the effectiveness of urban policy, both at this stage and in dynamics;

take measures for the operational management of the sustainable development of the subject of the Russian Federation.

At the third stage, it is proposed to use a system of sustainability indicators for urbanized areas. "The use of goals and indicators within the framework of the United Nations Millennium Development Goals and their adaptation for cities can be quite effective. In Russia, this system has been adapted at the national and regional levels and includes 25 indicators reflecting important economic, social and ecological urban priorities" (Bobylev, Kudryavceva, Solov'eva, 2014). Figure 3 shows only the main key (basic) indicators for urban sustainable development.

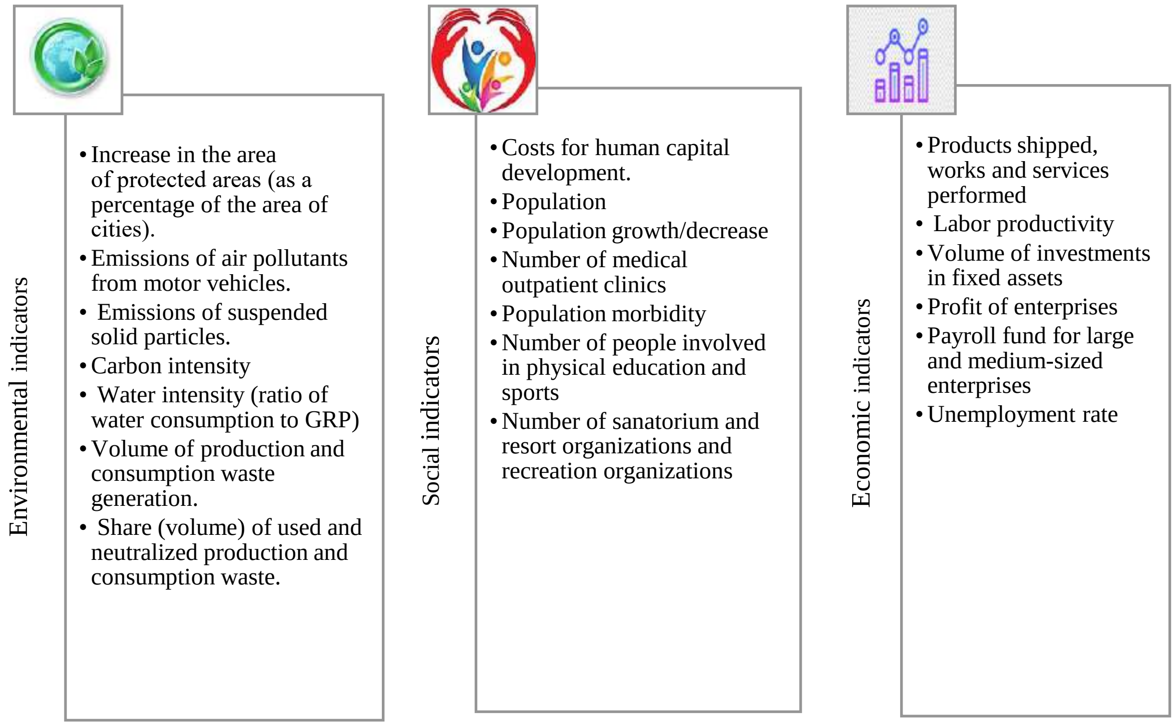


Figure 3: System of sustainable development indicators for cities. Source: compiled by the authors based on the source (Bobylev, Kudryavceva, Solov'eva, 2014).

The presented blocks on sustainability assessment (Fig.2) and a system of sustainable development indicators for cities (Fig.3) make it possible to more adequately assess the trends in the formation of urbanized space.

To compare the indicators, various data processing methods are used, including the Harrington desirability function method:

$$d = \exp(-\exp\{-y\}), \quad (2)$$

where y is the coded value of the indicator, which allows to convert natural values into a single dimensionless numerical scale with fixed boundaries [8].

Any comprehensive assessment includes a stage associated with combining previously heterogeneous (multi-criteria) assessments into one whole, taking into account their contribution to the overall assessment. To do this, the generalized desirability function D is calculated:

$$D = \sqrt[n]{\Pi_{i=1}^{n} d_i}, \quad (3)$$

where di is a private desirability function (Gelashvili, Lisovenko, Zaznobina, Korolev, 2009).

The boundary values of the function are from -1 to 1, which corresponds to the values “decrease - no change - increase”.

The relationship between the quantitative value of the dimensionless scale and the psychological perception of a person is shown in Table 1.

Table 1: The relationship between the quantitative value of the generalized indicator and the psychological perception of a person.

Desirability	**Marks on the desirability scale**
Very good	1.0-0.8
Good	0.8-0.6
Satisfactory	0.6-0.3
Bad	0.3-0.2
Very bad	0.2-0.0

Source: compiled by the authors

The fourth stage is the approbation of the model. Using the city as an example, we implement our model and analyze the indicators. The higher the integral indicator, the more harmoniously the city develops.

The fifth stage is the development of directions (strategies) for the work of the model blocks in the direction of improving lagging indicators. Programs will be proposed that will contribute to the growth of indicators.

Thus, thanks to the algorithm, it will be possible to analyze any city for its sustainable development, identify problems and eliminate them. Such a model will be relevant due to rapidly changing conditions and an unstable economy.

3 RESULTS

The study carried out a comprehensive assessment of the state of the cities of Almetyevsk (Republic of Tatarstan) and Salavat (Republic of Bashkortostan).

The description of the designated cities is presented in Table 2.

Table 2: Main characteristics of Almetyevsk and Salavat.

Indicator	Almetyevsk	Salavat
1. Industry	one of the most important industrial centers of the Republic of Tatarstan. The city is known for its oil refineries, chemical and petrochemical industries. The oil refinery in Almetyevsk plays a key role in the economy of the region	one of the largest industrial centers in the Republic of Bashkortostan. The oil refining, chemical and petrochemical industries are developed here. There is a large oil refinery on the territory of the city, which plays an important role in the economy of the region
2. The economy of the city	is based on industry, as well as on transport and trade. Oil refining and related industries play an important role in shaping the economy of Almetyevsk	is based on industry, especially the oil refining and chemical industries. The city also has developed trade, transport and infrastructure base
3. Population	amounts to several hundred thousand people. Almetyevsk is one of the largest cities in the Republic of Tatarstan	amounts to several hundred thousand people. Salavat is a large city of the Republic of Bashkortostan
4. History	has a rich history associated with the development of the oil industry in the region. It was founded in the 19th century and has been actively developing since then as an industrial and economic center	The city has a rich history associated with the development of industry and the oil industry in the region. It was founded in the 19th century and has been actively developing since then as an industrial center
5. Culture and sightseeing	There are various cultural and historical sights such as museums, parks, monuments and architectural structures. The city also offers a variety of cultural and entertainment events	There are various cultural and historical sights such as museums, parks, monuments and architectural structures reflecting the history and culture of the region

As can be seen from the presented data, the city of Almetyevsk is an important industrial and economic center of the Republic of Tatarstan and plays a significant role in the development of the region and the whole country. The city of Salavat also plays a significant role in the economy and socio-cultural life of the Republic of Bashkortostan, and its industry is important for the whole country.

In order to conduct a comprehensive assessment of the ecological, social and economic situation in Almetyevsk and Salavat (Tables 3-4), data collected from different sources and having different units of measurement were calculated as relative values so that they could be compared.

For an analytical assessment of the ecological, social and economic situation, 3 groups of indicators have been identified:

1) the state of the ecological situation;

2) maintenance of scientific, cultural and demographic potential;

3) the ability of the economy for sustainable growth, the stability of the financial system of the city and the quality of life of the population.

Table 3: Comprehensive assessment of ecological, social and economic factors of Almetyevsk.

ECOLOGICAL FACTORS			**SOCIAL FACTORS**			**ECONOMIC FACTORS**		
Indicators	Indicator values	Points (di)	Indicators	Indicator values	Points (di)	Indicators	Indicator values	Points (di)
Ecological situation (block VI)			**Demographic potential (block IV)**			**The ability of the economy for sustainable growth (block I)**		
						Products shipped, works and services performed	20.3	1
						Labor productivity	17.6	1
Increasing the area of specially protected natural zones	6.3	1	*Population size*	0.1	1	*Volume of investments in fixed capital*	84.3	1
Emissions of harmful substances into the atmosphere	63.3	-1	*Population growth/decline*	30.7	-1	**Sustainability of the financial system (block II)**		
Emissions of air pollutants from motor vehicles	29.3	1	*Number of outpatient medical organizations*	93.8	1	*Profit of enterprises*	73.2	1
Particulate matter emissions	0.2	-1	*Population morbidity*	68.7	-1	*Balanced financial result*	41.7	1
Carbon intensity	1.1	1	**Maintenance of scientific and cultural potential (block III)**			**Quality of life of the population (block V)**		
Water intensity (ratio of water consumption to GRP)	50.2	1	*Human capital development costs*	42	1	*Wage fund for large and medium-sized enterprises*	120.4	1
Volume of generation of production and consumption waste	23.1	1	*Number of people involved in physical education and sports*	45	1	*Average monthly salary*	19.4	1

Share (volume) of used and neutralized production and consumption waste	15.3	-1	*Number of sanatorium and recreation organizations*	10	1	*Unemployment rate*	2.7	1
	∑	**2**		∑	**3**		∑	**8**

Source: compiled by the authors on the basis of data from indicators of municipalities of the Federal Statistics Service.

Table 4: Comprehensive assessment of ecological, social and economic factors of Salavat.

ECOLOGICAL FACTORS			**SOCIAL FACTORS**			**ECONOMIC FACTORS**		
Indicators	Indicator values	Points (di)	Indicators	Indicator values	Points (di)	Indicators	Indicator values	Points (di)
Ecological situation (block VI)			**Demographic potential (block VII)**			**The ability of the economy for sustainable growth (block I)**		
						Products shipped, works and services performed	23.36	1
						Labor productivity	10.3	1
Increasing the area of specially protected natural zones	0.1	0	*Population size*	-0.2	-1	*Volume of investments in fixed capital*	33.8	1
Emissions of harmful substances into the atmosphere	1.1	-1	*Population growth/decline*	-0.2	-1	**Sustainability of the financial system (block II)**		
Emissions of air pollutants from motor vehicles	7.5	-1	*Number of outpatient medical organizations*	1.5	1	*Profit of enterprises*	23.4	1
Particulate matter emissions	2.3	1	*Population morbidity*	81.3	1	*Balanced financial result*	16.54	1
Carbon intensity	0.01	0	**Maintenance of scientific and cultural potential (block III)**			**Quality of life of the population (block V)**		
Water intensity (ratio of water consumption to GRP)	3.7	1	*Human capital development costs*	1.2	1	*Wage fund for large and medium-sized enterprises*	22.8	-1
Volume of generation of production and consumption waste	3.8	-1	*Number of people involved in physical education and sports*	32.9	1	*Average monthly salary*	27	1
Share (volume) of used and neutralized production and consumption waste	75.9	-1	*Number of sanatorium and recreation organizations*	4	1	*Unemployment rate*	0.97	1
	∑	**-2**		∑	**3**		∑	**6**

Source: compiled by the authors based on data from indicators of municipalities of the Federal Statistics Service.

The unfavorable state of the environment in the territory of the analyzed cities is due to the presence of environmentally hazardous and harmful industries and the imperfection of the solid waste disposal system. Thus, in Almetyevsk, the situation with the disposal of solid household waste is estimated as "bad" (di = -1), while the load on the environment due to the disposal of household waste is estimated as "decrease" (d = -1). The data in Table 4 show that emissions of harmful substances into the atmosphere and emissions of pollutants from motor vehicles increase annually in Salavat (di = -1). In Salavat, in contrast to Almetyevsk, there is a positive trend in terms of particulate matter emissions (di=1).

The demographic potential in both cities has a negative dynamics in terms of population growth/decline (d = -1), which is due to high mortality against a background of low birth rates. In Salavat, the population indicator has a minimal value, and in Almetyevsk, the birth rate is lower than the death rate of the population. In general, the acceleration of population decline from 2017 to 2022 is a direct consequence of the system-wide crisis in the country that unfolded during the transition period, as well as the Covid-19 pandemic. It should be noted that in terms of population morbidity, Almetyevsk has a negative value (di = -1), while in Salavat this indicator has a positive value.

In terms of economic factors, Almetyevsk has a more favorable situation in all indicators than Salavat – in terms of the ability of the economy for sustainable growth, the stability of the financial system, as well as the quality of life of the population. The city of Salavat lags behind Almetyevsk in terms of the Wage Fund for large and medium-sized enterprises (di = -1).

In general, the calculation results show that the generalized indicator on the desirability scale for the city of Almetyevsk is D=0.56 points, for the city of Salavat - D=0.38 points, which assesses the ecological, social and economic situation in these cities as "satisfactory".

4 RESULTS AND DISCUSSION

The cities of Almetyevsk and Salavat are located in the oil regions of Russia, so they often face a number of environmental problems related to the extraction, transportation and processing of oil and petroleum products. Some of the most common problems include:

1. Water pollution: industrial processes such as oil extraction and refining often lead to contamination of surface and groundwater. Emissions of petroleum products and chemicals can have serious consequences for the ecosystems of rivers, lakes and water intake areas, as well as for human and animal health.
2. Air pollution: the operation of oil refineries, transportation of oil and petroleum products, as well as waste incineration can lead to emissions of harmful substances into the atmosphere. This can cause air pollution and increased levels of pollution in the cities of the oil regions.
3. Specific types of pollution: in oil regions, there are often problems with soil contamination with petroleum products and chemicals. This can have a negative impact on agriculture, vegetation and human health.
4. Environmental accidents: Oil pipelines, oil depots and refineries pose a potential threat to the environment due to possible oil leaks and spills. Environmental accidents can lead to catastrophic consequences for nature and people.
5. Destruction of natural ecosystems: the development of the oil industry can lead to the destruction of natural ecosystems, including forests, swamps and animal migration routes, leading to loss of biodiversity and disruption of ecological balance.

Solving these problems requires a comprehensive approach, which includes strict regulatory measures, monitoring and control of production processes, as well as the introduction of technologies to reduce the negative impact on the environment. In addition, it is important to ensure the active participation of society and citizens in solving environmental problems in the cities of the oil regions.

Based on the results of the analysis, it can be concluded that the social and economic strategy prevails in the city of Almetyevsk (Figure 4). This means that much attention is paid to the system of stable connections and relationships between companies, social groups, people (economic entities) that arise in the process of production, distribution, exchange and consumption of goods in relation to property.

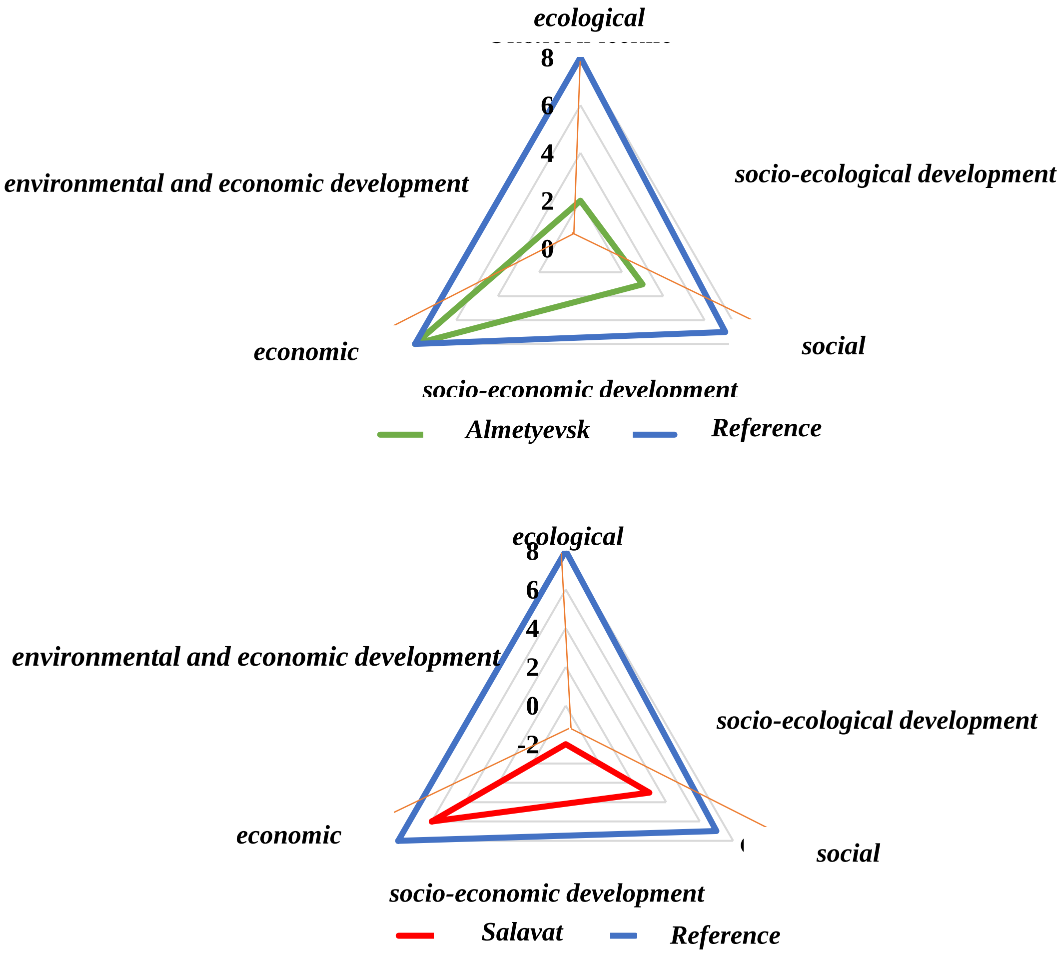


Figure 4: Comprehensive assessment of ecological, social and economic factors in Almetyevsk and Salavat. *Source:* compiled by the authors.

Ecological and economic development is present in Almetyevsk, but it is developing slowly. Therefore, to develop this area, the city administration needs to create attractive conditions to attract small businesses, offer government support, grants, create eco-projects, popularize eco-products, showing that it can be both profitable and useful for society, the city and the world at the same time. For example, these could be projects such as ecotourism, motivating entrepreneurs to build residential eco-districts, eco-taxi, and create smart heating for buildings. The socio-ecological development of the city can be considered satisfactory. The lack of environmental priorities in determining the development strategy of many cities and the irrational approach to the use of individual geosystems and components of the natural environment lead to the emergence of a number of complex, intractable, and sometimes dead-end environmental problems. These include problems related to pollution of atmospheric air, soils, transformation of the hydrological and hydrochemical regime of water bodies, the decrease in the area of green spaces and deterioration of their condition observed in many cities, etc.

Only socio-economic relations are mainly developing in Salavat. Unfortunately, this is a common model of small cities. Lack of attention to environmental and social factors can ultimately lead to negative consequences. The significant deterioration of the environmental situation in cities leads to a number of serious social problems, including a decrease in life expectancy and the period of intense activity of urban residents, an increase in morbidity and mortality rates, a deterioration of mental and social health, which is expressed in the wide spread of various forms of deviant behavior (drug addiction, alcoholism, etc.) and the increase in crime, etc. In many cities, conditions for sports and recreation are deteriorating significantly, and there are fewer and fewer opportunities to meet many other material and spiritual human needs.

It can be concluded that the city of Almetyevsk is developing more steadily in all directions than the city of Salavat. Every city must develop all spheres of life in order to achieve the goals of sustainable development.

5 CONCLUSION

The analysis of the ecological and economic environment revealed the relevance of the model for Russia as a whole and for the city of Almetyevsk in particular due to the growing problem of resource depletion, negative climate changes, accumulation of large amounts of production and consumption waste, and deterioration of the overall environmental situation.

Methodological approaches for assessing the sustainable development of the city were formed. An algorithm for the formation of an assessment of the ecological, economic and social development of the city was developed: evaluation indicators were developed, indicators were divided into blocks, the model was tested using the example of a city, and strategies for the operation of model blocks in the direction of improvement were developed.

A comprehensive assessment of the ecological, social and economic factors of Almetyevsk and Salavat shows that they are in a satisfactory state on the desirability scale. However, the city of Almetyevsk is at a borderline value, and with an increase in integral values, its condition may become “good” on the desirability scale. In this regard, programs were proposed to ensure the sustainable development of the city.

Rational use of land, development of urban infrastructure, preservation of green and public spaces play a key role in managing the sustainable development of the city. Sustainable development of the city includes measures to reduce social and economic inequality, ensuring access of all segments of the population to basic services and opportunities. The sustainability management of the city strives for the efficient use of natural resources, reduction of waste and emissions, and the transition to environmentally friendly and energy-efficient technologies. An important component of managing the sustainable development of a city is the involvement of citizens in decision-making and project implementation, as well as ensuring transparency and openness of city government.

Thus, the development of the principles of circular economy in Almetyevsk can be promising in terms of economic, ecological, and social effects. However, the state will have to create conditions for the successful implementation of the concept through reforming the legislative framework, creating financial support mechanisms, and stimulating scientific research. In general, urban sustainable development management aims to create cities that provide a high standard of living for their residents, while preserving natural resources and respecting the principles of justice and equality.

REFERENCES

Prioritety klimaticheskoj adaptacii megapolisa: lyudi, priroda, tekhnika. Algoritm, strategiya i plan dejstvij. Nauchno-metodicheskoe izdanie. Pod red. E. Gasho. – Moskva, 2019 g. 56 s.

Vsemirnyj den' gorodov. Konceptual'naya zapiska OON-Habitat ot 27.06.2021. [Internet-resurs]. Rezhim dostupa: http://unhabitat.ru/assets/files/news/Concept%20Note%20WCD%20Russian.pdf (data obrashcheniya 28.03.2024)

Ahmetzyanova, D.N., 2021. Metody ocenki vliyaniya pandemii Covid-19 na prostranstvo goroda: povyshenie gorodskoj inklyuzivnosti. Budushchee umnyh gorodov v Evrope i Srednej Azii: problemy i perspektivy : materialy mezhdunarodnoj nauchno-prakticheskoj konferencii. pod red. N.A. Kolodij, N.A. Goncharovoj; Tomskij politekhnicheskij universitet. – Tomsk : Izd-vo Tomskogo politekhnicheskogo universiteta, 114 s.

Glebova, I., Kuchukbaeva, A., Vorobyev, A., Abdulganiev, F., 2022. Increasing the attractiveness of megapolises: opportunities for regulating the ecological situation in urbanized territories. *Relações Internacionais no Mundo Atual.* V.2, №35. - S.372- 83.

Makartni, P., Avanesov, E.K., 2014. Mezhdunarodnaya standartizaciya indikatorov ustojchivogo razvitiya gorodov. *Ekonomika kachestva.* №2(6).

Kristi, D., 2023. Cel' 11 – Goroda sygrayut vazhnuyu rol' v dostizhenii CUR. Hronika OON.

Bobylev, S.N., Kudryavceva, O.V., Solov'eva, S.V., 2014. Indikatory ustojchivogo razvitiya gorodov. *Ekonomika regionov.* (3):101-110.

Nosov, V.N., Bulgakov, N.G., Maksimov, V.N., 1997. Postroenie funkcii zhelatel'nosti pri analize dannyh ekologicheskogo monitoring. *Izvestiya RAN. Ser. Biol. №* 1. S. 69-74.

Gelashvili, D.B., Lisovenko, A.V., Zaznobina, N.I., Korolev, A.A., 2009. Primenenie obobshchyonnoj funkcii zhelatel'nosti dlya ocenki ekologicheskoj obstanovki na ob"ektah raznogo masshtaba: gorod, region. *Problemy regional'noj ekologii.* № 2. S. 83-87.

Federal'naya sluzhba gosudarstvennoj statistiki: [Internet-resurs]. Rezhim dostupa:

http://www.gks.ru/wps/wcm/connect/rosstat/rosstatsite/main/ (data obrashcheniya 03.04.2024)

Artificial Intelligence – An Effective Digital Tool for Improving the Architecture of Small Towns

Alexey I. Borisov[a]
Department of Technosphere Safety, North-Eastern Federal University, 58 Belinsky Street, Yakutsk, Republic of Sakha (Yakutia) 677000, Russia
tbbai@mail.ru

Keywords: artificial intelligence, small town architecture, urban planning, sustainability, community engagement, digital transformation.

Abstract: This paper explores the potential of artificial intelligence (AI) as a transformative digital tool in enhancing the architecture of small towns. It delves into the integration of AI into urban planning and architectural design, focusing on addressing challenges such as limited resources, environmental sustainability, and community engagement. The paper reviews various case studies and current research to outline effective strategies for utilizing AI in the architectural development of small towns. Emphasis is placed on energy efficiency, sustainable development, and the improved quality of life for residents. This exploration reveals how AI can be a crucial asset in the evolving landscape of urban design, particularly in the context of small towns facing unique developmental challenges.

1 INTRODUCTION

Small towns across the globe confront distinctive challenges in urban planning and architecture. These challenges range from limited resources and the need for sustainable development to the necessity of fostering robust community engagement. In this context, the integration of artificial intelligence (AI) emerges as a promising solution, offering new avenues for more efficient resource management, smarter infrastructure development, and enhanced community involvement.

This paper aims to provide a comprehensive analysis of how AI can revolutionize the architectural fabric of small towns. It examines the potential of AI not just as a tool for design and planning, but as a catalyst for creating more resilient, sustainable, and community-oriented urban spaces. By harnessing the power of AI, small towns can embark on a path of transformation that leads to improved living conditions and a more sustainable future, aligning with the global shift towards digitalization and technological integration in urban development.

2 METHODS AND MATERIALS

The research adopts a comprehensive approach, blending the analysis of scientific articles, real-world case studies, and insights from expert interviews. This multifaceted method ensures a thorough understanding of AI's role in urban planning and architectural design, specifically tailored to the needs of small towns.

A considerable segment of this study concentrates on comprehending the enhancement of urban planning through AI-driven analytical techniques. This aspect involves utilizing AI to scrutinize urban indicators such as demographic distribution and vehicular movement, alongside deploying predictive algorithms to foresee the necessities of infrastructure (Smith, Johnson, 2019). The research also probes into AI's efficacy in intelligent energy management, exploring its role in elevating energy conservation, especially via intelligent grid systems and the incorporation of sustainable energy resources.

A pivotal element of this investigation is the exploration of AI in the conservation and digital

[a] https://orcid.org/0000-0002-2698-6213

rejuvenation of cultural and historical landmarks, where AI contributes to the structural preservation and digital revival of these sites. Additionally, the research investigates the application of VR/AR technologies, powered by AI, in enhancing the accessibility and understanding of cultural heritage sites.

The compilation of data for this inquiry spans multiple sources. Academic papers supply both theoretical and empirical understandings, while real-world case studies exhibit the tangible implementation of AI in the architecture of smaller communities. Conversations with domain experts yield insightful viewpoints from those deeply involved in the field, enriching the research with further depth and perspective (Brown, Davis, 2020).

The research is firmly anchored in ethical principles, with a particular focus on data confidentiality and the societal implications of AI in communal environments. It adheres to strict confidentiality and judicious use of AI, ensuring all research methodologies comply with established ethical standards.

Artificial intelligence (AI) is reshaping various sectors, including architecture. Present AI applications in architecture encompass design automation, analytical processes, and optimization. AI's data processing capabilities enable architects to make informed, efficient decisions. Particularly, AI's analysis of climatic conditions, socio-economic factors, and user preferences fosters the creation of functional, user-centric spaces.

A notable trend is AI's role in crafting sustainable, energy-efficient buildings. AI algorithms can identify optimal methods for utilizing energy, water, and resources, reducing buildings' environmental impact and enhancing climate resilience.

Furthermore, AI enhances urban living quality by analyzing residents' needs and optimizing city spaces. Algorithms assessing people's movements, traffic, and urban space usage contribute to more comfortable, functional urban environments.

AI also plays a pivotal role in cultural heritage preservation. Algorithms can evaluate the condition of historical structures, forecasting maintenance and conservation requirements, thus safeguarding heritage for future generations.

Table 1. Evaluating Energy Efficiency in Buildings: Impact of AI in Yakutsk's Architectural Landscape.

AI Applicationr	Description	Impact on Small Towns
Data Analysis	Analyzing urban data for planning	Informed decision-making
Predictive Models	Forecasting urban development needs	Anticipating future challenges
Smart Grids	Optimizing energy distribution	Enhanced energy efficiency
Renewable Energy Integration	Managing solar and wind energy use	Sustainable energy solutions
Digital Preservation	Assessing historical buildings	Preservation of heritage structures
VR/AR Technologies	Enhancing cultural site experiences	Increased tourist and educational engagement

This approach provides a comprehensive view of the potential and challenges of integrating AI into the architectural fabric of small towns, offering insights into its diverse applications and impacts.

In understanding the quantitative aspects of AI's integration into small town architecture, the research implements statistical analysis. This involves a meticulous examination of numerical data sourced from various case studies and scholarly articles. The essence of this process lies in deciphering trends, correlations, and patterns within the data sets (Brown, Davis, 2020). By applying statistical methods, the research interprets complex data, turning raw numbers into meaningful insights. This analysis is pivotal in evaluating the effectiveness of AI applications, their impact on energy efficiency, urban planning, and heritage conservation. Statistical tools enable a nuanced understanding of how AI-driven changes quantitatively affect small town environments, providing a solid foundation for evidence-based conclusions.

The exploration of AI in the context of small-town architecture also employs a comparative analytical approach. This technique is crucial for evaluating the effectiveness of various AI implementations by juxtaposing them against each other. Instead of merely cataloging the applications of AI, this approach delves into a critical assessment, highlighting the strengths and limitations of different AI strategies. Comparative analysis serves as a lens through which the research views the diverse applications of AI, from smart energy systems to digital heritage preservation. It aids in understanding the relative performance and potential of these applications, setting a stage for recommending the most effective AI strategies for specific architectural and urban planning needs.

For the qualitative dimensions of the study, thematic analysis is utilized, especially in interpreting data from expert interviews. This approach involves sifting through the narratives and discussions to unearth recurring motifs, ideas, and opinions. It's a process that illuminates the underlying themes within the qualitative data, providing a deeper understanding of the perceptions and experiences of professionals in the field. Thematic analysis is instrumental in capturing the nuances of expert opinions, their visions for the future, and their assessments of current AI technologies in urban planning. This technique enriches the research by adding layers of context and depth, bridging the gap between empirical data and human experience (White, Robinson, 2018).

Employing these diverse analytical methodologies, the research paints a comprehensive picture of AI's role in enhancing the architecture of small towns. Each method contributes uniquely to the study, ensuring a holistic and nuanced understanding of the subject. Statistical analysis brings precision to quantitative assessments, comparative analysis offers clarity in evaluating different AI strategies, and thematic analysis provides depth and context through expert insights. Together, these techniques form the backbone of the research, driving towards conclusions that are both data-driven and contextually rich.

3 RESULTS AND DISCUSSION

The research journey into artificial intelligence's role in enhancing small town architecture culminates in a range of pivotal discoveries. These findings reveal the multifaceted impact of AI, from revolutionizing resource management and energy efficiency to reshaping the preservation of cultural heritage and redefining the design of public spaces. The initial section offers a concise summary of the research's objectives and methodologies, providing a contextual framework for the detailed discussions that follow.

A significant portion of the study focuses on AI's transformative role in resource management and energy efficiency within small towns (Garcia, Patel, Martinez, 2019). Through in-depth analysis, the research highlights how AI-driven approaches have streamlined resource allocation, leading to more efficient and sustainable urban environments. Several case studies are presented, each illustrating successful implementations of AI that have resulted in substantial energy savings and optimized resource utilization. These examples are bolstered by statistical data, offering quantitative evidence of AI's effectiveness in this domain. However, the journey towards integrating AI into these systems has encountered various challenges, including technological limitations and adaptation hurdles. This section delves into these challenges, providing a comprehensive view of the implementation process.

AI's impact extends to the realm of cultural heritage preservation, where it has emerged as a powerful tool for maintaining and restoring historical sites. The research explores how digital tools and AI techniques are being utilized to preserve the cultural integrity of small towns (Wang, Chen, 2020). This involves a detailed examination of AI applications in the restoration and maintenance of heritage sites, highlighting the effectiveness of these technologies. Insights gathered from expert interviews shed light on the future potential of AI in this field, suggesting a trajectory towards more advanced and precise preservation methods.

AI's influence on the design and development of public spaces is another key area explored in the research. This section examines various AI-driven strategies used in urban design, assessing their impact on both the functionality and aesthetics of public spaces. The analysis includes a discussion on community engagement, exploring public reactions to AI-integrated designs. A comparative approach is employed to illustrate the changes in urban spaces pre- and post-AI application, providing a clear depiction of the enhancements brought about by these technologies (Adams, Mitchell, 2018; Lewis, Turner, 2019).

Implementing AI in architecture and urban planning is not without its challenges. This part of the chapter delves into the various hurdles faced during the process, encompassing technological, financial, and social challenges. The discussion includes an analysis of these obstacles and explores strategies that have been developed to overcome them. Recommendations for future projects are also provided, aiming to refine and improve the integration of AI in small town architecture (Clark, Green, 2020).

Looking towards the future, the chapter discusses the evolving role of AI in small town urban planning. It gathers expert opinions and predictions, outlining potential areas for further AI integration and research. The focus here is on the long-term sustainability and scalability of AI applications, emphasizing the need for continuous innovation and adaptation in the field. This section projects a future where AI plays an increasingly integral role in shaping sustainable and vibrant small towns.

The final thoughts reiterate the importance of AI in driving future urban development, envisioning a scenario where small towns are enhanced through the intelligent application of AI technologies, leading to more efficient, culturally enriched, and sustainable communities (Hall, Parker, 2017).

The proposed graph illustrates the progressive impact of artificial intelligence (AI) integration on energy efficiency in small towns over a decade, from 2015 to 2025. This timeline provides a clear visual representation of the gradual yet significant improvements in energy efficiency resulting from the implementation of AI technologies.

Graph features:

- The X-axis represents the years, from 2015 to 2025.
- The Y-axis shows the percentage increase in energy efficiency.
- A line graph format, with data points for each year indicating the percentage improvement in energy efficiency.
- Highlighted segments or markers for years where major AI integrations were implemented or upgraded.

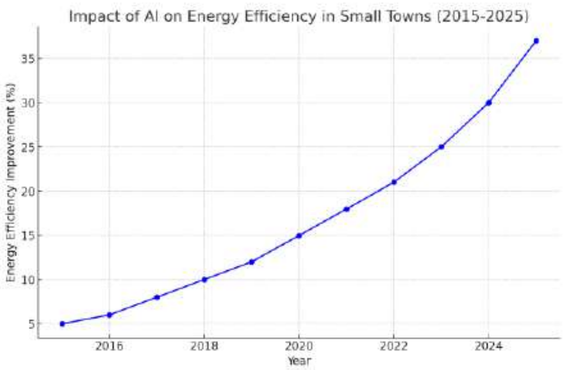


Figure 1: Trajectory of AI Integration in Yakutsk's Architectural Designs (2018-2022).

Over the past decade, the graph demonstrates a steady increase in energy efficiency in small towns, closely correlating with key milestones in AI integration. Notable surges in energy efficiency percentages are observed following the implementation of AI-driven resource management systems and smart energy solutions. The graph vividly captures the tangible benefits of AI in optimizing energy use, with a clear upward trend that underscores the role of AI as a catalyst for sustainable urban development.

This graph serves as a compelling visual tool to convey how systematic AI integration in small towns has positively influenced energy efficiency. It not only showcases the results of the research but also emphasizes the practical value of AI in real-world applications, reinforcing the discussion presented in the research findings.

4 CONCLUSIONS

The fusion of artificial intelligence (AI) within the structural essence of small townscapes signifies a critical transition towards enhanced sustainability and resilience. This evolutionary process, thoroughly investigated in this study, underscores the comprehensive advantages AI imparts to urban evolution. AI's strategic management of resources has established itself as a crucial element in refining energy usage and other vital resources. This refinement plays a significant role in bolstering the towns' sustainability and fortifying their resistance to diverse environmental and economic tribulations.

Furthermore, AI's contribution to the conservation of cultural assets is a prominent feature of this technological amalgamation. Its capability to preserve and rejuvenate historical landmarks accentuates its role as a protector of cultural identity. Utilizing sophisticated digital methodologies, small towns are now equipped to safeguard and honor their historical heritage. This empowers them to ensure the continuation and vibrancy of their rich cultural stories in the contemporary world.

The influence of AI on community engagement is also noteworthy. The AI-driven redesign of communal areas enhances the sense of unity and belonging among the inhabitants. Spaces improved by AI are not just more practical and visually appealing; they are also more welcoming, fostering active involvement and interaction within the community.

However, the path to embedding AI in the architecture of small towns involves its own set of challenges. As revealed through various case studies and analytical observations, the integration process is intricate, necessitating meticulous planning and consideration of technological, economic, and societal aspects. Despite these obstacles, the long-term advantages of integrating AI for the development of smarter, more sustainable towns are evident and persuasive.

In summation, AI's function in sculpting the future of small towns is both groundbreaking and essential. As these towns advance, AI emerges as a vital catalyst for innovation, environmental sustainability, and societal welfare. The outcomes of this research highlight AI's capacity not just to transform the physical environment of small towns but also to enhance the quality of life for their inhabitants, charting a course towards a more intelligent, sustainable future.

REFERENCES

Smith, J., Johnson, A., 2019. Application of AI in Small Town Architecture Enhancement. *International Journal of Architectural Research,* 12(2), 45–58.

Brown, M., Davis, L., 2020. AI-Driven Solutions for Small Town Infrastructure Development. *Journal of Smart City Technology,* 6(1), 12–25.

White, E., Robinson, P., 2018. Enhancing Urban Design in Small Towns with Artificial Intelligence. *Urban Planning and Development Journal,* 15(3), 87–100.

Miller, R., Harris, B., 2017. AI-Enhanced Planning for Sustainable Small Towns. *Sustainable Cities and Society,* 25, 45–58.

Garcia, S., Patel, N., Martinez, L., 2019. Integrating AI into Small Town Architecture for Smart Growth. *Journal of Urban Innovation,* 8(4), 112–125.

Wang, Q., Chen, H., 2020. Artificial Intelligence for Small Town Redevelopment: A Case Study. *International Journal of Computational Design,* 7(2), 34–47.

Adams, T., Mitchell, R., 2018. AI-Driven Solutions for Small Town Transportation Planning. *Transportation Research Part C: Emerging Technologies,* 22, 56–69.

Lewis, M., Turner, J., 2019. Improving Small Town Housing with AI-Based Design. *Journal of Housing and Built Environment,* 30(1), 78–91.

Clark, A., Green, D., 2020. AI Applications in Small Town Urban Regeneration. *Urban Studies Research,* 14(3), 102–115.

Hall, S., Parker, L., 2017. AI-Enabled Smart Utilities for Small Towns. *Utilities Management Journal,* 19(4), 67–80.

Innovative Architectural Solutions in Yakutsk Using Artificial Intelligence

Alexey I. Borisov[a]
Department of Technosphere Safety, North-Eastern Federal University, 58 Belinsky Street, Yakutsk, Republic of Sakha (Yakutia) 677000, Russia
tbbai@mail.ru

Keywords: artificial intelligence, architecture, urban planning, Yakutsk, energy efficiency, smart cities, sustainable architecture.

Abstract: This paper delves into the innovative architectural practices in Yakutsk, focusing on the incorporation of artificial intelligence (AI). It explores how AI is being integrated into the urban planning and sustainable architecture spheres. The research methodology encompasses a study of current architectural trends, Yakutsk's unique climatic features, and instances where AI has been applied to address challenges in architecture and urban planning. The findings underline AI's potential to improve energy efficiency, functionality, and visual attractiveness in urban settings. This research is crucial for advancing architectural and urban development, especially considering Yakutsk's distinct climate and cultural aspects.

1 INTRODUCTION

The evolution of AI technology opens new avenues in architecture and urban planning. This paper investigates the role of AI in enhancing architectural designs in Yakutsk, a city known for its distinct climate and cultural richness. The aim is to understand AI's contribution to more effective, sustainable, and visually appealing architectural solutions in Yakutsk. The study reviews the latest trends in AI's application to architecture, analyzes specific cases in urban development, and assesses the benefits and challenges of integrating AI into architectural processes. Special focus is given to tailoring AI for Yakutsk's specific needs, such as energy efficiency, sustainability, and preservation of cultural heritage. This research not only analyzes the current landscape but also projects future trends in architecture and urbanism driven by AI, emphasizing its critical role in shaping future urban environments.

Peng and team discuss the progression of AI in urban planning, identifying four key stages in its development and emphasizing its potential to enhance urban planning methods. Stojanovski and colleagues explore the intersection of smart cities, digitization, and AI in architecture and urbanism, highlighting AI's new opportunities for urban space and architectural practice development. Luusua and associates in their study, delve into AI's emerging role in smart cities, discussing how it bridges the gap between urbanism and technology, advocating for a more democratic planning approach. Burry focuses on AI's impact on urban design and planning, outlining new AI-driven directions in architecture and urbanism, especially in integrating technology into planning processes. Santi examines how AI aids in designing urban communities, showing that AI improves not just functionality but also the aesthetic aspect of urban areas. Jha and team review AI's role in developing sustainable, intelligent cities, analyzing various AI and IoT applications in urban planning, underscoring their significance for smart city development. Leach discusses AI's influence on creative potential in urban planning and architecture, exploring how AI expands human creativity in planning and design. Andrews and colleagues investigate AI's opportunities and challenges in planning, discussing how planners can prepare for AI adoption to ensure its equitable and inclusive use. Cugurullo analyzes AI's role in city management, examining the shift from automation to autonomy in smart cities, and highlighting AI's crucial role in urban system management. Sanchez and team contemplate AI's prospects in urban planning, discussing findings from a literature review and a

[a] https://orcid.org/0000-0002-2698-6213

national survey of urban planners on AI usage and associated professional concerns.

2 METHODS AND MATERIALS

The integration of artificial intelligence (AI) in urban studies marks a significant shift, introducing advanced tools for urban data analysis, planning, and management. AI's ability to process and interpret vast data volumes is crucial for optimizing city infrastructure, enhancing transportation systems, and boosting overall urban efficiency. AI's role in urban planning extends beyond mere data analysis; it involves utilizing machine learning and algorithms to forecast urban trends and requirements. For instance, AI-driven algorithms can analyze real-time traffic patterns to optimize traffic light controls, reducing congestion. AI also contributes to urban space planning by proposing layouts for buildings, parks, and public areas, maximizing land use efficiency.

Yakutsk, situated in an extreme northern climate, confronts distinctive architectural challenges due to its severe weather conditions. These challenges encompass coping with extremely low winter temperatures, often dropping below -50°C, prolonged frozen ground periods, and a limited construction season. Addressing these challenges requires innovative design and construction techniques, including selecting materials capable of withstanding such harsh conditions and methods that ensure effective insulation and protection from extreme cold.

The climate's influence on Yakutsk's architecture is evident in various aspects, from material selection to building layouts. Key considerations include employing thermal insulation and heating systems to ensure comfortable living conditions during harsh winters. Furthermore, the architecture must address the issue of preventing permafrost thawing beneath foundations, often achieved through innovative technologies like thermosyphons.

Incorporating cultural heritage into Yakutsk's contemporary architecture is vital for preserving the region's unique cultural identity. This encompasses not only the preservation and restoration of historical structures but also integrating traditional design elements into new constructions. When designing modern buildings, it is essential to incorporate Yakutsk's cultural traits, including traditional motifs and symbols, to create a seamless blend of the new and old.

Emphasis is placed on using local materials and traditional construction techniques. This approach not only aids in preserving cultural heritage but also ensures buildings are adapted to withstand the harsh climate. This method maintains a link to the region's history and culture while employing modern architectural solutions to forge functional and comfortable living spaces.

Yakutsk, positioned in the far north, confronts unique architectural difficulties due to its geographical and climatic specifics. A primary concern is construction on permafrost, necessitating specialized building technologies and materials. Challenges linked to permafrost include the risk of foundation freeze-up and structural instability. Additionally, extreme cold and frequent temperature shifts demand robust thermal insulation and structural integrity.

The brief construction window in Yakutsk poses another significant challenge. Harsh winters confine most building activities to the summer months, curtailing construction time and elevating costs. This constraint obliges builders and architects to strategize meticulously and employ rapid construction techniques.

Artificial intelligence (AI) is reshaping various sectors, including architecture. Present AI applications in architecture encompass design automation, analytical processes, and optimization. AI's data processing capabilities enable architects to make informed, efficient decisions. Particularly, AI's analysis of climatic conditions, socio-economic factors, and user preferences fosters the creation of functional, user-centric spaces.

A notable trend is AI's role in crafting sustainable, energy-efficient buildings. AI algorithms can identify optimal methods for utilizing energy, water, and resources, reducing buildings' environmental impact and enhancing climate resilience.

Furthermore, AI enhances urban living quality by analyzing residents' needs and optimizing city spaces. Algorithms assessing people's movements, traffic, and urban space usage contribute to more comfortable, functional urban environments.

AI also plays a pivotal role in cultural heritage preservation. Algorithms can evaluate the condition of historical structures, forecasting maintenance and conservation requirements, thus safeguarding heritage for future generations.

3 RESULTS AND DISCUSSION

AI is introducing groundbreaking methods in architecture, revolutionizing design and construction processes. AI's applications in architecture range from developing smart algorithms for building layout optimization to enhancing energy efficiency and sustainability. AI analyzes various design elements, including climatic conditions, location, and user preferences, leading to adaptive, sustainable solutions.

AI enables architects to conduct complex calculations and simulations, previously cumbersome or time-consuming, improving projects' energy efficiency and living comfort. Machine learning algorithms predict buildings' heating, cooling, and lighting needs, optimizing resource utilization and reducing environmental impact.

Table 1: Evaluating Energy Efficiency in Buildings: Impact of AI in Yakutsk's Architectural Landscape.

Parameter	Before AI Implementation	After AI Implementation
Energy Consumption (MWh)	6.5	4.2
Carbon Emissions (tons/year)	5.0	2.5
Total Operating Cost (rubles)	7,500,000	5,250,000
Payback Period for Energy Efficiency Measures (years)	5	3
Percentage of Renewable Energy Usage	30%	60%
Ventilation System Efficiency (on a scale of 1 to 10)	6	9
User Satisfaction Level (on a scale of 1 to 10)	7	9

This table offers a detailed comparison of energy efficiency in buildings before and after the adoption of AI-driven systems in Yakutsk's architecture. It examines critical parameters including energy consumption, carbon emissions, and total operational expenses. The data reveals significant improvements in energy management post-AI implementation, illustrating AI's pivotal role in fostering both sustainability and economic viability in architectural designs.

In the realm of urban development, AI's role is pivotal in the analytical and optimization processes of urban landscapes. Algorithms are employed to evaluate pedestrian dynamics, vehicular traffic, and spatial usage, facilitating the creation of urban spaces that are both functional and inviting.

The impact of AI in the field of architecture is evidenced through various innovative implementations. Notably, AI has been instrumental in the development of intelligent buildings, designed to dynamically adjust to environmental variations and user requirements. These structures, outfitted with sophisticated sensors and control mechanisms, autonomously regulate aspects like illumination, temperature, and air circulation based on continuous data analysis. This not only heightens comfort levels but also significantly cuts down on energy consumption.

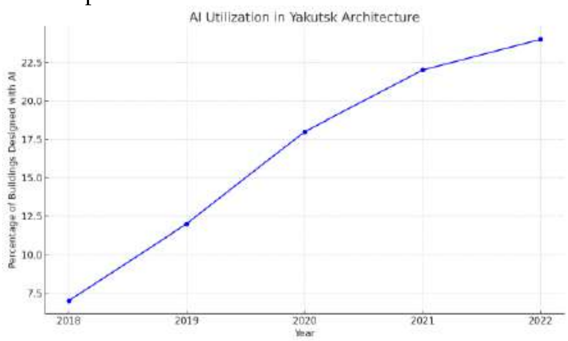


Figure 1: Trajectory of AI Integration in Yakutsk's Architectural Designs (2018-2022).

This chart illustrates the incremental rise in the utilization of AI in Yakutsk's architectural designs from 2018 through 2022. The graphic represents the growing incorporation of AI into architectural methodologies, leading to more creative and efficient design solutions.

AI's influence extends to the urban design and planning sectors as well. Algorithms adeptly handle large-scale data concerning human movement, traffic circulation, and spatial utilization within urban settings. This facilitates the design of urban landscapes that are more efficient, user-friendly, and conducive to the well-being of residents.

In the preservation of historical edifices, AI's contribution is invaluable. By applying machine learning algorithms, the condition of historical structures is meticulously analyzed, enabling the identification of optimal methods for restoration and conservation. This approach not only ensures the longevity of these cultural landmarks but also integrates modern techniques in their upkeep.

These instances showcase AI's capacity to bring about more efficient, sustainable, and comfortable architectural designs. This contributes significantly to the enhancement of life quality and the reduction of environmental footprints.

4 CONCLUSIONS

Investigating the application of AI in Yakutsk's architectural landscape uncovers a myriad of new prospects and directions for urban development. AI offers robust solutions to the distinct climatic and cultural challenges encountered in this region. The deployment of AI in architectural projects has resulted in considerable advancements in building energy efficiency, reduction of carbon emissions, and an increase in the comfort of occupants. This research underlines the critical role of AI in driving sustainability, adaptability, and innovation in urban planning, which is especially pertinent in regions with extreme climatic conditions like Yakutsk.

Beyond its technical contributions, AI also plays a significant role in the preservation and integration of cultural heritage within modern architectural designs. By analyzing historical and cultural data through AI, new projects can be designed to respect and reflect the regional heritage while incorporating contemporary technologies to enhance living standards.

In conclusion, the integration of AI into the architecture of Yakutsk symbolizes a forward-looking direction that contributes to the creation of smart, sustainable, and culturally significant architectural projects. This opens avenues for architectural development that not only align with current technological trends but also cater to the unique requirements and traditions of the region.

REFERENCES

Peng, Z.-R., Lu, K.-F., 2023. The Pathway of Urban Planning AI: From Planning Support to Plan-Making.

Stojanovski, T., Zhang, H., Peters, C. E., Frid, E., 2021. Architecture, urban design and Artificial Intelligence (AI) - Intersection of practices and approaches. SimAUD 2021.

Luusua, A., Ylipulli, J., Foth, M., Aurigi, A., 2023. Urban AI: understanding the emerging role of artificial intelligence in smart cities. AI & Society, 38, 1039–1044.

Burry, M., 2022. A new agenda for AI-based urban design and planning. In Artificial Intelligence in Urban Planning and Design (pp. 3-20).

Santi, P., 2023. AI improves the design of urban communities. Nature Computational Science, 3, 735–736.

Jha, A. K., Ghimire, A., Thapa, S., Jha, A., 2021. A Review of AI for Urban Planning: Towards Building Sustainable Smart Cities. 2021 6th International Conference on Inventive Computation Technologies (ICICT).

Leach, N., 2022. AI and the limits of human creativity in urban planning and design.

Andrews, C., Cooke, K., Gomez, A., Hurtado, P., Sanchez, T., Shah, S., Wright, N., 2022. AI in Planning: Opportunities and Challenges and How to Prepare.

Cugurullo, F., 2020. Urban Artificial Intelligence: From Automation to Autonomy in the Smart City. Front. Sustain. Cities, 2.

Assessment Indicators of Company's Ecosystem Development Level

Victoria L. Simonova[a], Korzh F. Nadezhda[b]
Ural Institute of Management, RANEPA, 8th of March Street, 66, Yekaterinburg, Russia
vlsimonova1409@gmail.com, nadianad1aa@yandex.ru

Keywords: assessment of ecosystem development, evaluation indicators, the company's ecosystem.

Abstract: In recent years, ecosystems have been actively introduced into management practices. Ensuring business growth is one of the most important tasks. Therefore, there is a need to assess the level of their development. Although with the steady growth of the population itself this phenomenon is poorly studied and to date there are no unified methods for assessing the level of the firm's ecosystem and their indicators. Based on the analysis of scientific literature, the authors propose a list of indicators that will help to assess the level of development of the firm's ecosystem.

1 INTRODUCTION

Currently, ecosystem longevity is decreasing, but there is a dynamic development of value in successful ecosystems. The survival of an ecosystem tomorrow is not guaranteed by its reputation, age, or size (Kogdenko V.G., Mel'nik M.V., 2017).

This raises the need to assess the level of development of a firm's ecosystem.

In theory and in practice, there are no recognized unified methods of quantitative assessment and quality indicators of business ecosystem participants, but it is clear that should be determined by the collective governing body and it depends on the specifics of each ecosystem participant (Kafiyatullina Yu. N., 2022).

The purpose of this study is to develop a system of indicators for assessing the level of development of the firm's ecosystem.

2 FEATURES OF THE COMPANY'S ECOSYSTEM DEVELOPMENT

The ecosystem of a firm means the space of economic relations not only with suppliers, consumers and competitors, but also with the authorities, media, universities and scientific organizations - all structures that in one way or another affect the economic activity of the company (Plahin A.E., 2022).

The attractiveness of a company's ecosystem is determined by its capabilities for products and services. A company's ecosystem includes a number of stakeholders, including private sector producers and suppliers, consumers of goods and services, and public sector regulators.

Most key actors are focused on changing internal processes to adapt to the dynamics of the ecosystem. The roles of firms in the ecosystem are unstable, one not entirely stable configuration is replaced by another, forcing firms to change, otherwise ecosystem participants will not be able to see the signs of emerging opportunities in a timely manner (Popov E., 2022).

The existence of an ecosystem requires several factors that characterize its effectiveness: participants, structure, competitiveness, interaction and strategic choice.

A firm's ecosystem cannot exist without participants, an unstructured approach can damage its investment and profitability climate, without competition, both internal and external, ecosystems become monopolies, which is illegal in a number of countries and hinders the development of the entire industry (Mihajlov N.V., 2022).

[a] https://orcid.org/0000-0003-2814-464X
[b] https://orcid.org/0009-0002-4442-0130

A firm's ecosystem goes through several levels of development. After passing through all levels, the firm's ecosystem is formed.

At the initial stage, there is a low level of interaction between new firms and other participants in the firm ecosystem. Next, a leader emerges in the firm ecosystem who can deeply develop the system and lead other participants.

In the next stage, the territory expands and the level of communication between new companies and other ecosystem participants increases. The level of recycling of resources increases, with new resources appearing both outside and inside the ecosystem.

Then there is a high level of interaction between ecosystem participants, strengthening positions. New sources of income come from outside. The ecosystem leader closely monitors other participants.

In the next stage of ecosystem development, the relationships between firms weaken and the recycling of resources within the ecosystem stops. If the firm's ecosystem fails to control new innovations and adapt to the requirements of the business environment, this may be the last step in the development of the ecosystem.

The "self-renewal" phase is based on the continuous enrichment of knowledge and technology. This phase occurs when the development of new ecosystems and innovations is threatened. Ecosystem development plays a vital role in long-term success and self-renewal (Popov E., 2023).

Stakeholders are present throughout the firm's ecosystem.

The very concept of "stakeholder" has evolved over time. Today's stakeholders are not secondary and subservient market participants. Stakeholders are active groups or individuals who can effectively influence the firm's ecosystem, having a significant impact on the solution of the main production issues: what, how and for whom to produce.

As for the development of stakeholder management in Russia, it should be emphasized that progressive and successful organizations in Russia continue to pay special attention to their stakeholders (Kupreeva V.V., 2021).

According to the premise of the stakeholder concept, it is necessary to establish, maintain and develop relationships with all stakeholders regardless of their importance (Sheresheva M.Yu., Palt M.M.,2014).

The development of the concept of stakeholders is a concept of shared values, which justifies the need to improve organizational competitiveness of an individual by contributing to the well-being of the organization by improving the economic and social conditions for the survival of these particular communities (Kogdenko V.G., Mel'nik M.V., 2017).

Stakeholders include organization owners, employees, customers, clients, partners, competitors, investors, government agencies, media and civil society institutions. The needs of a company and its stakeholders do not always coincide, and therefore there are relationships that require leadership. In today's world, organizations are aware of the need to build strategic, transparent, convincing, stable and mutually beneficial relationships with stakeholders.

Thus, it is the creation of such relations that forms the business reputation of the organization, which is the most important intangible resource (Kupreeva, V.V., 2021)

Internal and external stakeholders are distinguished in the ecosystem of the firm. Internal stakeholders include owners and employees of the company. External stakeholders include counterparties, consumers, government, mass media. Sometimes the interests of stakeholders do not coincide, but they are forced to interact according to certain rules.

The multiplicity and conflicting nature of stakeholders makes it difficult to develop a holistic, integrated approach aimed at maximizing the well-being of participants (Harin A.G., Gareev T.R., 2014).

Methods for assessing the firm ecosystem can be categorized into three groups:

1) Analytical type
2) Structural type
3) Matrix type

The analytical method is the most applicable for the formation of indicators for assessing the development of the firm's ecosystem. This method includes indicators for assessing economic efficiency and assessment of stakeholder groups.

Currently, there is no system of indicators for assessing the level of development of the firm's ecosystem. This article proposes to consider the indicators for assessing the level of ecosystem development.

3 THE RESEARCH PROCEDURE

The object of the study is the ecosystem of the firm. The subject of the study is economic relations on the assessment and management of the development of the firm's ecosystem.

The information base is scientific articles on the subject indexed in the RSCI database for 2015-2023 and author's developments on the evolution of the content of the firm's ecosystem.

Research algorithm: criticism of previous studies, problem formulation, development of the author's system of indicators for assessing the level of development of the firm's ecosystem, identification of advantages and disadvantages of the author's system, formulation of theoretical and practical significance of the results obtained.

4 INDICATORS FOR ASSESSING THE DEVELOPMENT OF THE COMPANY'S ECOSYSTEM

This paper considers elements of the firm's ecosystem as indicators for assessing its development.

The customer is a key link in modern economic society. It is the customer who chooses a product based on his own taste preferences, advertising, and imported advice (Kupreeva, V.V., 2021).

Partners in turn help to create conditions for the realization of products and satisfaction of customer's needs. Table 1 presents such elements as customers and partners as the most important components of the firm's ecosystem.

Table 1: Indicators for assessing the development of the firm's ecosystem.

Ecosystem element	Evaluation indicator	Essence of the indicator
Analyzing potential and existing partnerships (Bereza O.V., 2022)	A general model for integrated economic analysis of ecosystem performance	The formula is used to calculate a generalized quantitative indicator of the effectiveness of partnership relations: $E_s=\sum_{i=1}^{n}(V_i*R_i)$ where Es-a generalized indicator of the effectiveness of partnership relations in the banking ecosystem, score; Vi - ballot evaluation of the i-th efficiency indicator, score; Ri - significance of the i-th indicator in the general system of indicators of partnership relations definition efficiency; n - total number of characteristics.
Customer lifetime value (Tkachenko S.N., 2020)	A measure of a customer's lifetime value, calculated in terms of services and the ecosystem as a whole. in terms of services and the ecosystem as a whole.	The indicator is calculated using the formula: $CLV = t \cdot c \cdot f$, where t is the duration of interaction with the customer; c is the average price of customer purchases during the interaction; f is the frequency of purchases per unit of time. The key parameter affecting loyalty is the time of interaction between a company and its customer.
Intersubject linkages of ecosystem participants (Plahin A.E., 2022)	Assessment of intersubjective relationships of ecosystem participants	First, the specificity of relationships between ecosystem participants is determined, which determines their interdependence, taking into account the resource potential of each partner. Then the form of coordination of interaction between ecosystem participants is assessed. After that, the correspondence between the form of coordination of interaction between ecosystem participants and the interdependence of ecosystem participants will be determined.
Assessments of compliance of the actual results of the industrial	Integral indicator calculated on the basis of the proposed scales of	The assessment of the potential of each actor (PA) depending on its role in the ecosystem can be represented by an integral value containing the

ecosystem actors' activities with the target settings (Gamidullaeva L. A., 2020)	indicators and preference assessments	following elements:P3i = f (G1i, G2i, G3i, G4i, G5i, G6i, G7i, G8i, G9i), i = 1,..., n, (1) where n - number of ecosystem actors; G1i - production potential; G2i - innovation potential; G3i - intellectual potential; G4i - human resource potential; G5i - financial potential; G6i - technological potential; G7i - project potential; G8i - resource potential personnel potential; G5i - financial potential; G6i - technological potential; G7i - project potential; G8i - resource potential; G9i - managerial potential.

Currently, there is no clear position on the method and direction of analysis in the study of partners. Some authors emphasize only financial analytical indicators as the most important ones. However, another part of the authors are of the opinion that it is also necessary to pay special attention to qualitative indicators that determine the type of activity, the company's position in the market and its business reputation.

To analyze partnerships, the author Bereza O.V. proposes to use the following indicators:

- analyzing the dynamics of business partnerships;
- analyzing the structure of partnerships;
- analyzing the permanence of partners;
- analyzing partnership risk and the share of the market segment belonging to the partner;
- loyalty analysis (level of satisfaction with cooperation);
- analysis of financial results of work with partners (Bereza O.V., 2022)

Determining the overall performance indicator of a partnership requires calculating the importance of its elements. This requires expert judgment to establish the relevance of each overall performance indicator and determine their impact on the outcome and quality of the partnership.

In assessing the lifetime value of a customer, the key parameter that influences loyalty is the duration of the interaction between the firm's ecosystem and its customer. The duration of this relationship is influenced by financial and non-financial factors (Tkachenko S.N., 2020)

When assessing the intersubjective relationships of ecosystem participants, it is necessary to take into account the organizational features of functioning, ways of coordinating the interaction of ecosystem participants and indicators characterizing additional synergistic effects. At the end of the assessment, a complete picture of intersubjective interaction for all ecosystem participants is formed and it becomes possible to manage such a complex management object as an ecosystem with a multi-subject structure (Plahin A.E.,2022).

It should be noted that ecosystem actors are not permanent players in the ecosystem. Actors can try on different roles in different projects, as the ecosystem is dynamically developing and changing depending on the life cycles of implemented projects.

To assess the compliance of ecosystem actors' activities with the target parameters and actual results, we can use an integral indicator calculated on the basis of planned indicators and evaluation parameters (Gamidullaeva, L. A., 2020).

5 THE IMPACT OF THE COMPANY'S ECOSYSTEM DEVELOPMENT ON BUSINESS EFFICIENCY

Efficiency assessment not only reflects the calculation of specific quantitative indicators reflecting the ratio of results to costs, but also reflects the reserves of economic growth, certain forms of progressive qualitative changes (Kokujceva T.V., Ovchinnikova O.P., 2021).

Economic efficiency refers to the relative value determined for the obtained resource using the coefficient of the final result (Yakovleva A. K., 2019).

Evaluate the impact of the development of the firm's ecosystem by conducting a digital transformation performance assessment based on time, labor and financial criteria.

It is advisable to implement a digital transformation strategy in stages (if available) or in phases, taking into account the delayed time lag of the digitalization effect due to delays associated with the release of the workforce.

Assessing the effectiveness of digital transformation of the organization, it is important to develop measures to improve it, identify errors and obstacles in the development of the organization, and find points of growth of the organization. As a result, the competitiveness of the company increases, which contributes to strengthening its position in the market, as well as increases capitalization and attracts investors for accelerated development (Kokujceva T.V., Ovchinnikova O.P., 2021).

An important factor in the development of a firm's ecosystem is the interaction of its participants. Each participant must cooperate with others to increase the overall return on the services provided (Mihajlov, N.V., 2022).

6 CONCLUSION

Ecosystem development in Russia is still much slower than abroad. Timely assessment of the level of ecosystem development contributes to increased competitiveness in the market and reduces the likelihood of premature "death" of the firm's ecosystem.

In the process of developing a firm's ecosystem, it is very important to develop a positive outlook in the process of interacting with the customer. This requires taking into account the behavior of multiple users based on statistical data. Also, analyzing the partners of the firm's ecosystem allows for the formation of an ecosystem image that helps improve competitiveness and increase customer loyalty, which helps accelerate sales and increase sales. A strong ecosystem image also improves stakeholder relations (government, media, etc.) and contributes to investment attractiveness.

ACKNOWLEDGEMENTS

The study was carried out with financial support from the Russian Science Foundation № 24-18-20036

REFERENCES

Bereza, O.V., 2022. Assessment of the effectiveness of the banking ecosystem. *Financial Markets and Banks, №*3, pp. 51-59

Gamidullaeva, L. A., Tolstykh, T. O., Shmeleva, N. V., 2020. Method of integrated assessment of the industrial ecosystem in the context of sustainable development of the region. *Models, systems, networks in economics, technology, nature and society,* № 2(34), pp. 29-48.

Kafiyatullina, Yu.N., Panfilova, E.E., 2022. Business ecosystem sustainability. *Managemen*t, Vol. 10, № 2, pp. 33-42.

Kogdenko, V.G., Mel'nik, M.V., 2017. Modern Trends in Business Analysis: Studying the Company's Ecosystem, Reviewing the Business Model's Information Content, Evaluating Growth Opportunities. *Economic Analysis: Theory and Practice,* vol. 16, № 10, pp. 1878–1897.

Kokujceva, T.V., Ovchinnikova, O.P., 2021, Methodological approaches to performance evaluation of enterprises digital transformation in high-tech industries. *Kreativnaya ekonomika*. Vol.15,№6, pp. 2413–2430.

Kupreeva, V. V., Gavrish, E. S., 2021. Digital economy influence on project stakeholder management. *In Rormation strategy of digital economy ecosystems, 3rd International Scientific and Practical Conference.* Southwestern State University

Mihajlov, N. V., 2022. Ecosysten development in thr business approach paradigm. *Voprosy ustojchivogo razvitiya obshchestva*, № 4. Pp. 77-81.

Plahin, A.E., Ogorodnikova, E.S., Blinkov, I.O., Rostovcev, K.V., Hoholush, M.S., 2022. Research of the interaction effects industrial ecosystem participant *Bulletin of the Altai Academy of Economics and Law*, №7(2), pp. 276-281

Popov. E., Simonova V., 2022. Potential of a company's ecosystem digitalization. *Management Issues*, №1, pp. 34–46.

Popov, E.V., Simonova, V.L., Belyaeva, N.F., 2023. The co-evolution of digital technology and the development of the fi rm's ecosystem. *Kreativnaya ekonomika*, Vol. 17, №6, pp. 2185–2204..

Tkachenko, S.N., Stavickij, A.M., Maklahova, I.S., 2020. Non-financial mechanism for attracting and retaining customs in the bank sectors. *Bulletin of the Baltic Federal University*, №1, pp. 23-29.

Harin, A.G., Gareev, T.R. stakeholder approach in the management of organization: prospects for the use of game-theoretic. Terra economicus, №4, pp. 105-113.

Sheresheva, M.Y., Palt, M.M., 2014. Coordination of stakeholders interests in network intercompany interaction Soglasovanie interesov stejkholderov v setevom mezhfirmennom vzaimodejstvii. *Bulletin of the Baltic Federal University*, №3, pp. 17-23

Yakovleva, A.K., Fedulova, E.A., Sal'kova, O.S., 2019. Assessing the efficiency of ecosystem function of Sberbank. *Finans and kredit.* Vol. 25, № 10(790), pp. 2304-2321.

Measuring the Level Sustainability of Regional Industrial Production

Vladimur S. Zharov[1,2][a]
[1] *Luzin Institute of Economic Problems Kola Scientific Center of the Russian Academy of Sciences, 24a Fersman Street, Apatity, Russia*
[2] *Branch of Murmansk Arctic University in Apatity, 29 Lesnaya Street, Apatity, Russia*
zharov_vs@mail.ru

Keywords: Sustainability measurement, quantitative assessment, industrial production, method, sustainability index, technological development, life cycle.

Abstract: Measuring the level of stability of economic systems of various types and levels is still an unsolved problem. The aim of the work is to substantiate a new method for quantifying the level of sustainability of production systems. Based on the previously developed graphical model of the life cycle of technological development of production, we propose a method for scoring the stability of production systems of various types and levels of hierarchy (enterprises, industries, types of production activities) and calculating the stability index, which allows us to compare the level of their stability in different periods of time and among themselves. The practical implementation of the method is considered on the example of industrial production (by types of industrial activity) in four regions of Russia that are completely geographically included in the Arctic Zone of the Russian Federation over a fifteen-year period. The performed calculations showed a low level of stability of almost all the analyzed objects. It is determined that the technological development of production systems, which has the main impact on the level of sustainability, is cyclical. Taking this factor into account will allow us to more reasonably consider the prospects for improving their sustainability.

1 INTRODUCTION

Managing the sustainable development of industrial production based on the ESG principles (Alsayegh et al., 2020) is the most important direction in the activity of production systems in the world practice. However, for effective management, primarily strategic (León-Soriano et al., 2010), it is necessary to set goals, that is, to define goals in the form of any indicators, the achievement of which is desirable in a certain period of time. At the same time, tactical goals should be interrelated with strategic ones (Hristov et al., 2019) and they should have a quantitative dimension.

Unfortunately, this problem has not yet been solved in the world of science and practice (Pazienza et al, 2023). For example, to determine corporate sustainability, many specialists offer various sets of indicators that reflect the economic, environmental and social aspects of sustainable development from different angles (Kuhlman and Farrington, 2010) and, accordingly, form the so-called triple result of corporate sustainability, first formulated in the 90s of the last century by J. Elkington (Elkington and Rowlands, 1999). As a result of their convolution, single or integral indices and complex indicators are formed (Nikolaou et al, 2019; Diez-Cañamero et al., 2020). However, in all such cases, in order to measure the importance of individual indicators, it is necessary to use the procedure of expert evaluation of their weights (Bamford et al., 2014; Büyüközkan and Karabulut, 2018). This, on the one hand, significantly increases the subjectivity of the proposed approaches to assessing sustainability, and on the other hand, it does not allow using the developed index or indicator to compare different enterprises, industries and sectors of production.

In (Pazienza et al., 2023), thirty different methodological approaches and methods for developing indicators of corporate sustainability assessment are considered. At the same time, its authors show that currently there is no single concept that would allow us to develop a single standardized and simple indicator for evaluating, and most importantly, in our opinion, measuring sustainability,

[a] https://orcid.org/0000-0002-1877-9214

which could be used to compare the level of sustainability of various production systems. The main reason for this situation, in our opinion, is that to determine the quantitative effectiveness of corporate sustainability, it is necessary to use non-financial qualitative indicators and provisions reflected in environmental management (environmental aspect of sustainability) and the concept of corporate social responsibility (social aspect of sustainability). At the same time, the technological aspect of sustainable industrial development ("green technologies" that allow achieving industrial sustainability (Bendig et al., 2023; Bhatt et al., 2020) and rational use of natural resources, which allows reducing the ever-increasing consumption of natural resources, including energy resources, disappear from attention (Arda et al., 2021; Taghavi, 2021).

The aim of the work is to substantiate a new method for quantifying the level of sustainability of production systems based on the previously developed methodology for analyzing the technological renewal of production.

2 RESEARCH METHODOLOGY

In our opinion, the sustainability of industrial development is directly related to its technological development due to the introduction of technological innovations into production, so we have justified the concept of technological sustainability, which includes simultaneous provision of three aspects of sustainability – economic, environmental and social (Zharov, 2022a; Zharov, 2022b). Achieving its maximum level implies maximizing the efficiency of the use of fixed production resources (material, labor, and physical capital in the form of fixed assets), that is, maximizing the values of material efficiency, capital efficiency, and labor productivity (the economic aspect of sustainability). However, reducing the material intensity of production, including its energy intensity, is achieved by reducing the volume of production waste and energy consumption due to a decrease in the specific consumption of raw materials, materials, fuel and energy, which leads to minimizing environmental damage and, accordingly, reflects the environmental aspect of sustainability. At the same time, its social aspect is manifested in the possibility of a more significant increase in average wages at enterprises (compared to the growth rate of labor productivity) due to a decrease in the material intensity of production, as well as in the creation of more favorable working conditions due to active automation and digitalization of technological processes. Thus, in essence, technological sustainability ensures that enterprises achieve corporate sustainability.

Based on the previously developed matrix of possible directions for the development of production systems and a graphical theoretical model of the life cycle of technological development of production (Zharov, 2018), it was shown that technological stability is provided at three stages out of six possible, but the level of stability at each stage is different. Accordingly, indicators for determining the level of sustainability were developed for each stage (Meshalkin et al., 2023). At the same time, the maximum level of sustainability is achieved at one stage of technological development, when a simultaneous increase in the values of material and stock returns and an increase in the value of the coefficient of the level of technological efficiency of production (Cutp) as the ratio of material productivity (MP) to capital productivity (CP) is ensured.

The practical application of the above methodology to assess the level of technological development sustainability and, accordingly, the overall sustainability of various industrial enterprises, industries and industry as a whole at the level of regions-subjects of the Russian Federation-has shown that indeed technological innovation development, the level and trends of which are shown by the values of Qutp, has a decisive impact on the level of technological stability of production systems. However, the change in the stages of technological development, determined by the financial statements of enterprises and statistical data on the development of regions-subjects of the Russian Federation, does not always occur consistently in accordance with the schedule of the life cycle of technological development of production. This is explained, on the one hand, by the multiple effects of various objective factors on the operation of production systems, including force majeure, for example, emergencies. On the other hand, there are also subjective factors, including insufficiently effective management activities and imperfect management and statistical accounting of production activities.

3 RESULTS AND DISCUSSION

Thus, it becomes difficult to determine trends in the level of technological stability over a long period of activity of production systems (ten or more years), and without this, it is impossible to assess the prospects for sustainable technological development, since any technical and economic system develops inertially. The way out of this situation was found in determining a comparative point assessment of the level of stability and instability of each stage of technological development based on the indicators developed earlier by us (Meshalkin et al., 2023). As a result, each of the six stages is assigned a score from one to six (Table 1).

Table 1: Criteria for assessing the level of sustainability of industrial systems.

Number of the technological development stage	Indicators of the level of sustainability	The level of sustainability	Assessment of the level sustainability
2	**MP increases** CP decreases Qutp increases	Low level of sustainability	4
1-1	MP increases **CP increases** Qutp increases	High level of sustainability	6
1-2	MP increases CP increases **Qutp decreases**	Average level of sustainability	5
3	**MP decreases** CP increases Qutp decreases	Low level of instability	3
4-1	MP decreases **CP decreases** Qutp decreases	High level of instability	1
4-2	MP decreases CP decreases **Qutp increases**	Average level of instability	2

At the same time, three stages with scores of 4, 5, and 6 characterize an increasing level of stability, while stages with scores of 3, 2, and 1 show levels of increasing instability. It should be noted that the gradation of points can be different, for example, from -3 to +3. Then points from one to three will show an increasing level of stability, and points from minus one to minus three will show an increasing level of instability. Accordingly, a zero score will determine the boundary of stability and instability.

The proposed approach to quantifying the level of sustainability of technological development can be used for production systems at various levels of hierarchy (enterprises, industries, types of production activities). Accordingly, it can be used to compare the level of stability of each of these systems in different periods of time and perform a corresponding retrospective analysis of technological renewal of production, as well as to compare the level of stability of production systems of various types in a certain period of time. For this purpose, the average stability score for any analyzed time period is calculated using a simple arithmetic mean value. For example, you can calculate it for the last five years, ten years, or fifteen years, which allows you to take into account the dynamics of changes in the level of sustainability and form prospects for the future technological development of production systems on this basis. In this case, the resulting arithmetic mean value can be called the stability index of various types of production systems. Unlike all the methods of assessing and measuring sustainability discussed in (Pazienza et al., 2023), such a simple indicator-index is calculated on a single methodological basis for production systems of any type and level, that is, it can be standardized, and has an upper quantitative limit that characterizes the maximum possible level of sustainability.

The considered approach to determining the level of sustainability over a long fifteen-year period of time was also used by us in relation to the development of industrial production in four regions-subjects of the Russian Federation that are completely included in the Arctic Zone of the Russian Federation (Murmansk Region, Nenets (NAD), Yamalo-Nenets (YNAD) and Chukotka (CAD) Autonomous Districts). At the same time, for a more objective assessment of the level of sustainability, three types of industrial activities are analyzed separately – mining, manufacturing, electricity, gas and water production. As a result, it is shown that over the time period under review, the average level of sustainability of technological development in all regions was more than three, but less than four points, that is, sustainability of development is at a low level. At the same time, among all regions, the highest score was scored by the CAD (3.67) and the Yamalo – Nenets Autonomous District (3.60). Moreover, in the Yamalo – Nenets Autonomous District, this level of sustainability was achieved due to the technological development of the predominant type of activity-mining, and in the CAD-the production of electricity, gas and water.

In the Murmansk Region, the low level of sustainability (3.27 points) was determined by the development of manufacturing industries (average score 3.27), while in the NAD, on the contrary, the manufacturing industry developed steadily (average score 4.07), but it has a low share in the structure of industrial activities, so the overall average score was also less than four (3.47).

Thus, as a result of the analysis performed, it can be concluded that in the future, in order to significantly increase the level of sustainability of industrial production in the regions of the Russian Arctic, it is necessary to update production technology using the latest high-performance equipment.

4 CONCLUSIONS

1. We hope you find the information in this template useful in the preparation of your submission. It is shown that in the world science and practice the problem of quantitative measurement of the level of stability of production systems has not yet been unambiguously solved.

2. Based on the previously developed graphical model of the life cycle of technological development of production and indicators of the level of sustainability, a method is proposed for scoring the sustainability of production systems of various types and hierarchy levels (enterprises, industries, types of production activities) and calculating the sustainability index, which allows for comparing the level of their sustainability in different periods of time and among themselves.

3. The practical implementation of the method is considered on the example of industrial production (by types of industrial activity) in four regions of Russia - subjects of the Russian Federation that are completely geographically included in the Arctic Zone of the Russian Federation. The performed calculations showed a low level of stability of almost all the analyzed objects.

4. It is determined that the technological development of production systems, which has the main impact on the level of sustainability, has a cyclical character, so in further studies it is intended to consider the influence of this factor when justifying the prospects for increasing the level of sustainability.

REFERENCES

Alsayegh, M.F., Abdul Rahman, R., Homayoun, S., 2020. Corporate Economic, Environmental, and Social Sustainability Performance Transformation through ESG Disclosure. *Sustainability*.12(9). 3910.

Arda, O. A., Montabon, F., Tatoglu, E., Golgeci, I., Zaim, S., 2021. Toward a holistic understanding of sustainability in corporations: resource-based view of sustainable supply chain management. *Supply Chain Management: An International Journal*. 28(2). 193-208.

Bamford, D., Yang, J.-B., Sureeyatanapas, P., 2014. Evaluation of corporate sustainability. *Front. Eng. Manag.* 1.176–194.

Bendig, D., Kleine-Stegemann, L., Gisa, K., 2023.The green manufacturing framework—A systematic literature review. *Cleaner Engineering and Technology*. 13, 100613.

Bhatt, Y., Ghuman, K., Dhir, A., 2020. Sustainable manufacturing. Bibliometrics and content analysis, *Journal of Cleaner Production*, 260, 120988.

Büyüközkan, G., Karabulut, Y., 2018. Sustainability performance evaluation: Literature review and future directions. *J. Environ. Manag.* 217. 253–267.

Diez-Cañamero, B., Bishara, T.,Otegi-Olaso, J.R., Minguez, R., Fernández, J.M., 2020. Measurement of corporate social responsibility: A review of corporate sustainability indexes, rankings and ratings. *Sustainability*. 12, 2153.

Elkington, J., Rowlands, I. H., 1999. Cannibals with forks: The triple bottom line of 21st century business. *Alternatives Journal.* 25(4). 42.

Hristov, I, Chirico, A, Appolloni, A., 2019. Sustainability value creation, survival, and growth of the company: A critical perspective in the Sustainability Balanced Scorecard (SBSC). *Sustainability*. 11(7).211.

Kuhlman, T., Farrington, J., 2010. What is Sustainability? *Sustainability*. 2. 3436-3448.

León-Soriano, R, Jesús Muñoz-Torres, M, Chalmeta-Rosaleñ, R., 2010. Methodology for sustainability strategic planning and management. *Industrial management & data systems*.110(2).249-68.

Nikolaou, I.E., Tsalis, T.A., Evangelinos, K.I., 2019. A framework to measure corporate sustainability performance: A strong sustainability-based view of firm. *Sustain. Prod. Consum.* 18. 1–18.

Pazienza, M., de Jong, M., Schoenmaker, D., 2023. Why Corporate Sustainability Is Not Yet Measured. *Sustainability* 15. 6275.

Taghavi, N., 2021. Sustainable Development of Operations: Actors' Involvement in the Process of Energy Efficiency Improvements. *Sustainability*. 13(11). 6121.

Zharov, V. S., 2018. Interrelation of technological and economic development of production systems. *Scientific and technical bulletin of St. Petersburg State Polytechnic University. Economic sciences.* 11(3). 32-44.

Zharov, V. S., 2022. A system of indicators for evaluating the effectiveness of various types of technological innovations. *Drucker's Bulletin*. 2(46). 243-250.

Zharov, V. S., 2022. Technological stability as a basis for sustainable industrial development of regions. *Drucker's Bulletin*. 5(49).167-176**.**

Meshalkin, V.P., Zharov,V.S., Leontiev, L.I., Nzioka, A.M., Belozersky, A.Y., 2023. Sustainable Environmental Impact Assessment Using Indicators for Sustainable Energy-Intensive Industrial Production. *Energies.* 16(7), 3172.

Search for Optimal Location of a Fire Department at a Refinery by Solving a Special Kind of Mathematical Problem

Masaev Sergey Nikolaevich[a], Kovalchuk Natalya Nikolaevna[b]
Department of Information and Control Systems, Reshetnev Siberian State University of Science and Technology, Krasnoyarskii rabochii prospekt 31, Krasnoyarsk, Russia
faberi@list.ru, kovalchuk_natalya2000@mail.ru

Keywords: Transportation problem, Resource optimization, Fire safety, Minimum element method, Potential method.

Abstract: The article describes the problem of optimizing the placement of an additional fire department on the territory of the Achinsk Refinery VNK. This is necessary to increase the speed of response to possible fire emergencies. The described method of the transport problem takes into account the arrival time of vehicles from fire stations and the volume of foam mixture for extinguishing. The results of the research improve the fire safety system at the facility and develop a methodology applicable to similar production facilities.

1 INTRODUCTION

The oil refining industry is considered a key industry in the Russian Federation. Its products largely determine the pace of development of other sectors of the economy of our country. Oil refining industry enterprises are complex multi-purpose production facilities. This is a high degree of mechanization and automation, a continuous cycle of work and the interconnection of various technological installations (Masaev, 2020).

Every year, large fires occur at oil refining industry facilities, killing people and causing significant economic losses to the Russian national economy. In the event of an emergency (fire, explosion), the enterprise may suffer large material losses.

In this context, the problem arises of optimizing the placement of additional fire departments at the Achinsk Refinery. The goal is to minimize the time of arrival to the fire site and optimal use of the foam mixture for extinguishing. Achieving the goal is possible using a transport task. It allows you to optimize the allocation of resources and funds for effective response to emergency situations.

The object of the research is the operational response indicators of the emergency rescue units of a production facility using the example of Achinsk Refinery VNK JSC.

The research is of practical significance for ensuring safety at the Achinsk Refinery. The theoretical value lies in the development of a methodology for optimizing the fire protection system at industrial facilities. The results obtained can be applied not only in this specific case, but also adapted to other industrial plants, which contributes to the overall strategy for improving the safety and sustainability of industrial processes (Brushlinskiy, Sokolov, 2011; Brushlinskiy, Sokolov, Alyokhin, 1997).

That is why the task was set to determine, using calculations of the transport problem, the optimal distribution of resources (foam mixture for extinguishing fires) from each fire station to each fire point. The following parameters were taken into account: minimizing the cost of delivery, reducing the number of casualties and material damage, reducing the time of rapid response and the rational use of fire extinguishing agents.

2 METHOD

The transportation problem is a special type of linear programming problem. To solve the transport problem, you can use methods for solving linear

[a] https://orcid.org/0000-0002-5825-2708
[b] https://orcid.org/0009-0000-6006-7336

programming problems, however, due to the specific type of problem, algorithms were built specifically for solving this problem.

The general formulation of the transport problem is to determine the optimal plan for transporting some homogeneous cargo from departure points A1, A2, ..., Am to destinations B1, B2, ..., Bn. The optimality criterion is the minimum cost of transportation or the minimum delivery time of cargo.

In our case, the point of departure is a possible variant of a located inverter, the destination is a fire-hazardous object. Cargo reserves are the volume of foam, delivery time is the response time before arriving at a fire-hazardous facility.

The minimum response time for arriving at a fire-hazardous facility was taken as an optimality criterion. Let us denote by Cij the time of arrival from departure point i to destination j. Let us denote by Ai the foam reserves at the i-th point of departure, and by Bj the foam needs at the j-th destination, and by Xj the number of units of foam transferred from the point of departure i to the destination j.

The mathematical model of the transport problem allows us to determine the minimum value of the optimal criterion function

$$F = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}\,, \tag{1}$$

to

$$\sum_{i=1}^{m} x_{ij} = b_j \ \ (j = 1, \ldots, n), \tag{2}$$

$$\sum_{j=1}^{n} x_{ij} = a_i \ \ (i = 1, \ldots, m), \tag{3}$$

$$x_{ij} \geq 0 \ \ (i = 1, \ldots, m, j = 1, \ldots, n). \tag{4}$$

Since conditions (2) - (4) are satisfied, the required amount of foam is delivered to each destination, foam is removed from all points of departure, and return transportation is eliminated.

Definition 1. Any non-negative solution $X_{ij} = \| x_{ij} \|$ (i=1,..,m; j=1,...,n) of systems (2) and (3) is called an admissible plan of the transport problem.

Definition 2. The plan $x_{ij}^* = \left\| x_{ij}^* \right\|$ $(i = 1, \ldots, m; j = 1, \ldots, n)$ at which function (1) takes the minimum value is called the optimal plan for the transport problem.

If the amount of foam stock held by suppliers is equal to the total demand at destinations

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j \tag{5}$$

then the model of the transport problem is called closed (or balanced). If (5) is not satisfied, then the transport problem model is called open (or unbalanced).

Theorem 1. For the transport problem to be solvable, it is necessary and sufficient that condition (5) be satisfied.

If the stock exceeds the requirement, then

$$\sum_{i=1}^{m} a_i > \sum_{j=1}^{n} b_j, \tag{6}$$

a fictitious (n+1)’th destination with the requirement is introduced

$$b_{n+1} = \sum_{i=1}^{m} a_i - \sum_{j=1}^{n} b_j. \tag{7}$$

The corresponding tariffs are considered equal to zero: $c_{i\,n+1} = 0$ $(i = 1, \ldots, m)$. After these transformations we obtain a closed model of the transport problem.

Similarly, when $\sum_{i=1}^{m} a_i < \sum_{j=1}^{n} b_j$, a fictitious (m+1) departure point with foam is introduced $a_{m+1} = \sum_{j=1}^{n} b_j - \sum_{i=1}^{m} a_i$, and tariffs are assumed to be zero: $c_{m+1j} = 0$ $(j = 1, \ldots, n)$. After these transformations we obtain a closed model of the transport problem.

We will consider a closed model of the transport problem. If the model of the transport problem is open, then using the above transformations we build a closed model of the transport problem.

Typically, the data of a transport task is recorded in the form of a table (Fig. 1).

Departure point	Destination					Reserves
	B_1	…	B_j	…	B_n	
A_1	c_{11} x_{11}	… …	c_{1j} x_{1j}	… …	c_{1n} x_{1n}	a_1
…	… …	… …	… …	… …	… …	…
A_i	c_{i1} x_{i1}	… …	c_{ij} x_{ij}	… …	c_{in} x_{in}	a_i
…	… …	… …	… …	… …	… …	…
A_m	c_{m1} x_{m1}	… …	c_{mj} x_{mj}	… …	c_{mn} x_{mn}	a_m
Needs	b_1	…	b_j	…	b_n	

Figure 1: Type of transport task.

The number of variables Xij is equal to mn, where m is the number of points of departure - Fire Department (FD), and n is the number of destinations - fire hazardous objects. The number of equations in (2) and (3) is m+n. Since we are considering a closed model of the transport problem (equality (5) is satisfied), the number of linearly independent equations is equal to m+n−1. Therefore, the reference plan of a transport problem can have no more than m+n−1 non-zero unknowns.

If in the support plan the number of non-zero components is exactly m+n−1, then the support plan is called non-degenerate, and if less, then degenerate.

To solve a transportation problem, an initial reference plan is first determined, and then an optimal plan is determined by improving the current reference plan.

There are several methods for determining the initial reference plan: the northwest corner method, the minimum element method, and the Vogel approximation method.

We find the reference plan for the transport problem as follows. At each step in the table of task conditions, we fill in one cell, which is called occupied. Let us denote by Kij the cell, where i is the number of the point of departure (row), j is the number of the destination (column). We fill out cell Kij so that the needs of destination j are fully satisfied, or foam is completely removed from departure point i.

In the first case, we temporarily exclude column j from consideration and change the foam stock at departure point i. In the second case, we temporarily exclude line i from consideration and change the foam volume requirement of destination j. Next, we repeat the procedure with the condition table with the excluded row or column.

In the m+n−1st step we obtain a problem with one departure point and one destination. One cell remains free. The supplies of the remaining origin will be equal to the needs of the destination. Having filled this cell, we finish the m+n−1st step and get a reference plan.

If at some step (but not the last) the needs of the next destination are equal to the reserves of the departure point, then we temporarily exclude from consideration either a column or a row (only one of the two). Then we consider either the reserves of a given point of departure or the needs of a given destination to be equal to zero. At the next step we write this zero into the next cell to be filled. This approach provides exactly m+n−1 occupied cells, which makes it possible to check the resulting support plan for optimality and find the optimal plan.

Using the transport problem, we will be able to calculate the most advantageous location of the inverter, taking into account arrival at the most fire-hazardous objects. This reduces possible damage and the number of victims.

3 RESULTS

Having analyzed the plan and response time of fire departments and their arrival at dangerous objects, we can propose another option for the location of an additional fire department, which is justified by the closest location of relatively dangerous objects in production .

The estimated location of fire stations at JSC "Achinsk Oil Refinery VNK" is presented Figures 2-3:

1. Fire department, which is currently located at the refinery (FD No. 1);
2. Fire department, located at the top of the plan map (FD No. 2);
3. Fire department for 12 vehicles, located outside the refinery (FD No. 3);
4. Additional option for the location of the fire station (FD No. 4).

Figure 2: Proposed location of FD No. 1 and FD No. 2.

Figure 3: Proposed location of FD No. 3 and FD No. 4.

The location of protection facilities at JSC Achinsk Oil Refinery VNK is shown Figure 4:

1. Installation of loading into railway tanks (object No. 1);
2. Fuel park (object No. 2);
3. RVS-50000 (object No. 3);
4. Installation for the production of petroleum coke (object No. 4);
5. Installation of LK-6Us (object No. 5).

Figure 4: Location of protection objects.

Having made calculations for FD planning using Excel, we will write the obtained data in a table. The data is presented Table 1.

Table 1: Distribution of FD resources for fire extinguishing.

FD	Fire points (location of protection)					Amount of foam from FD (liters)
	№1	№2	№3	№4	№5	
№1	1,5	2,5	1,2	1	1	39236
№2	4,6	4,3	5,6	6,1	4	26389
№3	2,1	2,4	2	1,2	1,5	39236
№4	1	1,2	1,2	1,7	1	26389
	272 10	226 20	277 40	260 20	27660	
	Foam volume for fire extinguishing/containment					

Due to the irrationality of the use of frequency converters and the response time of emergency rescue divisions using the transport problem, we offer the most profitable calculation.

To solve the transportation problem, we will use the method of finding the first reference plan, which will allow us to quickly determine the initial allocation of resources. We will then apply a method to determine the optimal plan, which will allow us to improve the initial plan and achieve optimal resource allocation at minimal cost. Using both methods will allow us to effectively solve the problem and achieve an optimal result.

The data for the transport task table will be presented as follows: the Achinsk Refinery facilities will be the destinations, and the FD will be the departure points. The last column contains inventory, which is the amount of firefighting foam available at each FD, while the last row represents the amount of resources required (in this case, foam mixture) to fight fires at each facility. This transport task is shown in Table 2.

Table 2: Transport task for a FD.

FD	Facilities of the Achinsk Refinery (location of protection)					Foam reserves (FR)
	B_1	B_2	B_3	B_4	B_5	
A_1	15 10	25 10	12 10	1	1	39236
A_2	46 10	43 10	56 10	61 10	4	26389
A_3	21 10	24 10	2	12 10	15 10	39236
A_4	1	12 10	12 10	17 10	1	26389
Foam needs	272 10	226 20	277 40	260 20	276 60	

The number of departure points is m=4, and the number of destinations is n=5. Therefore, the reference plan of the problem is determined by the numbers in m+n−1=4+5−1=8 filled cells of the table. The transportation time of a unit of foam from each FD to all Facilities of the Achinsk Refinery is specified by the matrix:

$$C = \begin{matrix} 1.5 & 2.5 & 1.2 & 1 & 1 \\ 4.6 & 4.3 & 5.6 & 6.1 & 4 \\ 2.1 & 2.4 & 2 & 1.2 & 1.5 \\ 1 & 1.2 & 1.2 & 1.7 & 1 \end{matrix}$$

The presence of foam mixture in the FD is equal to:

$$A_i = 9236 + 6389 + 9236 + 6289 = 31250$$

The total demand for foam at the Achinsk Refinery facilities is equal to:

$$B_i = 7210 + 2620 + 7740 + 6020 + 7660 = 31250$$

$\sum A_i = \sum B_i$. The transport problem model is closed. Therefore, it is solvable.

2.1 The First Base Plane

The reference design of the problem was successfully found using the minimum element method (Hillier, 2010). The results of the decision are presented in Table 3.

Foam reserves - FR, foam needs - needs.

Table 3: Basic plan of the transport problem.

FD	Facilities of the Achinsk Refinery (location of protection)										FR
	B_1		B_2		B_3		B_4		B_5		
A_1	15 10		25 10		12 10		1		1		0
								26020		13216	39236
A_2	46 10		43 10		56 10		61 10		4		0
		821		22620		2948					26389
A_3	21 10		24 10		2		12 10		15 10		0
						24792				14444	39236
A_4	1		12 10		12 10		17 10		1		0
		26389									26389
needs	0		0		0		0		0		131250
	27210		22620		27740		26020		27660		

After finding the first reference plan, we move on to the second stage - improving the reference plan. At this stage, we strive to optimize resource allocation, taking into account the current plan and conditions of the transport problem.

2.2 Improving the Base Plan

Let's find the optimal plan for the transport problem using the potential method using the formulas:

$$\beta_j - \alpha_i = C_{ij},$$

where C_{ij} is the value in the transport task cell corresponding to departure point i and destination j.

Then, using the found potentials, we can calculate the potentials for unfilled cells:

$$\alpha_{ij} = \beta_j - \alpha_i - C_{ij},$$

for cells with C_{ij}=0, where α_{ij} is the potential for an unfilled cell with coordinates (i,j).

After several iterations, the optimal plan for the transport problem was found, the results of which are presented Table 4.

Table 4: Optimal basic plan for a transport problem.

FD	Facilities of the Achinsk Refinery (location of protection)										FR
	B_1		B_2		B_3		B_4		B_5		
A_1	1510		2510		12 10		1		1		39236
		821				27740				10675	

A2	4610		4310		5610		6110		4		26389
				22620						3769	
A3	2110		2410		2		1210		1510		39236
								26020		13216	
A4	1		1210		1210		1710		1		26389
		26389									
needs	0		0		0		0		0		131250
	27210		22620		27740		26020		27660		

$$X = \begin{matrix} 821 & 0 & 27740 & 0 & 10675 \\ 0 & 22620 & 0 & 0 & 3769 \\ 0 & 0 & 0 & 26020 & 13216 \\ 26389 & 0 & 0 & 0 & 0 \end{matrix}$$

$$S = \frac{15}{10}\cdot 821 + \frac{12}{10}\cdot 27740 + 1\cdot 10675 + \frac{43}{10} + 22620 + 4\cdot 3769 + \frac{12}{10}\cdot 26020 + \frac{15}{10}\cdot 13216 + 1\cdot 26389 = \frac{469947}{2}$$

Let us check the resulting reference plan for optimality. To do this, we find the potentials of the points of departure and destination. For filled cells, we compose a system of 8 equations with 9 unknowns:

$\beta_1-\alpha_1=15/10$
$\beta_3-\alpha_1=12/10$
$\beta_5-\alpha_1=1$
$\beta_2-\alpha_2=43/10$
$\beta_5-\alpha_2=4$
$\beta_4-\alpha_3=12/10$
$\beta_5-\alpha_3=15/10$
$\beta_1-\alpha_4=1$

Assuming $\alpha_1=0$, we find $\beta_1=15/10$, $\beta_3=12/10$, $\beta_5=1$, $\alpha_4=1/2$, $\alpha_2=-3$, $\alpha_3=-1/2$, $\beta_2=13/10$, $\beta_4=7/10$.

For each free cell we calculate the number $\alpha_{ij}=\beta_j-\alpha_i-c_{ij}$:

$\alpha_{12}=-6/5$, $\alpha_{14}=-3/10$, $\alpha_{21}=-1/10$, $\alpha_{23}=-7/5$, $\alpha_{24}=-12/5$, $\alpha_{31}=-1/10$, $\alpha_{32}=-3/5$, $\alpha_{33}=-3/10$, $\alpha_{42}=-2/5$, $\alpha_{43}=-1/2$, $\alpha_{44}=-3/2$, $\alpha_{45}=-1/2$.

There are no positive numbers among a_{ij}, so this reference plan is optimal.

Thus, the initial reference plan obtained by the minimum element method allowed us to establish a baseline for the distribution of fire departments and firefighting materials. Then, using the potential method, we were able to further improve this plan, identifying optimal routes for delivering resources and reducing emergency response times.

3 CONCLUSIONS

In the course of this work, an algorithm for the optimal allocation of resources in a fire protection system at industrial facilities was considered using methods of the transport problem. An optimal support plan allows for efficient use of fire departments and resources to extinguish fires on site. By optimizing delivery routes and minimizing emergency response times, this plan improves the safety and security of both personnel and property (Parygin, Masaev, Malikov, 2019).

Thus, the use of transport problem methods to optimize the fire protection system at industrial facilities is an effective approach. The results can be used as a basis for further improvements in fire safety and for the development of fire prevention and control strategies for other industrial sites.

REFERENCES

Masaev, S. N., 2020. Instability of the Environment as a Necessary Condition for Optimal Control of an Economic Object. *International Scientific and Practical Conference “Russia 2020 - a new reality: economy and society” (ISPCR 2020): Proceedings of International Scientific and Practical Conference “Russia 2020 - a new reality: economy and society”*. – Veliky Novgorod: Atlantis Press, 2021. – P. 338-343.

Brushlinskiy, N.N., Sokolov, S.V., 2011. Mathematical methods and models of management in the State Fire Service: *The book*. M.: Academy of the State Fire

Service of the Ministry of Emergency Situations of Russia. 255 pp. (in Russian).
Brushlinskiy, N.N., Sokolov, S.V., Alyokhin, E.M., 1997. Methodological, theoretical and applied problems of fire-fighting services in cities. Scientific and technical support of the State Fire Service activity: a collection of scientific articles. - pp. 29-41. (in Russian).
Brushlinskiy, N.N., Sokolov, S.V., Wagner, P., 2007. Mankind and fires. 142 pp. (in Russian).
Map «Achinsk Oil Refinery of East Oil Company», URL: https://nedronavigator.ru/map/npz/achinskij-neftepererabatyivayushhij-zavod.html
Dorrer, M. G., 2020. The prototype of the organizational maturity model's digital twin of an educational institution. *Journal of Physics: Conference Series, Krasnoyarsk (*Krasnoyarsk: Science and Technology City Hall) p. 12121.
Gavriley, V.M., Brushlinskiy, N.N., Sobolev, N.N., 1983. Distribution of operative subdivisions of fire protection by city districts,Economics and management in fire protection: a collection of scientific articles. MOSCOW: VNIIPO OF THE MINISTRY OF INTERNAL AFFAIRS OF THE USSR. pp. 125-130. (in Russian).
Davydov, A.P., 2012. Time factor. Fire business. № 4. p. 4-8. (in Russian).
Kazanskiy, N.N., 1990. Firefighting. № 3. pp. 30. (in Russian).
Fire risks. Basic concepts [Text] / edited by. N.N. Brushlinskogo. - M.: FGU VNIIPO of the Ministry of Emergency Situations of Russia, 2004. - Release 1. - 57 pp. (in Russian).
Hillier, F. S., 2010. *The book,* Introduction to operations research / Frederick S. Hillier, Gerald J. Lieberman, 9th edition.
Parygin, D., Masaev, S. N., Malikov, V., 2019. Urban Areas Development Analysis and Management Decision Support based on Residential Real Estate Objects Evaluation Methods. *System Modeling & Advancement in Research Trends: SMART–2019. Proceedings of the 2019 8th International Conference, Moradabad.* EXCEL INDIA PUBLISHERS, 2019. P. 184-189. EDN SAKCKW.

Investigating the Association Among CO2 Emissions, Unemployment Rate and Economical Development in Central Asia: Panel – Ardl Approach

Sanat Chuponov[1][1], Javoxir Babajanov[2][2], Nilufar Sapayeva[2][3], Suxrob Davlatov[3][4] and Jamoliddin Majidov[1][5]

[1] *"Mamun university", 220900, Qibla Tozabog, Khiva, Uzbekistan.*

[2] *"Urgench state university", 220100, Khamid Olimjon, Urgench, Uzbekistan.*

[3] *"Bukhara state university", 200117, M. Ikbal, Bukhara, Uzbekistan*

chuponov_sanat@mamunedu.uz, javohirbabajanov07@gmail.com, rafulin5082@gmail.com, s.s.davlatov@buxdu.uz, jamoliddin-1985@list.ru

Keywords: unemployment, CO2, CA, correlation-regression analyses.

Abstract: This paper studies the effect of unemployment rate and GDP per capita on carbon dioxide emissions in Central Asia was determined using the "Panel ARDL - PMG" model. In the study, the unemployment rate and GDP per capita in Central Asia have a long-term positive effect on the annual CO2 emissions, and a short-term positive effect was observed only in the countries' economic development factor. According to the results of the research, unemployment rate in two countries in Central Asia has a negative effect on annual CO2 emissions in the short term, and in three countries it has a positive effect. Also, GDP per capita has a positive effect on annual CO2 emissions in the short term in one country in four countries. It was estimated that the secret was statistically insignificant. These results have important implications for policymakers, emphasizing the potential role of unemployment mitigation strategies in promoting environmental sustainability in Central Asia.

1 INTRODUCTION

In recent years, the interconnection between economic indicators and environmental sustainability has garnered increasing attention worldwide. Central Asian countries, nestled between Europe and Asia, have been particularly affected by the complex interplay between economic dynamics and environmental challenges. In order to shed light on the complex relationship between the region's economic conditions and environmental impact, this study will investigate the correlation-regression analysis between unemployment rates and carbon dioxide (CO_2) emissions in Central Asian countries. Following its independence from the Soviet Union, Central Asia—which is made up of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan—has experienced substantial economic changes.

While the region boasts abundant natural resources and strategic geographic positioning, it also grapples with socio-economic challenges, including unemployment, poverty, and underemployment. Economic activities in Central Asian countries, ranging from extractive industries to agriculture and manufacturing, have profound implications for carbon emissions and environmental sustainability.

Unemployment rates serve as a key barometer of economic health, reflecting the availability of job opportunities, labor market dynamics, and overall

[1] https://orcid.org/0000-0001-7388-9224
[2] https://orcid.org/0009-0000-0827-2383
[3] https://orcid.org/0009-0000-9931-666X
[4] https://orcid.org/0000-0001-9154-9688
[5] https://orcid.org/0009-0003-7370-3938

economic performance in a given country. High unemployment rates can lead to social unrest, economic instability, and adverse consequences for individuals and communities. However, the relationship between unemployment and environmental outcomes, particularly CO2 emissions, remains a topic of debate and empirical inquiry. Existing literature on the correlation between unemployment and CO2 emissions offers mixed findings, reflecting the diverse socio-economic contexts and methodological approaches employed in different studies. Some scholars argue that high unemployment rates are associated with lower CO2 emissions due to reduced economic activity and energy consumption. Others contend that unemployment may lead to increased energy use in households and reduced investments in clean technologies, resulting in higher carbon emissions. In light of this, the purpose of this research is to investigate empirically the connection between Central Asian nations' CO2 emissions and unemployment rates.

By employing correlation and regression analyses based on comprehensive datasets, we aim to elucidate the extent to which economic conditions influence environmental outcomes in the region. Such analysis can provide valuable insights for policymakers, researchers, and stakeholders seeking to promote sustainable development, green growth, and inclusive economic policies in Central Asia.

2 LITERATURE REVIEW

The following scientists have conducted research on topics related to correlation of unemployment and CO2. Global CO2 emissions peaked at 31,983.6 million tons in 2020 and have grown at an average annual rate of 1.4% over the last ten years, according to the Statistical Review of World Energy 2021. This impact is extremely dangerous to human survival and causes significant economic damage because it typically lingers in the atmosphere and oceans for many generations. Given the wide range of links that exist between many nations and areas in the age of globalization, no nation can be left alone. Consequently, it is now essential to take concrete action to lower carbon emissions globally. (Xu et al. 2021; Wang et al. 2019)

Mrabet & Jarboui have examined the effects of institutional determinants on the GDP and CO2 emissions efficiency in Gulf and Maghreb nations between 1995 and 2013. They demonstrated that labor and other inputs had a favorable impact on the CO2 emission efficiency of Arabic nations. The capital of Maghreb countries influences the GDP efficiency. The Gulf countries' massive investments result in the creation of jobs and, consequently, lower unemployment (Mrabet et al. 2017). In the Asia-Pacific area and the United States, unemployment has a major indirect effect on CO2 emissions (Nestor et al. 2022). Between 1980 and 2011, Wang, Li, and Fang examined the connections among 170 nations' energy consumption, CO2 emissions, urbanization, and economic growth. The findings showed that there was a statistically significant positive association between the variables over the long term and that there was a co-integration relationship between the variables in all of the nations that were analyzed (Wang et al. 2021).

Researchers from the Viet Nam National University of Agriculture Anh Tru NGUYEN found that whereas per capita CO2 emissions have a negative impact on per capita GDP in Central Asia, per capita energy consumption has a positive link with per capita GDP. Furthermore, the region's per capita energy consumption is negatively impacted by per capita GDP. The findings show that energy consumption continues to be a major factor in the economic development of Central Asian nations. Nonetheless, as CO2 emissions have been identified as a factor contributing to a decline in economic growth, there is a need to lower them in this area (2021).

Emphasizing the risks associated with using fossil fuels for energy is crucial to reducing the rate of ecological disturbance. Nowadays, with so many environmental issues facing the world, it is critical to look for environmentally acceptable energy solutions for both residential energy needs and product production. Consequently, numerous research works have emphasized the significance of renewable energy in enhancing economic expansion and guaranteeing environmental sustainability (Chunyu et al., 2021). When total energy and non-renewable energy consumption are equated for ecological conditions, it is discovered that renewable energy sources are most effective at promoting environmental sustainability. In the G7, the use of renewable energy contributes positively to both environmental conservation and economic prosperity (Carfora et al. 2019).

Energy use and CO2 emissions have a significant impact on global health indicators. Domen looked into the average CO2 emissions from cities as well as the emissions per person in such cities. 14% of emissions were attributed to agricultural activities, while 19% were attributed to the industrial sector

(2009). These days, people are exposed to small concentrations of dangerous gases like carbon monoxide and carbon dioxide on a daily basis, which can have serious negative effects. This is due to the rapidly developing technological media, the quickly expanding industry, the hundreds of cars that drive through major cities every day, and the use of pesticides and other poisonous substances for the inflated production of products. The goal of the examined regions' environmental policies should be to control CO2 emissions in order to slow down global warming. The broad adoption of low-carbon, energy-saving, ecologically friendly, and energy-efficient technologies—including increasing the efficiency of coal energy use—should be the approach taken to lower CO2 emissions (Volchyn et al. 2018).

Measures promoting energy production and conservation, foreign direct investment, trade openness, and economic growth would be ideal for the entire region. Even if there is a political intent to develop similar goals and objectives, separate policy and strategy designs for participant subgroups should most likely be considered to enhance the environmental protection of the region (Tukhtamurodov et al. 2024)

3 METHODOLOGY

3.1 Data description

In this research, we used co2_emissions_per_capita and net_migration panel data for Central Asian countries. This panel covered annual data from 1991 to 2021 for five countries.

3.2 Cross-sectional dependence test

To select the proper unit root test, it is significant to test the cross-sectional dependence (CD) test for the given series in the panel datasets (Pesaran 2006). For this, the empirical study applies (Pesaran 2004) CD method. To determine the CD test (Pesaran 2004) purpose the following model:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T p_{ij}^2\right) \qquad (1)$$

In Eq. 1, T is the time period dimension and N is the cross- sectional dimension, is p_{ij}^2 the sample estimation for the pairwise residual correlation.

3.3 Panel unit root test

The initial phase in the study is to evaluate variables' stationery to prevent false regression and reliability of the predicted outcomes. The panel unit root approach has gained popularity and is most frequently utilized in research articles because of its better power in comparison to unit root tests based on a single time series. The estimation analysis may be biased while the stationary method is applied without considering the cross- sectional dependence. Since the first-generation panel unit root test do not consider the cross-sectional dependence, however, considering the potential of cross-section dependency in our study, we utilize a second generation panel unit root test proposed by (Pesaran 2006) including cross-sectionals Augmented Dickey–Fuller (CADF) and cross-sectional Im, K. S., Pesaran, M.H., Shin, Y (CIPS) unit root tests, both kinds of panel unit root tests are considered to robust to CD test. The CADF model can be presented as fellows in Eq. 2

$$\Delta y_{it} = \alpha_i + \beta_i Y_{it-1} + \varphi \bar{y}_{t-1} + \sum_{j=0}^{q} \theta_{j+1} \Delta \bar{y}_{t-j} + \sum_{k=1}^{q} \omega_k \Delta y_{it-k} \qquad (2)$$

Here, $\bar{y}_{t-1}$ is the average of lagged levels at time t of all N observations and $\bar{y}_t$ is the first difference of the individual series of the model. After estimating the CADF regression for each cross-section, the CIPS (Cross-sectional augmented IPS) statistics can be calculated by averaging the t-statistics of the coefficient β in the CADF model:

$$CIPS = N^{-1} \sum_{t=1}^{N} CADF_t \qquad (3)$$

Where the $CADF_i$ is the cross-sectional augmented Dickey– Fuller statistics for i^{th} cross-section unit. In the existence of CD, this test gives more consistent and accurate results than the first generation test.

3.4 ARDL – PGM approach

In this context, the ARDL modeling proposed by Pesaran et al. (1996, 2001) is considered relevant insofar as it can be specified as an error correction model when the underlying variables are integrated of order one (I(1)), or fractionally integrated (I(0) and I(1)), except that the dependent variable is constrained to be I(1). However, this technique cannot be applied in the case where variables are integrated for order 2. In addition, ARDL modeling provides consistent and efficient estimators because it eliminates endogeneity problems by including lag length in both endogenous and exogenous variables. The ARDL (p, q) model used in this study can be expressed as follows:

$$\mathrm{co2\_emissions\_per\_capita}_{it} = \mu_i + \sum_{j=1}^{p-1} \beta_{1_{ij}} \mathrm{co2\_emissions\_per\_capita}_{it-j} + \sum_{j=0}^{q-1} \beta_{2_{ij}} \mathrm{net\_migration}_{it-j} + \nu_{it} \quad (4)$$

According to Pesaran et al. (1996, 2001), this equation can be reformulated as follows:

$$\Delta \mathrm{co2\_emissions\_per\_capita}_{it} = \mu_i + \gamma_{1i}\mathrm{co2\_emissions\_per\_capita}_{it-1} + \gamma_{2i}\mathrm{net\_migration}_{it-1} + \sum_{j=1}^{p-1} \delta_{1_{ij}} \Delta \mathrm{co2\_emissions\_per\_capita}_{it-j} + \sum_{j=0}^{q-1} \delta_{2_{ij}} \Delta \mathrm{net\_migration}_{it-j} + \varepsilon_{it} \quad (5)$$

where terms in level reflect long-run dynamics, while terms in first difference reflect short-run effects. ε_{it} denotes the error term and Δ the first difference operator. The choice of lagged variable (p, q) is determined according to the Akaike Information Criterion (AIC) or Schwarz Bayesian criterion (S.B.C). Regarding the estimation of the panel ARDL model, Pesaran and Smith (1995) and Pesaran et al. (1999) introduced two techniques respectively the Mean Group (MG) and the Pooled Mean Group (PMG) estimation. However, these procedures, based on the maximum likelihood method, are considered to be the most consistent since they take into account the specificities of the different regions and make a better interpretation of long-run equilibrium.

4 RESULTS AND DISCUSSION

Table 1 illustrates the results of the cross-sectional dependence test. Based on the results of this method, the null hypothesis is rejected because ($P-values < 5\%$), which indicates that the existence of cross-sectional dependence at 1% significance level for all series.

Table 1: Results of cross-sectional dependence test.

	$LOG(CO_2$	$LOG(unem\_ra$	$LOG(gdp\_per\_cap$
Pesaran CD	3.621	14.669	16.48
Prob.	0.00	0.000	0.000

The findings of the cross-sectional dependence test represent that any shock or amendment in the variables can effects in any of the panel regions as well. Indeed, the second-generation panel unit root tests are applied in the next step.

At the next stage, a panel unit root test was conducted for 3 variables at their own level (level) and at the 1st order level (first difference) (Table 2).

Table 2: Panel unit root test outcomes.

Variables	Level	First difference
CADF		
$LOG(CO_2)$	6.52	55.44***
$LOG(unem\_rate)$	72.55***	69.09***
$LOG(gdp\_per\_capita)$	1.83	25.28***
CIPS		
$LOG(CO_2)$	0.36	-6.07***
$LOG(unem\_rate)$	-8.32***	-7.65***
$LOG(gdp\_per\_capita)$	2.12	-2.91***

It can be seen from the table that the variables $LOG(CO_2)$, $LOG(gdp_per_capita)$are stationary at the 1st order level according to the CADF and CIPS unit root tests. It can also be observed that the variable $LOG(unem\_rate)$ is stationary at its level and at the level of order 1 according to CADF, CIPS. Therefore, it is appropriate to use the level of order 1 when integrating these variables into equations.

Based on the above, long-term and short-term effects of unemployment rate and GDP per capita on environmental degradation in Central Asian countries were assessed (Table 3).

Table 3: Estimation ARDL (PMG).

Dependent variable: $DLOG(CO_2)$				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
	Long Run Equation			
$LOG(unem\_rate)$	0.133578	0.044280	3.016641	0.0031
$LOG(gdp\_per\_capita)$	0.332340	0.024040	13.82418	0.0000
	Short Run Equation			
$ECT(-1)$	-0.250911	0.125376	-2.001277	0.0474
$DLOG(unem\_rate)$	-0.039114	0.083670	-0.467485	0.6409
$DLOG(gdp\_per\_capita$	0.170144	0.059549	2.857209	0.0050
C	3.645767	1.854825	1.965559	0.0514

The evaluation's findings indicate that, over time, a 1% rise in the Central Asian nations' unemployment rate may cause an increase in yearly CO2 emissions of 0.13%, whereas a 1% increase in GDP per capita may cause an increase in CO2 emissions of 0.33%. The impact of the unemployment rate on annual CO2 emissions is statistically negligible in the near run, whereas GDP per capita has a positive influence with a coefficient of 0.17. Additionally, 25% of the disequilibrium from the previous year is corrected this year, according to the adjustment parameter (0.25) in the equation indicating the short-term effect (speed of adjustment parameter), which is negative and substantial at the 1% level.

In addition, in our research, we evaluated the short-term impact of unemployment rate and GDP per capita on annual CO2 emissions for each country in Central Asia separately (Table 4).

Table 4: Individual country results.

Country	Estimation ARDL (PMG)		
	$ECT\ (-1)$	$DLOG(unem\_rate$	$DLOG(gdp\_per\_capita$
Kazakhstan	-0.148*** (0.003)	-0.054*** (0.001)	0.157** (0.005)
Kyrgyzstan	-0.323*** (0.007)	0.031** (0.008)	0.348*** (0.036)
Tajikistan	-0.061*** (0.008)	-0.352*** (0.032)	0.241** (0.054)
Turkmenistan	-0.705*** (0.031)	0.13 *** (0.006)	0.104*** (0.02)
Uzbekistan	-0.015*** (0.001)	0.05*** (0.003)	-0.001 (0.004)

***Significance of 1%; **significance of 5% and *significance of 10%

According to the evaluation results, it can be seen that in some countries of Central Asia, the level of unemployment in the short term has a negative effect on the volume of annual CO2 emissions, and in some countries it has a positive effect. Also, GDP per capita has a positive effect on annual CO2 emissions in the short term in four countries, and in one country, the effect was statistically insignificant. Specifically, in Kazakhstan, a 1% increase in unemployment causes annual CO2 emissions to drop by 0.05%, whereas a 1% increase in GDP per capita causes CO2 emissions to rise by 0.15%. In Kyrgyzstan, annual CO2 emissions increase by 0.03% for every 1% increase in the unemployment rate and by 0.34% for every 1% increase in GDP per capita. In Tajikistan, annual CO2 emissions decrease by 0.35% with a 1% increase in the unemployment rate and increase by 0.24% with a 1% increase in GDP per capita. Additionally, there was a 1% rise in the unemployment rate in the Republics of Uzbekistan and Turkmenistan, as well as a yearly rise in CO2 emissions.

5 CONCLUSION

Based on the findings of our research investigating the association among CO2 emissions, the unemployment rate, and economic development in Central Asia using a panel-ARDL approach, several key conclusions can be drawn. The study reveals a consistent long-term positive relationship between both the unemployment rate and GDP per capita in Central Asia and annual CO2 emissions. This underscores the significant influence of economic factors on environmental outcomes in the region over extended periods. In the short term, the relationship between economic indicators and CO2 emissions exhibits more nuanced patterns. While economic development, as measured by GDP per capita, positively impacts CO2 emissions across most countries in the short term, the effect of the unemployment rate varies. Some countries experience a negative short-term relationship between unemployment and CO2 emissions, indicating potential environmental benefits during economic downturns. However, in other countries, higher unemployment is associated with increased CO2 emissions, suggesting complex interactions between economic activity and environmental outcomes.

These findings have significant implications for policymakers in Central Asia. Efforts to address CO2 emissions must consider the broader socioeconomic context, including the unemployment rate and GDP per capita. While reducing the environmental impact of industrial activity, strategies aiming at encouraging sustainable economic development should place a high priority on investments in clean energy infrastructure, technological innovation, and job creation.

Moreover, policies to alleviate unemployment should be designed with environmental sustainability in mind to ensure that economic growth is not achieved at the expense of environmental degradation. While this study provides valuable insights into the relationship between economic development, unemployment, and CO2 emissions in Central Asia, further research is needed to explore the underlying mechanisms driving these relationships. Future studies could investigate the role of specific industries, energy sources, and policy interventions in shaping environmental outcomes. Additionally, incorporating a more comprehensive dataset spanning a longer time period and considering the impacts of external factors, such as international trade and investment, could enhance our understanding of the dynamics of CO2 emissions in the region. In conclusion, our research highlights the complex interplay between economic factors and environmental outcomes in Central Asia. By elucidating these relationships, policymakers can develop more effective strategies to promote sustainable development and address the pressing challenges of climate change while fostering economic prosperity and social well-being in the region.

REFERENCES

BP, 2021. BP Statistical Review of World Energy 2021. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

Wang, Y., Duan, F., Ma, X., He, L., 2019. Carbon emissions efficiency in China: key facts from regional and industrial sector. *J Clean Prod.* 206:850–869.

Xu, L., Du, H., Zhang, X., 2021. Driving forces of carbon dioxide emissions in China's cities: an empirical analysis based on the geodetector method. *J Clean Prod* 287:125169

Mrabet, A., Jarboui, S., 2017. Do institutional factors affect the efficiency of GDP and CO_2 emission? Evidence from Gulf and Maghreb countries. *Int. J. Glob. Energy Issues* 40, 259.

Nestor, Sh., Solomiya, O., Ihor, K., Wlodziemers, S., Yuriy, F., Ramualdas G., Joanna, C., 2022. CO2 Emissions and Macroeconomic Indicators: Analysis of the Most Polluted Regions in the World. Energies 15(8), 2928.

Wang, S., Li, G., Fang, C., 2018. Urbanization, Economic Growth, Energy Consumption, and CO2 Emissions: Empirical Evidence from Countries with Different Income Levels. *Renewable and Sustainable Energy Reviews,* 81, 2144-2159.

Anh Tru NGUYEN, 2019. The Relationship between Economic Growth, Energy Consumption and Carbon Dioxide Emissions: Evidence from Central Asia. Eurasian Journal of Business and Economics 12(24), 1-15.

Chunyu, L., Zain-ul-Abidin, S., Majeed, W., 2021. RETRACTED ARTICLE: The non-linear relationship between carbon dioxide emissions, financial development and energy consumption in developing European and Central Asian economies. Environ Sci Pollut Res 28, 63330–63345.

Carfora, A., Pansini, R.V., Scandurra, G., 2019. The causal relationship between energy consumption, energy prices and economic growth in Asian developing countries: a replication. Energy Strategy Rev 23:81–85

Domen, K., 2009. Efficient hydrogen evolution sites of photocatalysts for water splitting; Proceedings of the 21st North American Meeting (NAM); San Francisco, CA, USA.

Melas, D., 2007. Atmospheric Diffusion and Dispersion. University Publication. Aristotle University of Thessaloniki.

Volchyn, I., Haponych, L., 2018. Carbon dioxide emissions at the Ukrainian pulverized-coal thermal power plants. Sci. Works NUFT 2018, 24, 131–142.

Tukhtamurodov, A., Sobirov, Yu., Toshalieva, S., Ibrayimova, D., Matkarimov, F., 2024. Determinants of CO2 emissions in the BRICS. A dynamic Panel ARDL approach. BIO Web of Conferences , 06002.

Pesaran, M. H., 2006. Estimation and inference in large heterogeneous panels with a multifactor error structure. Econometrica 74:967–1012.

Pesaran, H. M., 2004. General diagnostic tests for cross-sectional dependence in panels, 435. Univ. Cambridge, UK: Cambridge Work. Pap. Econ.

Pesaran, M.H., Shin, Y., Smith, R.J., 1996. Testing for the existence of a longrun relationship. Faculty of Economics, University of Cambridge

Pesaran, M.H, Shin, Y., Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationships. *J Appl Econ* 16(3):289–326

Pesaran, M.H., Smith, R.P., 1995. Estimating long-run relationships from dynamic heterogeneous panels. *J Econ* 94:79–113.

Pesaran, M.H, Shin, Y., Smith, R.P., 1999. Pooled mean group estimation of dynamic heterogeneous panels. *J Am Stat Assoc* 94:621–634

Job Satisfaction Assessment in IT Companies in Hanoi

Tran Q. Toan[1,a], Loan T.B. Nguyen[1,b], Rimma S. Zaripova[2,c], Maxim G. Kuznetsov[3,4,d] and Maksim S. Shkinderov[5,e]

[1]*Thuongmai University, Hanoi, Vietnam*

[2]*Kazan State Power Engineering University, Kazan, Russia*

[3]*Kazan National Research Technological University, Kazan, Russia*

[4]*Kazan State Agrarian University, Kazan, Russia*

[5]*Kazan National Research Technical University named after A. N. Tupolev – KAI, Kazan, Russia*

quoctoan2880@gmail.com, bichloandhtm@tmu.edu.vn, zarim@rambler.ru, max-kuzz@yandex.ru, shkinderov@rambler.ru

Keywords: Job Satisfaction, Information Technology, Employee Well-Being, Human Resources, IT Companies, Vietnam.

Abstract: The information technology workforce in Vietnam is only 1.1% of the total labor force. The level of information technology workforce in Vietnam is quite low compared to technology-oriented countries such as the USA (4%), Korea (2.5%) or India (1.78%). The total revenue of the information technology industry in the first 5 months of 2023 is estimated to reach over VND 1.22 million (equivalent to $52.2 billion), 8% less than the same period in 2022. What are the reasons affecting the information technology industry, the ratio of human resources and the quality of information technology human resources in information technology enterprises in recent times are issues that are still being researched. Job satisfaction is a measure of how satisfied an employee is with his or her job. Typical factors affecting comprehensive satisfaction include working conditions, pay, comfort and safety, and job content. We have developed a questionnaire to investigate the level of job satisfaction among the employees of IT companies to understand whether the nature of the job is suitable for the employees working in the departments and whether they have been assigned jobs according to their experience, abilities, and personal needs.

1 INTRODUCTION

Over the past 20 years, the development of the information technology industry in Vietnam has made great progress. According to statistics in 2000, the information technology industry accounted for only about 0.5% of the country's GDP (Nominal Gross Domestic Product). However, in just two decades, the IT industry has made incredible leaps in development:

- Industry revenue in 2019 reached $120 billion, 400 times higher than in 2000 and corresponding to an average growth of 37 percent per year for 19 years;
- the industry accounted for 14.3 percent of Vietnam's GDP, 28 times more than in 2000 (only 0.5 percent);
- labor productivity in the IT industry is 7.6 times higher than the national average;
- 1030000 workers in the IT industry, accounting for 1.88 percent of the total number of workers in Vietnam. Compared to 2000, this number has increased 20 times;
- exports have reached 89.2 billion USD, accounting for 33.7 percent of Vietnam's total export value. The export value generated by one worker in the industry is 18 times higher than the national average.

[a] https://orcid.org/0009-0005-7722-7005
[b] https://orcid.org/0009-0000-9869-4343
[c] https://orcid.org/0000-0002-3548-1866
[d] https://orcid.org/0000-0002-1590-9343
[e] https://orcid.org/0009-0005-4992-7047

Figure 1 shows the demand for IT human resources in Vietnam from 2018 to 2022.

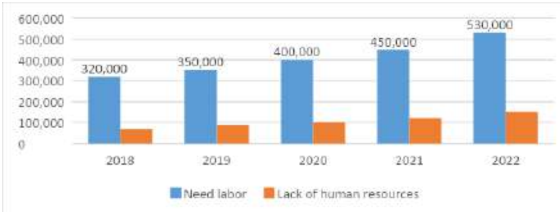


Figure 1: IT human resource requirement in Vietnam (2018-2022).

As of December 2021, there were about 64000 digital technology enterprises in Vietnam. The revenue of these enterprises reached 18779 million USD, accounting for 13.8% of the total industry revenue. Experts estimate that in 6 months in 2022, the revenue of the information technology industry reached 72.5 billion USD, up 17.8% in the same period. The total revenue of the information technology industry in the first 5 months of 2023 is estimated to reach over VND 1.22 million (equivalent to $52.2 billion), a decrease of 8% over the same period in 2022.

Vietnam has a great advantage with its «golden structure» population, where 69% are of working age, but still has a significant shortage of digital human resources. According to FPT Digital's recent «Digital Human Resource Development Strategy» DxReports, Vietnam graduates around 400000 information technology engineers annually and has more than 50,000 IT students. However, only about 30% of this IT workforce meets the actual requirements of employers.

Hanoi City is now among the top three cities in the country in terms of digital transformation, information technology, competitiveness index, innovation, security, and network security. Many technology companies have mastered "core" technologies, developing about 40 «made in Vietnam» platforms, such as Viettel Business Solutions Corporation; DTT Technology Company; CMC Technology and Solutions Corporation; VNPT Hanoi; Phenikaa Maas Technology Joint Stock Company, Samsung, Apple, LG, Foxconn, Cisco, Toshiba and so on.

In recent years, the number of Vietnamese digital companies has been growing steadily, with 45600 in 2019, 58000 in 2020, and 64000 enterprises in 2021 (figure 2). The planned targets set for 2022 have reached 70000 enterprises in Vietnam. However, the total revenue of the information technology industry in the first 5 months of the year is estimated to reach more than VND 1.22 million (equivalent to $52.2 billion), down 8% from the same period in 2022. The main reason is due to the sharp decline in exports of equipment and electronics, which account for a large part of the information technology industry's revenue structure. The sharpest decline in March and April 2023 is 22.8% and 22.4% respectively. It also shows that except for large enterprises such as FPT, FPT IS, FPT Software, FPT Telecom, CT-IN, MK Smart, MobiFone, NashTech Vietnam, One Mount, Viettel IDC, Viettel Digital, Viettel Media, Viettel Post, Viettel Solutions, VNPT Technology, most of the remaining enterprises have not truly realized the ability to adapt to global changes, which means that the quality of human resources in information technology in information technology enterprises is not quite up to date. Human resources are still limited in their business development initiatives and integration into the global labor market.

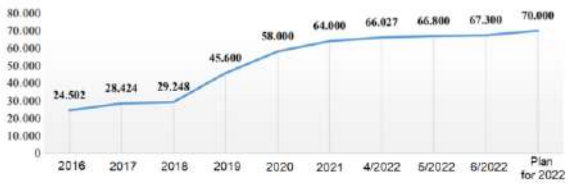


Figure 2: Number of enterprises in Vietnam.

However, the development of Vietnamese digital technology enterprises in regions is uneven. The number of digital technology enterprises is mainly concentrated in 4 localities with a very high ratio of digital technology enterprises, such as Ho Chi Minh City (3.19), Hanoi (2.29), Da Nang (2.24) and Bac Ninh (1.02). The total number of digital technology enterprises in these four provinces accounts for more than 72% of the total number of digital technology enterprises in the country.

2 RESEARCH METHODOLOGY

The research methodology of this study is grounded in a rigorous analytical approach, focusing on a comprehensive review and analysis of scholarly literature and empirical data regarding job satisfaction in the IT sector of Hanoi, Vietnam. This methodology aims to uncover the multifaceted aspects of employee satisfaction within the dynamic environment of information technology workplaces.

The initial phase involved an extensive literature review aimed at identifying and synthesizing existing research related to job satisfaction. This review helped in understand the various factors that influence job satisfaction and the specific challenges faced by IT professionals in urban Vietnamese settings. Key academic databases such as IEEE Xplore, ScienceDirect, and Google Scholar served as the primary sources for accessing relevant academic articles, conference papers, and other scholarly publications. This comprehensive review ensured that the study was built on a solid foundation of existing knowledge while aiming to fill significant gaps identified during the process.

The study utilized a mixed-methods research design, combining quantitative and qualitative techniques to collect a wide array of data. Quantitative data were collected through a structured questionnaire developed to assess various dimensions of job satisfaction, including standardized items measuring satisfaction with pay, work conditions, career growth opportunities, and interpersonal relationships at work. The survey was administered to a representative sample of employees from multiple IT companies in Hanoi, ensuring a diverse participant pool. Responses were collected through both online platforms and paper-based methods to maximize response rates and accessibility for all employees.

Qualitative data were collected through in-depth interviews with selected participants who had unique insights or experiences reflective of broader trends observed in the survey. These interviews were semi-structured, allowing for flexibility in responses and the exploration of nuanced perspectives on job satisfaction. Additionally, observational studies were conducted in different IT company environments where researchers noted behaviors, workplace interactions, and the general atmosphere, providing context to the quantitative data and highlighting factors that influence satisfaction but may not be directly expressed by employees.

Data collected through surveys, interviews, and observations were analyzed using various techniques to ensure a thorough understanding of the underlying themes and patterns. Quantitative data underwent descriptive and inferential statistical analysis to describe the data distribution and explore relationships between different variables. Techniques such as correlation analysis, t-tests, ANOVA, and regression models were employed. Qualitative data were analyzed through coding and thematic analysis using qualitative data analysis software, which helped in managing and sorting the data effectively. Content analysis was also used to interpret the context and implications of textual data from interviews and open-ended survey responses, providing deeper insights into the qualitative aspects of job satisfaction.

The final phase involved integrating the quantitative and qualitative findings to paint a comprehensive picture of job satisfaction among IT employees in Hanoi. This synthesis highlighted the complex interplay of factors affecting job satisfaction and provided a nuanced understanding that can inform targeted interventions. This detailed methodological approach ensured the study was both comprehensive and sensitive to the local context, providing robust insights into the factors affecting job satisfaction in Hanoi's IT sector. The findings are expected to contribute valuable perspectives to the literature and offer practical recommendations for IT companies looking to improve employee satisfaction and retention.

3 RESULTS AND DISCUSSION

In terms of digital technology enterprises, in 2022, there were more than 9,300 IT and electronics enterprises operating in Hanoi with a total revenue of about $12.8 billion, attracting more than 207000 employees. Hanoi in particular, and information technology companies in general, often face difficulties in finding suitable, highly skilled professionals. Information technology skills are often required in many positions and at all staff levels, playing a crucial role in business development and performance.

The IT human resource quality research step is to understand the needs of the business and determine the current state of human resources. From there, businesses conduct assessments and improve internal capabilities through training programs, courses, etc. The survey process also helps in developing a deep understanding of employee priorities and desires, resources, and attracting excellent human resources for the business.

After the survey stage, businesses need to develop a detailed human resource development plan to fully meet the quantity and experience needs. The internal hiring and training process also needs to be planned in detail.

We have developed the following IT employee satisfaction survey for IT companies to show whether the nature of the job is suitable for employees working in departments and whether they have been assigned jobs according to their experience, abilities, and personal needs (Table 1). In this case, enterprises will conduct employee satisfaction surveys in an anonymous form, asking employees to fill in the information in the evaluation sheet by themselves.

Let us propose a model of some factors influencing the level of employee satisfaction with business as follows (Fig. 3).

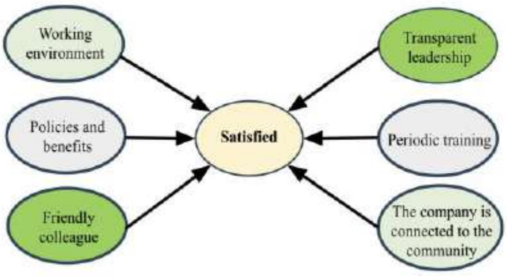


Figure 3: Model of factors affecting employee satisfaction.

From the above problems, business leaders can assess the quality of IT human resources in their business. The quality of human resources is expressed through a series of random surveys of 1000 employees about job fit, salary satisfaction, and working conditions at IT companies (Table 1). Satisfaction level of the company's employees: 1 – Not satisfied; 2 – Normal; 3 – Satisfied; 4 – Very satisfied.

Table 1: Employee satisfaction survey table in IT companies.

Survey questions	Satisfaction level			
	1	2	3	4
1. Convenient location	119	248	465	138
2. Satisfaction with wages and salaries	213	391	215	62
3. Working environment	132	247	485	139
4. Colleagues have good professional qualifications	56	357	469	118
5. Satisfaction with management	158	517	235	90
6. The company has reasonable criteria for evaluating the ability of employees, salary increases are being considered	362	322	193	123
7. The company's remuneration distribution method is reasonable and timely	156	183	625	36
8. Wages are competitive with those in other similar companies	71	358	472	99
9. The company has a plan for periodic professional training	207	385	391	17
10. Are you satisfied with your current job?	190	297	310	203

The diagram (Fig. 4.) with the survey parameters shows that most of the surveyed employees are satisfied with their jobs. There is not much difference between the jobs in terms of salary, bonuses, etc. Though mostly everyone feels satisfied with their job some people feel dissatisfied with their salary. The wages that the company pays to its employees are not in line with their professional qualifications or not in line with their job position, which leads to the fact that the salary is not satisfactory to them. Many people still feel dissatisfied with the company's salary, bonuses, and other benefits.

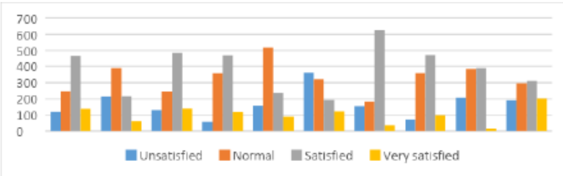


Figure 4: Graph showing the level of employee satisfaction.

4 CONCLUSIONS

From the above problems, we suggest the following solution for IT companies. The importance of employee remuneration policy should be properly assessed, jobs should be matched to the abilities and strengths of the employees. The policy of periodic salary increases, distribution of bonuses, and various benefits with different contribution levels should be considered. Employee relations, between employees and between employees and managers are also important. To help employees increase their sense of responsibility, it is necessary to appoint a highly qualified manager who understands what his or her employees do and has a clear understanding of the content of the work of all departments.

REFERENCES

Wang, Y., Lin, G., Y. Yang, 2011. Organizational socialization and employee job performance: An examination on the role of the job satisfaction and organizational commitment. *ICSSSM11*, pp. 1-5.

Chang, J. C., Lin, K. M., 2017. Exploring the role of professional development motivation between work values and job satisfaction. In *2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, pp. 2291-2295.

Arambepola, N., Munasinghe, L., 2021. What makes job satisfaction in the information technology industry?. In *2021 International Research Conference on Smart Computing and Systems Engineering (SCSE)*, pp. 99-105.

Gizatullin, Z. M., Shleimovich, M. P., 2023. A Technique for Research of the Conducted Interferences from Power Devices of the Aircraft under Modernization. *Russian Aeronautics* 66(1): 154-161.

Soloveva, O., Solovev, S., Zaripova, R., Khamidullina, F., Tyurina, M., 2021. Evaluation of the effective porosity of an open cell foam material for using in heat and mass transfer numerical simulations. *E3S Web of Conferences* 258: 11010.

Gerasimov, V. A., Nuriev, M. G., Gashigullin, D. A., 2022. The fiber-optic communication system in the enterprise. In *2022 International Russian Automation Conference (RusAutoCon)*, pp. 75-79.

Nuriev, M., Zaripova, R., Sitnikov, S., Nurgaliev, R., 2023. The principles of building a parallel program for steganographic file protection. *E3S Web of Conferences* 458: 09027.

Nuriev, M., Zaripova, R., Potapov, A., Kuznetsov, M., 2023. Achieving new SQL query performance levels through parallel execution in SQL Server. *E3S Web of Conferences* 460: 04005.

Viktorov, I., Gibadullin, R., 2023. The principles of building a machine-learning-based service for converting sequential code into parallel code. *E3S Web of Conferences* 431: 05012.

Kozlov, E, Gibadullin, R, 2023. Prerequisites for developing the computer vision system for drowning detection. *E3S Web of Conferences* 474: 02031.

Gizatullin, Z. M., Shkinderov, M. S., Mubarakov, R. R., 2022. Experimental studies of building access control systems under the influence of electrostatic discharge. In *2022 Conference of Russian Young Researchers in Electrical and Electronic Engineering (ElConRus)*, pp. 1350-1353.

Yoqubjonov, J., Gibadullin, R., Nuriev, M., 2023. Advanced robotic process automation for enterprise efficiency. *E3S Web of Conferences* 431: 07011.

Khasanov, S. R., Gracheva, E. I., Toshkhodzhaeva, M. I., Dadabaev, S. T., Mirkhalikova, D. S., 2020. Reliability modeling of high-voltage power lines in a sharply continental climate. *E3S Web of Conferences* 178: 01051.

Shakirzyanov, M., Gibadullin, R., Nuriyev, M., 2023. Prerequisites for the development of the system of automatic comparison of video and audio tracks by the speaker's articulation. *E3S Web of Conferences* 419: 02029.

Shakirzyanov, R. M., Shakirzyanova, A. A., 2021. Object Detection Using Color Segmentation, Radial Symmetry Detector, and Hough Method. In *2021 International Russian Automation Conference (RusAutoCon)*, pp. 714-718.

Gibadullin, R. F., Perukhin, M. Y., Mullayanov, B. I., 2020. Optimization of water supply by the method with model predictive. In *2020 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)*, pp. 1-6.

Zaripova, R., Kosulin, V., Shkinderov, M., Rakhmatullin, I., 2023. Unlocking the potential of artificial intelligence for big data analytics. *E3S Web of Conferences* 460: 04011.

State Support for Innovative Development in Russia to Achieve Sustainable Development of Agricultural Sector

Marinchenko T. E.[a]

Russian Research Institute of Information and Feasibility Study on Engineering Support of Agribusiness, the Federal State Budgetary Scientific Institution (Rosinformagrotekh FSBSI), 60, Lesnaya Str., Pravdinsky Township, 141261 Moscow Region, the Russian Federation

9419428@mail.ru

Keywords: agricultural, innovative development, sustainable development, state support.

Abstract: The purpose of the study is to determine the sufficiency of measures to support and stimulate innovation in the agricultural sector of Russia to ensure its sustainable development. To determine the information base, a search was used by keywords using general scientific research methods, as well as their expert selection, analysis, comparison and systematization was performed. To identify regulatory legal acts that govern innovation activities, a keyword search was used, the keywords were selected by an expert method. The identified documents were textual and logical analyzed and structuring by a graphical method to facilitate further analysis were performed. Analysis revealed that there are no separate programs aimed at the growth of innovative activity in the agricultural sector, but support is provided for by the activities of state programs and national projects. A number of national projects and programs are being implemented that are focused on achieving national goals, scientific and technological development, development of territories, and stimulation of innovative and entrepreneurial initiatives. Support measures under these programs and projects contribute to the development of innovation activities and the organization of highly productive, efficient and resource-saving agricultural production. Because stimulation of innovation activities in many countries is a factor that determines the global competitiveness of national economies, the sustainable development of the agricultural sector and the introduction of resource-saving techniques taking into account environmental protection, study of potential measures to support innovation in the industry is both timely, and relevant and will contribute to the growth of innovation activity. The novelty of the study lies in the analysis of support measures within the framework of programs and national projects for the presence of activities that provide support for innovation in agriculture, as well as the development of territories and scientific and technological progress, upgrading of production and forcing the entrepreneurial initiative.

1 INTRODUCTION

The rapid development of science and technology, global competition for ideas and means of their implementation currently determine the economic policy of the leading countries while orienting them towards stimulating innovation initiatives and attracting private investment in breakthrough technological areas (Kuzmin, 2021).

A model of the predominant use of foreign equipment, techniques and breeding achievements has developed in the Russian Federation, which indicates insufficient innovative activity in the agricultural sector.

The Strategy for the Development of the agricultural and fishery sectors of the Russian Federation for the period up to 2030 (further referred to as the Strategy) has been approved, which takes into account the need to ensure an integrated approach to achieving the national goals (Decree No. 474) outlined in the Decree of the President of the Russian Federation titled «On the national development goals of the Russian Federation for the period up to 2030», such as accelerating technological and innovative development, ensuring accelerated digitalization of production, creating a highly productive export-oriented sector in the agribusiness that develops based on up-to-date innovative techniques (Decree No. 474). The Agency

[a] https://orcid.org/0000-0003-3721-112X

for Strategic Initiatives, together with the business community, presented a roadmap for the development of the FoodNet food market in September 2017. The roadmap provides that the Russian companies should occupy more than 5% of the global market in five priority segments by 2035. These segments are smart agriculture, accelerated breeding, accessible organics, new sources of raw materials (biomass of algae, insects, etc., pseudo cereals, etc.) and personalized nutrition (The concept of the roadmap).

The government is making significant efforts to stimulate innovation activities: work has been carried out on state strategic planning that directs innovation activities in the most promising areas; an infrastructural support has been organized that assists enterprises at all stages of the life cycle of innovative projects and developing products of an intersectoral nature (IT technologies, biotechnologies, engineering, etc.).

The main program document stimulating innovation activities for the agricultural sector is the Federal Scientific and Technical Program for the Development of Agriculture for 2017-2030 (FSTP), whose tasks are, among other things, to create conditions for the development of scientific / scientific and engineering activities and obtain the results necessary for the creation of techniques, as well as the creation and implementation of techniques (Decree No. 996). The scientific and engineering development of the agricultural sector, first of all, involves the engineering and process renewal of economic entities and the introduction of knowledge-intensive forms of labor organization, management, marketing, etc. (Sandu, 2021).

Since the development of the agricultural sector based on knowledge and innovation is the only way to achieve national goals, the analysis of measures to support and stimulate innovation activities in the agricultural sector, as well as generalization of information on support measures implemented within the framework of state programs and national projects that contribute to the implementation of conditions for the development of innovation activities and the organization of highly productive, efficient and resource-saving agricultural production are relevant (Kharitonov, 2021, National Science project, Vasilchenko, 2020).

Stimulation of innovation activities as the main factor in the development of the agricultural sector, as well as the study of aspects that affect innovation activities, are reflected in many papers of domestic scientists, including those of A.V. Golubev (problems of innovative development of Russian agriculture), E.V. Orlova (analysis of innovative development of the agricultural sector in Russia), A.V.Bogoviz (investment development issues), and V.N. Kuzmin (stimulating innovation activity) (Golubev, 2021, Orlova, 2020, Bogoviz, 2018, Kuzmin, 2021). Main factors of scientific and technical development and basis for forecasting the innovative development of the agricultural sector are investigated in the works (Bogoviz, 2020, Vasilchenko, 2020). Despite the great role of these papers for understanding various aspects of innovative activities and its stimulation, no analysis of measures and tools for stimulating innovation activity that can be used by manufacturers from non-industry programs and national projects has been performed yet. Generalization and systematization of information in this area have not been performed too.

2 MATERIALS AND METHODS

The purpose of the study is to analyze them and determine their sufficiency to ensure the sustainable development of agriculture. The subject of the study is the support measures implemented within the framework of state programs and projects that stimulate innovation activities in the agricultural sector.

The following are the objectives of the study:

1. Analyze the definition of “sustainable development of the agricultural sector”;

2. Formulate problematic issues of state support for the innovative transformation of the agricultural sector;

3. Describe the trajectories of state support to agriculture for the modernization of the agricultural sector.

The information basis of the study was the regulatory legal acts (Decree No. 474, Decree No. 996), the official data from the Russian Federal State Statistics Service (Russian Federal State Statistics), and papers of leading scientists in the field of research (Bogoviz A., Golubev A., Kuzmin V., Orlova N., Sandu I., et al.). The study used the “appeal to authorities” method - generalization of the opinions of authors who had previously studied this topic. A. Z. Anokhina analyzed the issues of innovative evolution of the agricultural sector as a factor of competitiveness and identified key problems, trends, and prospects (Anokhina, 2020). In their research, A. V. Golubev identified new challenges to Russian agriculture (Golubev, 2021). The work of E. E. Kharitonov determined the role of innovations in agriculture development, using Russia as an example (Koutsouris, 2020). I. S. Sandu identified the main incentives for the scientific and technical evolution of Russian agro-industrial enterprises (Sandu, 2021).

The analysis of legal documents on state support of the agricultural sector used theoretical studies, including scientific approaches to ascent from the abstract to the concrete and a logical method. The study applied generalized (versatile) approaches to characterize the sustainable development of the agricultural sector. Such general scientific empirical methods as participant observation, thought experiment, and intellectual description were used in designing the economic situation of regions over the past ten years. The proposed research includes general logical methods: analysis, synthesis, abstraction, generalization, modeling, and analogy. The logical rules of analysis provide these methods for identifying and organizing the necessary documents.

When searching for legal information on web portals and analyzing existing regulatory legal acts in the field of promoting innovation, the author used the selection method for key terms: “innovation activity,” “research work,” “entrepreneurship,” “regulation of innovation,” etc. The expert method helped select legal documents stimulating innovation and entrepreneurship over the past ten years. These methods were compared textually and logically and systematized using a graphical method; after, the conclusions were drawn. Such a choice of scientific approaches is due to the fact that legislative and regulatory documents are freely available on electronic resources and portals, accessible for detailed analysis, comparison, and systematization. The considered methods were used in the order of mention.

3 RESULTS AND DISCUSSION

The significance of the innovative development of the agricultural sector in the short and long term is reflected in the State Program for the Development of Agriculture and the Regulation of Agricultural Products, Raw Materials and Food Markets (further referred to as the State Program), the Strategy, the FSTP, Science National Project and other regulations and strategic documents (Decree No. 717, Decree No. 996, Decree No. 474, National Science project). Strategic guidelines are determined by the Forecast of the long-term socio-economic development of the Russian Federation for the period up to 2030, which includes the section titled «Development of science, technology and innovation», the Forecast of the scientific and technical development of the agricultural sector of the Russian Federation for the period up to 2030, etc. (Decree No. 717).

Current vectors of scientific and engineering development of the agricultural sector are determined by the FSTP, which stimulates the creation of innovations, supports advanced research and the creation of scientific collaborations, as well as the creation of infrastructure for them. Within the framework of the FSTP, it is planned to implement a number of subprograms structured by key segments of crop production, animal husbandry, aquaculture, animal health and feed production, mechanization, etc., in the areas of which there is a high degree of import dependence (Anokhina, 2020, Bogoviz, 2020).

The ongoing Science Project, which, within the framework of the priorities of scientific and engineering development, is designed to ensure entry into the top five countries of the world in the field of scientific research and development (National Science project).

The specified national goals and strategic objectives of the country's development, including Russia's entry into the top five largest global economies, ensuring the accelerated introduction of digital technology and the creation of a highly productive export-oriented sector in basic industries, have been instrumentally embodied in the form of a list of national projects. Among the twelve areas of Russia's strategic development, half are focused on supporting the scientific, technological and innovation track in such national projects as Education, Science, Small and Medium Enterprises, Digital Economy, Labor Productivity and Employment Support, and International Cooperation and export (Troshin, 2019, Korolkova, 2020).

Currently, Russia does not have separate programs for stimulating innovation activities in the agricultural sector. However, support for innovation activities is provided by a number of state programs and national projects. Their certificates have been analyzed for the presence of projects and programs that provide for activities to support the innovation activities, as well as the development of rural areas and scientific and engineering progress, which form a favorable environment for innovation activities in the agricultural sector in the short term. It has been revealed that activities to support innovation activities are provided for by a number of state programs and national projects through subprograms, departmental programs, departmental target programs and federal projects to be implemented within framework of the state programs and national projects (table 1).

Table 1: State programs to support innovation in the agricultural sector.

State programs and projects		Subprograms for the development of rural areas and scientific and engineering progress in the agricultural sector
National Project: Small and Medium Enterprises (SMEs)and Support for Individual Entrepreneurial Initiatives		Federal Project: Creation of a support system for farmers and development of rural cooperation
		Federal Project: Improving the conditions for doing business
		Federal Project: Expanding access of SMEs to financial resources and concessional financing
		Federal Project: Acceleration of SMEs
		Federal Project: Promoting entrepreneurship
		Departmental Target Program: Ensuring state monitoring of rural areas
		Departmental Target Program: Modern look of rural areas
		Departmental Program: Development of transport infrastructure in rural areas
		Departmental Program: Development of engineering infrastructure in rural areas
		Departmental Program: Improvement of rural areas
		Departmental Program: Promoting rural employment
		Departmental Program: Development of housing construction in rural areas and improving the level of improvement of households
State program	Subprogram: Development of agricultural sector branches	Stimulating the renewal of the agricultural machinery fleet
		Departmental Program: Development of agricultural sector branches
		Departmental Program: Stimulation of investment activity in the agricultural sector
		Departmental Program: Technical upgrading of agricultural sector
		Federal Project: Export of agricultural products
		Federal Project: Creation of a support system for farmers and development of rural cooperation
		Support for SMEs in the agricultural sector of the federal project Acceleration of small and medium-sized businesses
	Subprogram: Providing conditions for the development of the agricultural sector	Departmental Program: Digital agriculture
		Departmental Target Program: Sustainable development of rural areas
		Departmental Program: Development of Russian reclamation sector
		Departmental Target Program: Ensuring the general conditions for the functioning of the agricultural sector branches
		Departmental Target Program: Scientific and engineering support for the development of agricultural sector
		Departmental Target Program: Organization of veterinary and phytosanitary supervision
FSTP: Subprograms to be implemented		Development of selection and seed production of potatoes in the Russian Federation Development of selection and seed production of sugar beet in the Russian Federation Creation of a domestic competitive crosses of meat chickens in order to obtain broilers Development of the production of feed and feed additives for animals Development of selection and seed production of oilseeds in the Russian Federation Improving the genetic potential of beef cattle Development of viticulture, including nursery Improving the genetic potential of dairy cattle Development of selection and seed production of industrial crops Selection and seed production of vegetable crops Development of selection and processing of grain crops Development of nursery and horticulture Development of selection and seed production of corn
FSTP: Subprograms to be drafted		Agricultural machinery and equipment Development of technologies for the production of medicines for veterinary use
National Project:International cooperation and export		Federal Project: Export of agricultural products
Federal Scientific and Technical Program for the Development of Genetic Technologies for 2019 - 2027		Biosecurity and Technological Independence
		Genetic technologies for the development of agriculture
		Genetic technologies for industrial microbiology

State Program: Economic development and innovative economy	Subprogram: Investment climate
	Subprogram: Development of small and medium business
	Subprogram: Stimulating innovation

Source: Compiled by the author

The analysis revealed a large number of projects and subprograms that provide for measures to support innovation activities, access to infrastructure, financial, scientific and engineering support.

The previous stage of state policy stimulated, through the Strategy for Innovative Development of the Russian Federation for the period up to 2020, the creation of an innovative environment that provided market participants with conditions for the development and implementation of innovations, and financed fundamental science and new developments. At the present stage, the role of the state becomes even more significant, since it has the ability to influence the degree of infrastructure development, the demand for innovation, financing, competencies and the culture of innovative entrepreneurship. The active position of the state in stimulating the innovation activities can significantly accelerate the pace of development of certain industries, including the agricultural sector (Russian Federation. Support, Marinchenko, 2023. Stimulation). Within the framework of the developed strategy for the development of the industry, the state has the opportunity to finance strategically important projects and fundamental research, as well as to ensure the demand for innovation through the state order, support through the sharing of financial responsibility for the success of research, stimulation of the innovation activities of universities, research institutes and companies, replication of innovations for innovations, stimulation involvement in the innovation activity system of companies, in which the state is a shareholder through corporate governance tools, etc. (Strategy for the development).

In recent years, there has been a positive trend towards an increase in spending on innovative activities of organizations and investments in business development, the total share of these sources has increased. There is also a positive trend associated with increasing expenses from the own funds of organizations and investments from businesses. The total share of these sources has increased from 45,6% to 63,0% in 2018-2022, which indicates their increased innovation activities (Russian Federal State Statistics).

It should be noted the growing influence of large integrator companies that take control of an increasing share of food systems and are able to achieve a high effect in achieving economic, environmental, social and other key goals and form global value chains.

In addition, in Russia until 2021, there were more than 40 different corporations, funds, and banks that had been established to support the innovation activities and more than 200 regional organizations that had been established in the form of support funds, regional venture funds, business incubators, etc., which, based on their functions, also supported the innovation activities and acted as development institutions (Marinchenko, 2023. Stimulation). Currently, development institutes are in a state of reorganization; upon completion of which the system of development institutions will represent a single national development institution at VEB.RF, a State Development Corporation, and 12 sectoral development institutions. As part of the reform, a system of seamless integration of state support measures has been formed, which provides end-to-end acceleration of the startup acceleration process from the establishment to launching products on the market or receiving investments. NTI Platform, a Russian Direct Investment Fund, as well as Innovation Promotion Fund, Skolkovo, Fund for Infrastructure and Educational Programs, subsidiaries of VEB.RF, also provide significant support to the innovation activities based on the mechanism of project financing of investment projects as per syndicated credit (loan) agreements using the state support measures (Bogoviz, 2020, Marinchenko, 2023. Stimulation).

The target institutions for the development and promotion of innovation activities in the agricultural sector are Rosagroleasing and Russian Agricultural Bank, which provide modernization of production and long-term and short-term investments, as well as stimulate the development of cooperation, small forms of business and rural areas. Export development is supported on a systematic basis by Russian Export Center, which provides Russian exporters with a wide range of financial and non-financial support measures within the framework of International Cooperation and Export National Project and Export of Agro-Industrial Products Federal Project. Financial, infrastructural, property, legal, methodological and other support for small businesses, cooperatives and farmers is provided by Corporation MSP (Novozhenina, 2021, Marinchenko, 2024).

The study of aspects that affect innovation activities, are reflected in many papers of domestic scientists (Kharitonov, 2021,Vasilchenko, 2020), at the same time, studies that analyze and systematize non-sectoral state programs for the presence of support measures (for example, the Federal Scientific and Technical Program for the Development of Genetic Technologies and Economic Development and Innovative Economy) that can be used in the interests of agriculture have not been discovered. As for 'Nauka' National Project, since science and education are key elements of progressive innovative development (Rodionova, 2019, Troshin, 2019), their development in the interests of the agricultural sector is given great attention, which is consistent with the data obtained (Marinchenko, 2023. Methodological approaches, Marinchenko, 2024).

A study of support measures within the framework of the FSTP has confirmed the great potential for stimulating innovative activities within the framework of this program; this confirms the previous research results in the papers (Marinchenko, 2023. Stimulation, Marinchenko, 2023. Improving the infrastructure).

The analysis has revealed a large number of activities of programs and projects within the framework of which the state provides support for innovation activities, for the same purposes there are funds and development institutions that form a system of seamless integration of state support measures and through acceleration of the process of accelerating projects, whose activities are aimed at achieving national goals.

4 CONCLUSIONS

Stimulation of innovative activities based on scientific and engineering development is a factor that determines the global competitiveness of national economies and industries. National goals are outlined, including the acceleration of technological development, the strengthening of innovative activity, the creation of highly productive industries, etc. To achieve them, national projects and programs are being implemented, which are aimed, among other things, at stimulating innovative and entrepreneurial initiatives. There is currently no sectoral program to stimulate innovation in the agricultural sector, but support is provided for by the activities of state programs and national projects. An analysis of their certificates has showed the presence of a large number of activities that provide support for innovation, infrastructure development of territories, modernization of production and stimulate innovative and entrepreneurial initiative.

The development of the agricultural sector based on knowledge and innovation is a condition for the industry to achieve national goals. Within the framework of state programs and national projects, it is possible to create conditions for the development of innovation activities and the organization of highly productive, efficient and resource-saving agricultural production. The state provides various measures and support tools for this.

Further research in this area is promising, so it will reveal practical examples of the use of 'non-industry' programs in the innovative activities of enterprises and determine their effectiveness for the development and stimulation of innovative activities in the agricultural sector.

ACKNOWLEDGMENTS

The author would like to thank the anonymous reviewers for all their constructive comments. Any errors or opinions expressed in this article are solely the responsibility of the authors. The opinions expressed in this article are those of the authors and do not necessarily reflect the position or policies of their institution.

REFERENCES

Anokhina, A. Z. et al., 2020. Innovative Development of the Agricultural Sector as a Factor of Competitiveness: Problems, Trends, Prospects. Vyatka State Agricultural Academy, Kirov, p 151-164

Bogoviz, A., et al., 2018.Scientific basis of innovative development of the agro-industrial complex: the mechanism of public-private partnership in venture capital investment. In *MATEC Web of Conf.*, vol. 212, p. 07006.

Bogoviz, A.V., 2020.A Competitive Model of Innovational Development of the Russia's AIC in the Conditions of the EAEU. In *LNNS*, vol. 73, pp. 211–217.

Decree No. 717 of the Government of the Russian Federation: "On the State Program for the Development of Agriculture and the Regulation of Agricultural Products, Raw Materials and Food Markets" dated July 14, 2012. Retrieved from https://base.garant.ru/70210644/ (accessed on 20/01/2024).

Decree No. 996 of the Government of the Russian Federation: "On Approval of the Federal Scientific and Technical Program for the Development of Agriculture for 2017-2025" dated August 25, 2017. Retrieved from http://pravo.gov.ru/laws/acts/68/575754.html/ (accessed on 11/03/2024).

Golubev, A V, Golubeva A A., 2021. Modern challenges of Russian agriculture. In *Scientific works of the Free Economic Society of Russia*, vol. 229(3), pp. 196-209.

Kharitonov, E. et al., 2021. The role of innovations in the development of agriculture in Russiaю. In *E3S Web of Conf.*, vol. 262, p. 01016.

Korolkova, A. P. et al., 2020. Factors of influence on the innovative activity of agricultural enterprises. In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 604, p. 012005.

Koutsouris A., Zarokosta E., 2020. Supporting bottom-up innovative initiatives throughout the spiral of innovations. In *Greece Journal of Rural Studies*, vol. 73, pp. 176-185.

Kuzmin, V.N. et al., 2021. Mechanism for increasing innovative activity in agriculture in Russia using programming. In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 723(3), p. 032055.

Marinchenko, T., 2023. Improving the infrastructure for the transfer of innovations in the agribusiness. In *E3S Web of Conf.*, vol. 371, p. 03001.

Marinchenko, T., 2023. Methodological approaches to the evaluation of innovative projects in the agribusiness. In *E3S Web of Conf.*, vol. 389, p. 03017.

Marinchenko, T., 2023. Stimulation of innovative activity in Russian agriculture. In *E3S Web of Conf.*, vol. 431, p. 01036.

Marinchenko, T., et al., 2024. Innovative activity of Russia: dynamics and position in international comparisons. In *AIP Conf. Proc.*, vol. 2969, p. 030019.

National Science project. Retrieved from https://tadviser.com/index.php/Article:National_Science_project (accessed on 09/02/2024).

Novozhenina, O., 2021. National goals and objectives of the development of the Russian Federation in the opinions of citizens. In *Nauka Kultura Obshestvo*, vol. 27, pp. 45-57.

Orlova N.V., Nikolaev D.V., 2022. Russian agricultural innovations prospects in the context of global challenges: Agriculture 4.0. In *Russian Journal of Economics*, vol. 8(1), pp. 29-48.

Presidential Decree No. 474 On the national development goals of the Russian Federation for the period up to 2030 dated July 21, 2020. Retrieved from http://www.kremlin.ru/events/president/news/63728 (accessed on 15/03/2024).

Rodionova, I. et al., 2019. Problems and status of innovative development of agriculture in Russia. In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 403, pp. 012146.

Russian Federal State Statistics Service. Retrieved from https://eng.rosstat.gov.ru (accessed on 15/03/2024).

Russian Federation. Support to agriculture. Retrieved from https://www.oecd-ilibrary.org/sites/635e0b2f-en/index.html?itemId=/content/component/635e0b2f-en (accessed on 15/03/2024).

Sandu, I. et al.,2019. Scientific basis for forecasting the innovative development of the agricultural sector of the region's economy (based on the materials of the Perm region) *IOP Conf. Ser.: Earth Environ. Sci.*, vol., 274, p. 012016.

Sandu, I. S., et al., 2021. Main factors of scientific and technical development of Russian agricultural industries. In I*OP Conf. Ser.: Earth Environ. Sci.*, vol., 650, p. 012076.

Strategy for the development of the agricultural and fishery sectors of the Russian Federation for the period up to 2030. Retrieved from http://www.consultant.ru/document/cons_doc_LAW_350437 (accessed on 15/02/2024).

The concept of the roadmap was approved by the expert commission to review the roadmap of the FoodNet market (2020). Retrieved from https://nti2035.ru/markets/foodnet (accessed on 09/02/2024).

Troshin, A. S., et al., 2019. Investment and innovative component of strategic development of the region (on the example of the Belgorod region). In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 272, p. 032236.

Vasilchenko, M. and Sandu I., 2020.Innovative-investment development of agriculture in the conditions of formation of the export-oriented economic sector: system approach. In *Scientific Papers. Series: Management, Economic Engineering and Rural Developmen*t, vol. 20(1), pp. 599-612.

Unsatisfactory Condition of Drinking Water on the Territory of Yakutia and Ways to Solve This Problem

Valeriy A. Yakovlev[a]
Department of Technosphere Safety, North-Eastern Federal University, 58 Belinsky Street, Yakutsk, Republic of Sakha (Yakutia) 677000, Russia
febra.t@yandex.ru

Keywords: ecology, water, ecosystem, environment, Yakutia.

Abstract: The article considers the current state of the water management complex of the Republic of Sakha (Yakutia), the main existing problems, as well as ways and measures to solve this problem in order to preserve public health by providing quality drinking water. Drinking water is the source of life, determines the quality and duration of life. The main content of the study is the analysis of factors that have a negative impact on public health. On the basis of various studies it was established that the fault of poor water quality is primarily the lack of water treatment facilities or extremely unsatisfactory technical condition and low capacity of existing water intake facilities of the water supply system. The quality of drinking water supplied to the population of the cities of the republic fully depends on the quality of water of the Lena River. Slowdown of geochemical reactions of river water in conditions of low temperatures leads to slow self-purification of pollutants. This, in turn, leads to deterioration of water quality. On the Vilyuy, Khrom, Upper Indigirka, on many small rivers near large settlements the maximum permissible concentrations of many compounds and elements have long been exceeded. Considerable attention in this work will be paid to the problem of water quality.

1 INTRODUCTION

An impressive number of publications are devoted to the problem of lack of quality water in Yakutia. There are more than 700 thousand rivers on the territory of Yakutia, many of which are more than 100 kilometres long. Such rivers of the republic as the Kolyma, Indigirka and the main tributaries of the Lena River (Table 1) - Aldan, Olekma and Vilyui - by their basic characteristics far surpass almost all rivers of the European part of Russia and the largest rivers of Western Europe. Even in dry years, the total annual flow of Yakutia's rivers exceeds 530 cubic kilometres. It is mainly fed by snow and rain, and in spring the water level may rise due to melting glaciers. The main river of the republic is the Lena. It is among the ten largest rivers in the world in terms of length and water content. The greatness of this river is confirmed by the fact that its basin covers about 62% of the total area of the Sakha Republic.

Table 1: Information on the main rivers of Yakutia.

River	River length, km	Basin area, thousand square kilometers	Average annual flow, cubic meters per second	Runoff volume, cubic km/year
Lena	4400	2488	16600	523
Olekma	1436	210	1040	33
Aldan	2273	729	5270	166
Maya	1053	171	1180	37
Amga	1462	69,3	178	6
Vilyui	2650	454	1520	48
Markha	1181	99,0	4021	13
Tung	1092	49,7	118	4
Anabar	939	100	444	14
Olenek	2270	219	1200	39
Yana	1490	238	1080	57
Indigirka	1726	360	1560	49
Alasea	1590	74,7	36,3	1
Kolyma	2129	681	3260	103

Significant water reserves are also concentrated in lakes, the total surface area of which in Yakutia exceeds 83 thousand square kilometers. Estimated reserves of water contained in the republic's lakes are about 300 cubic meters.

The total forecast reserves of underground water of drinking quality are about 10 cubic kilometers. Yakutia also has a lot of mineral groundwater sources, which, unfortunately, are currently underutilised. Fresh groundwater is the most valuable

[a] https://orcid.org/0000-0002-3765-5292

component of the republic's water resources. This is explained by certain main advantages they have over fresh surface waters:

1. A stable groundwater regime that is not subject to seasonal and multi-year changes.
2. Freshwater springs are found where other sources of drinking water supply are not available.
3. Water is less exposed to the danger of radioactive, chemical, bacteriological and other types of anthropogenic contamination.
4. Water contains a wide range of chemical elements and mineral compounds, beneficial to the human body.
5. Fresh groundwater is distributed in many hydrogeological structures of Yakutia and is represented by subfreeze, interfreeze and suprafreeze aquifers and complexes.

Subfreeze water has exceptional sterility, rich microcomponent composition, significant reserves and is characterised in some cases by only a slight excess of the content of some microcomponents relative to the norms for drinking water.

Of practical interest are ground waters formed in under-channel talik zones. In many uluses of the Republic these waters have significant resources and can serve as a basis for the organisation of centralised household and drinking water supply. However, the shallow occurrence of these waters from the day surface and their close connection with surface waters contribute to the fact that they lose the main advantages that are inherent, for example, in subfreezing waters. The total predicted exploitable reserves of fresh groundwater in Yakutia are quite high and amount to about 25 million cubic metres per day. Currently, less than 1% of this amount is used. Consequently, the potential opportunities of attracting fresh groundwater for household and drinking water supply in the Republic are very high. Mineral ground waters include waters containing physically active substances in concentrations that allow their use for therapeutic and preventive purposes. Such substances can be separate macro- and microelements, organic and silicon-containing compounds, gases dissolved in water.

It follows from all of the above that water resources of Yakutia are very significant. Nevertheless, there are serious problems of providing the population with clean drinking water. Their essence is connected with the pollution of natural waters. Residents of Yakutia do not always receive high-quality, and most importantly, tap water that meets the norms of SanPin 2.3/2.4.3590-20.

2 CAUSES OF CONTAMINATION OF DRINKING TAP WATER

Unfortunately, the quality of water in the capital of Yakutia significantly deviates from the established sanitary standards. Exceeding the maximum permissible concentration for the indicator "turbidity" reaches 3 times, "colour" - 2.7 times. During the periods of spring floods organoleptic indicators deteriorate up to 70 degrees (the norm is 20).

It is not unimportant that in areas with unscrupulous management companies, tap water can be rusty. This fact is justified by the fact that management companies suspend the flow in case of repair works or emergencies - and the next day black water flows from the tap. In fact, in such cases, emergency drains should work, at which the taps of residential buildings would be shut off so that the water with "ruffled" mud would not stagnate and would not pass through the household pipes through the meters, but would simply be drained. Also in the capital of the republic there are so-called "dead-end" points: our water supply system is not circular, where water would flow uninterruptedly, but branched, because of which dirt clogs up at the ends of "branches", and management companies and resource supplying enterprises do not always flush the systems qualitatively.

It should be taken into account that most of the water in the rivers on the territory of Yakutia is also considered polluted. It is obvious that such water contains phenol, oil products, copper and zinc, the values of which, as a rule, exceed the maximum permissible concentrations. The reason for this is the anthropogenic factor.

Among the regions of the Far Eastern Federal District, Yakutia ranks third in terms of insufficiently treated and polluted wastewater sources. More than half (58%) of the wastewater discharged into rivers does not undergo the necessary treatment. Industrial and gold mining enterprises, ports, shipyards, oil depots and housing and communal services are the main polluters of the Lena and Kolyma rivers and their basins. And due to natural peculiarities of the region and slow geochemical reaction in conditions of low temperatures, water bodies have slow self-cleaning from pollutants. As a consequence, water quality is significantly reduced.

In the Sakha Republic, only 87 per cent of residents are provided with good quality water. Rospotrebnadzor analysed 8,032 water samples from central water supply sources. Of these, 21.6% do not meet sanitary and chemical requirements and 10.1% do not meet microbiological requirements.

It should be noted that out of 670 municipalities of the Sakha Republic, only 32 have water treatment plants. They are mainly located in industrial districts and settlements. The cities of Yakutsk, Lensk, and Udachny have only mechanical treatment, and the city of Aldan has none. Due to the lack of financial resources, construction of treatment facilities is carried out in meagre amounts.

The poor condition of drinking water is due to the low capacity of existing water treatment facilities and the poor condition of water supply networks, which wear out up to 80%. There are also a number of problems that require prompt solution: creation of sanitary protection zones at water sources, washing and disinfection of water supply networks.

The Department of Rospotrebnadzor for the Republic of Sakha annually monitors the quality of water in the Republic's settlements. A regular inspection of the centralised drinking water supply system in the first quarter of 2023 showed that the proportion of samples that did not meet hygienic standards for sanitary and chemical indicators was 13 per cent and for microbiological indicators 3.5 per cent (table 2).

Table 2: Standards for microbiological and parasitological indicators.

Indicators	Units of measurement	Norms
Thermotolerant coliform bacteria	Number of bacteria in 100 ml	Absence of
Total coliform bacteria	Number of bacteria in 100 ml	Absence of
Total microbial count	Number of colony forming bacteria in 1 ml	No more than 50
Coliphages	Number of plaque forming units (PBU) in 100 ml	Absence of
Spores of sulphite-reducing clostridia	Number of spores in 20 ml	Absence of
Giardia cysts	Number of cysts in 50 litres	Absence of

As of 01.01.2023, according to the data of the state balance of reserves (FGIS "ASLN" section "Accounting and Balance"), 236 deposits (field sites) of drinking and technical groundwater have been explored and evaluated on the territory of the Republic of Sakha (Yakutia) (Table 3) with total approved balance reserves of 694,2461 thousand cubic metres per day, including 45,830 thousand cubic metres per day for the city of Yakutsk. In addition, reserves of 35,100 thousand cubic metres per day in 3 fields of fresh and brackish groundwater are classified as off-balance (FGIS "ASLN" section "Accounting and Balance").

Table 3: Number of assessed groundwater deposits in 2023.

Subject of the Russian Federation / center of the subject of the Russian Federation	Number of assessed groundwater deposits (according to FGBU "Rosgeolfond"), pcs. in distributed subsoil fund	Approved groundwater reserves (according to FGBU "Rosgeolfond"), thousand cubic meters /day	Groundwater production in 2022 (according to statistical reporting form 4- LS), thousand cubic meters / day	Reserves utilization rate, %
Republic of Sakha (Yakutia), including:	236	694,2461	96,4897	12
Yakutsk	13	45,830	0,636	1,4

According to the preliminary data of statistical reporting, in 2022 the total groundwater production in the Republic of Sakha (Yakutia) was 96.4897 thousand cubic meters per day, including 92.3119 thousand cubic meters per day at the fields (152 fields (sites) were in operation) and 4.1778 thousand cubic meters per day at sites with unapproved reserves. The degree of reserves development in the republic as a whole was 12 %. On the territory of Yakutsk city groundwater production was 0.636 thousand cubic meters per day, the degree of reserves development was 1.4 %.

In continuation of the topic of domestic drinking water supply to the population of the Republic of Sakha, it is provided by groundwater and surface water. In 2022, the share of groundwater use in the total balance of domestic drinking water supply in the territory of the Republic was 35%, in Yakutsk - 4%.

In the same year, at some water intakes, groundwater used for water supply to the population and industrial enterprises in the natural state exceeded the normative values for iron (up to 2.0 MAC), lithium (up to 14 MAC), magnesium (up to 2 MAC), fluorine (up to 2 MAC), sodium (up to 20 MAC), as well as exceeded MAC for mineralisation (up to 2 MAC) and total hardness (up to 2 MAC). The presence of these elements in groundwater, as already noted, is due to natural factors.

3 CONSEQUENCES OF DRINKING UNTREATED WATER

The majority of local residents of the Sakha Republic most often use tap water as drinking water and know nothing about water treatment and purification measures, and some are not interested in water treatment technologies in their town.

The unsatisfactory condition of drinking water is the reason for the high incidence of intestinal infections of bacterial and viral etiology. The problem of infectious diseases associated with poor quality drinking water is particularly acute in Yakutsk. First of all, the danger of waterborne transmission of intestinal pathogens such as cholera, typhoid, paratyphoid, and dysentery should be taken into account. About 70-80 per cent of all acute intestinal disorders are registered annually in this city. Especially their number increases in the spring and summer period. Ultraviolet disinfection units in most cases solve this problem, but, unfortunately, they are completely powerless in case of high colour indices. Every year in Yakutia there are up to 6,000 cases of infectious diseases related to poor quality drinking water. Among them, intestinal infections are in the first place, exceeding the overall figures for Russia by 1.5-2 times. Table 4 shows the high prevalence of Gallstone disease (GSD) among rural residents of the southern and central uluses of Yakutia.

Table 4: Comparison of GSD prevalence in residents of southern and central Yakutia in 2021.

№	Disease	Number of subjects n	Women n/(%)	Men n/(%)	Total n/(%)	χ2	p
1	GSD in the inhabitants of southern Yakutia	173	43/34,1	6/12,7	49/28,3	7,78	0,006
2	GSD in residents of central Yakutia	115	18/23,3	9/23,6	27/23,4	0,16	0,69
3	GSD in southern Yakutia	173	24/19,0	7/18,4	31/17,9	0,17	0,68
4	GSD in central Yakutia	115	13/16,8	7/18,4	20/17,3	0,03	0,87
5	GSD. After cholecystectomy in southern Yakutia	173	18/14,2	2/5,2	20/11,5	2,46	0,12
6	GSD. After cholecystectomy in central Yakutia	115	5/6,4	2/5,2	7/6,0	0,21	0,65

At the beginning of June the indicators reach the worst results - the colour level exceeds the norm by 10-12 times, reaching up to 250 degrees in some dead-end points, and the degree of turbidity - by 6-8 times. The iron content also jumps from 0.3 to 3-4.5 mg. An excess of iron gives water an unpleasant metallic taste, colours fruits, vegetables and other products, changes their properties. With water, our body receives up to 25% of the daily requirement of various macro- and microelements. However, a constant excess (as well as deficiency) of a certain chemical element has an extremely negative impact on health in general. For example, prolonged use of water with high iron content (more than 0.1 mg/litre) affects the bone system, and iron content of more than 0.3 mg/litre increases the risk of heart attacks and badly affects reproductive function. Dry and itchy skin is also a consequence of excessive iron in water.

Poor quality of drinking water can pose a serious threat to the health of children and pregnant women. This is due to the peculiarities of their body and increased sensitivity to various contaminants that may be present in the water. Drinking water of poor quality can adversely affect the growth and development of children, as well as lead to various diseases. Contaminants in water can penetrate the mother's placenta and harm the developing organism of the foetus, which can lead to health problems in the future. In addition, poor quality water does not wash soap off the skin well, leading to clogged pores and accumulation of sebum.

In order to improve water purification, water utilities increase the dosage of chlorine. But because of this water acquires a sharp specific odour. It should be known that chlorine interacting with a large number of inorganic and organic substances in the composition of water creates chlorine-containing toxins, carcinogens, mutagens, immunotoxins and even poisons. They slowly accumulate in the body, posing a dangerous threat to health. These substances can cause cancer of the stomach, oesophagus, liver, bladder, rectum, colon, larynx, lungs and breast. In addition, they provoke anaemia, atherosclerosis, hypertension, heart disease, inflammation of the joints and respiratory organs. Chlorine in water dries the skin, irritates the mucous membrane of the eyes, disturbs the structure of hair, making it weak, dull and brittle, and causes dandruff (Permyakov, Konstantinova, Kapitonova, 2015.).

To date, the situation with infectious diseases, the source of which is water, is solved by chlorination. As long as there are no treatment facilities, this is the only method to avoid mass infectious and viral diseases.

4 SOLVING THE DRINKING WATER PROBLEM

Today, one of the most modern water supply complexes in the country with a capacity of 110 thousand cubic meters of water per day is operating in the capital of the republic. The facility became operational in 2018, replacing old water intake complexes. In Yakutsk, JSC Vodokanal lifted more than 10.5 million cubic meters of water in the first six months of 2023. Of this, 9 million 129 thousand cubic meters were supplied to consumers. At the station, river water undergoes several stages of purification. Impurities, suspended solids, organic compounds, heavy metals and so on are removed using reagents harmless to humans. Then water is filtered using quartz sand and hydroanthracite. Next, the water is disinfected with sodium hypochlorite. The process of preparation of sodium hypochlorite, as well as other reagents, is organised on the territory of the complex. At the last stage water is disinfected by ultraviolet radiation.

The whole purification process is controlled by the technologists of the water intake facilities. Depending on the condition of water in the river, they select doses of reagents in the laboratory. Based on the results of the tests, they make changes in the water treatment process in order to immediately react to deterioration of river water quality (Androsov, Zavadsky, 2014).

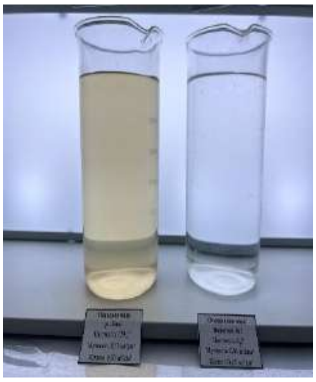


Figure 1: Source water taken from the Lena River and filtered in the complex of water intake and water treatment facilities.

This indicates that clean drinking water is supplied to the city water supply network. Figure 1 clearly shows the difference between river water and treated water. After treatment, water is delivered to waterworks and then through the main pipelines of Vodokanal JSC to the beginning of the intra-arterial networks. From there, the water flows through the intra-quarter networks of the transporting companies and domestic pipes serviced by management companies or HOAs to the flats of Yakutsk residents.

Meanwhile, even today a number of local residents complain about poor quality tap water. At the same time, Vodokanal specialists say that they cannot control the condition of internal networks in houses, as management companies are responsible for them. To ensure that the residents of the Republic of Yakutia can get quality water from under the tap, the Clean Water Programme continues to be implemented, which is aimed at ensuring that as many people as possible are supplied with purified drinking water.

The State Unitary Enterprise «Housing and Communal Services of the Republic of Sakha (Yakutia) is constructing four of the six facilities planned for commissioning. In particular, in Olekminsk, the company will complete the construction of a water supply system this year. The first stage in 2021 saw the commissioning of a water treatment plant with a capacity of 2,400 cubic meters per day, which supplied clean drinking water to over 7,000 local residents. The second stage envisages the construction of a water pipeline and water intake.

In addition, the State Unitary Enterprise "Housing and Communal Services of the RS(Ya)" will upgrade the water supply system in Bestyakh village of Khangalassky district, introduce a well water intake and a water treatment plant in Altantsy village of Amga district, and a water intake and a water conduit in Amga village. The regional programme is also implemented by Vodokanal, which continues to expand the geography of its operations in Yakutia. This year, the company will commission a water supply system in Suntar, which includes the construction of a water intake, a water pipeline and a water treatment plant.

Another project is under construction in the village of Berdigestyakh in the Gorny district. This facility, too, will be commissioned in 2023. Thus, this year 6 facilities will be commissioned in Yakutia under the Clean Water Programme - in the town of Olekminsk, Amga, Altantsy, Bestyakh, Suntar and Berdigestyakh. As the Ministry of Housing and Utilities and Energy of the Republic informed, in addition, in 2023 the construction of water supply system in Batagai settlement will start. This facility will be commissioned in 2024.

This year Vodokanal will complete construction of water treatment facilities in Suntar district in the course of implementation of the federal project "Clean Water" of the national project "Housing and Urban Environment". The design of water treatment facilities in the village of Namtsy has already been completed. Now the project is undergoing state expert appraisal. Fruitful work has been carried out with the administration of the Namtsy district. The issues of land allocation and tracing have been resolved.

As for the city of Yakutsk, the construction of waterworks No. 5 is being completed at the expense of republican funds. The design of main networks for the Beloye Ozero microdistrict and Markha settlement has been started. Vodokanal guarantees water quality at the main water pipelines and water points. The company annually flushes and disinfects the networks. However, further water is supplied to heating stations and delivered to consumers through intra-block and intra-house networks, which are under the jurisdiction of resource supplying organisations and management companies. The city administration needs to carry out serious work with them in order to ensure the proper condition of networks.

According to Vyacheslav Yemelyanov, Minister of Housing and Energy Vyacheslav Yemelyanov, today it has been possible to provide about 59% of the region's residents with quality drinking water. At the same time, in order to prevent the emergence and spread of infectious diseases with waterborne transmission factor, it is recommended that during the period of deterioration of water quality all the population should use boiled water, buy bottled water from reliable suppliers who have water bottling plants and laboratory production control, as well as use household filters for water purification. The quality of drinking water in Yakutsk remains under the control of the Department of Rospotrebnadzor for the Republic of Sakha (Yakutia) (Nechaeva, Petrov, Shandarova, 2014).

For many years Yakutians prefer to use purified drinking water in the household, considering it useful and safe in contrast to tap water. Meanwhile, an independent examination in 2016 of the five most popular producers of bottled water in Yakutia showed the absence of mineral substances necessary to maintain human health. The results showed that low levels of calcium, magnesium, sodium and fluorine were found in all water samples, the Republican Information and Analytical Center for Environmental Monitoring reported. According to the scientists, the chlorine used to purify tap water is harmful to the organism and does not provide sufficient purification of water from contaminants.

The same examination revealed that tap water in its turn is more saturated with mineral substances. Summarising the preceding arguments, we can say that purified bottled water in Yakutia is no better than tap water.

5 CONCLUSION

The quality of drinking water from the tap at the moment leaves much to be desired. There are several problems in conventional water supplies that can have a negative impact on the quality and taste of water. For example, the presence of chlorine can give the water an unpleasant odour and taste. Also, chlorine can cause irritation to the skin and mucous membranes, especially for people with sensitive skin.

Another consideration is that worn water pipes can become contaminated with rust, bacteria and other deposits. This can affect the colour and smell of the water, as well as create problems with its clarity. It has also been observed that regular tap water often lacks beneficial minerals and elements such as calcium, magnesium and potassium. These play an important role in keeping the body healthy and give water its characteristic flavour. Tap water can contain various contaminants, including chemicals, pesticides and other toxic substances. These can be especially harmful to pregnant women, young children and people with weak immune systems.

So, it is worth paying much more attention and effort to solving the problem of drinking water quality and trying to eliminate the problem as much as possible. Every year about 50 children's out-of-town stationary health camps function in the republic. Despite the fact that no cases of measles and diphtheria have been registered in Yakutia during 2022, the risk of these infections is very high. It was instructed to conduct preparatory work in medical organisations for the upcoming 2023 measles immunisation (Shepelev, Kornilova, Gotovtsev, 2019).

Quality control of drinking water in Vodokanal is carried out in accordance with the programme of industrial control of quality and safety of drinking water. It is carried out for 53 indicators, including metals, anionic surfactants, petroleum products and others. More than 60 research methods are used in the laboratory. The conducted research allows us to state that while the construction of water supply facilities is being implemented within the framework of the "Clean Water" project, residents whose tap water leaves much to be desired are recommended to use water filters and bottled water.

Water is a great value for mankind, and in the age of information technology, developed industry and constant population growth it requires special attention. The quality of drinking water that flows from the tap directly affects the health of all residents of the Republic.

REFERENCES

Permyakov, P. P., Konstantinova, T.I., Kapitonova, V.S., 2015. Groundwater Treatment Technology for Water Supply in the Conditions of Yakutia. *Fundamental and Applied Problems of Hydrogeology*.140-143.

Androsov, I. M., Zavadsky, A. S., 2014. Assessment of the negative impact of the Lena River waters on the settlements of the Republic of Sakha (Yakutia). Dynamics and thermics of rivers, reservoirs and coastal zone of the seas. Proceedings of the VIII International Scientific and Practical Conference: in 2 volumes. Peoples' Friendship University of Russia. 5-16.

Nechaeva, O. A., Petrov, M. E., Shandarova, D. D., 2014. The Problem of Drinking Water Pollution in the Republic of Sakha (Yakutia). *Meridian Journal* No. 13 5-16. , Meridian Journal No. 13. 270-272.

Shepelev, V. V., Kornilova, T. I., Gotovtsev, S. P., 2019. On a new promising direction in the use of groundwater in Yakutia. *Journal of Science and Technology in Yakutia* 32 no. 2. 85-87.

Federova, C. V., Pavlova, N. A., 2022. Fluorine in surface and suprapermafrost waters of central Yakutia. *Journal of Natural Resources of the Arctic and Subarctic* 27 No. 2. 233-245.

Shepelev, V. V., Pavlova, N. A., Ivanova, L. D., 2016. State and prospects of groundwater use in Yakutia. *Journal of Science and Technology in Yakutia 30* no. 1. 22-26.

Davydova, P. V., Levina, S. N., Gorodnichev, R. M., Pestryakova, L. A., Ushnitskaya, L. A., 2018. Assessment of the degree of water pollution in rivers of the southern economic zone of Yakutia. *Journal of Vestnik of Modern Research* 21 No. 6.1 (2018): 94-95.

Methods of Analysis of Demographic Behavior of the Population of Rural Territories as a Necessary Element of Overcoming Depopulation and Reproduction of Russian Society

Dianna Khripkova[a], Kirill Khripkov[b], Svetlana Vangorodskaya[c], Galina Gaidukova[d] and Alexey Krasovskyi[e]

Belgorod State National Research University, 85, Pobedy street, 308015 Belgorod, Russia

davtyan@bsu.edu.ru, khripkov@bsu.edu.ru, g_gaidukova@bsu.edu.ru, vangorodskaya@bsu.edu.ru, 458931@bsu.edu.ru

Keywords: socio-demographic development, socio-demographic behavior, demographic development, migration, mortality rate, birth rate, Central Black Earth economic region, rural area.

Abstract: The article examines the features of the analysis of demographic behavior of the population of rural areas. It is indicated that currently there is an objective need to develop an interdisciplinary and systematic approach to the analysis of demographic behavior, its structural elements, clarification of the methodological foundations, as well as the theoretical justification of the mechanisms for regulating this process. This task is especially relevant for rural areas. It is noted that the demographic behavior of the population of rural areas is influenced by specific factors, primarily related to the characteristics of rural areas as a unique social organization. The specific features of rural areas in the context of demographic behavior include economic, infrastructural and social features such as: weak diversification of rural employment; decline in the standard of living of the rural population; high share of the poor in rural areas; poor development of social infrastructure in sparsely populated settlements; closer (in comparison with urban areas) family and neighborhood ties that ensure interaction between individuals; the greater severity of the factor of attachment to place, identity; the greater role of traditions, customs and rituals; the severity of social control over individual behavior, especially from the older generation; significant influence of public opinion on the behavioral attitudes of the individual.

1 INTRODUCTION

Theoretical analysis of demographic behavior of the population is the focus of research in various fields of knowledge such as demography, sociology, psychology, political science, etc.

Demographic behavior is a complex category of scientific knowledge, which includes such elements as: marital and family (matrimonial) behavior; reproductive behavior; migration behavior; self-preservation behavior. In this regard, most modern scientific works are distinguished by a narrow-factor approach, when the researcher's attention is focused only on a certain element of demographic behavior.

As N. S. Krot reasonably states: “Demographic behavior should be attributed to both the macro and macro-demographic processes. In the scientific literature devoted to the problems of demographic behavior, a significant part of the publications is focused on the study of demographic processes. Various theories are used to explain trends in demographic behavior: 1. Economic theory of fertility; 2. Socio-psychological theory; 3. The demographic transition theory" (Krot, 2021).

Modern foreign and domestic authors examine in detail various factors and elements of demographic behavior.

For example, Serbian researcher D. P. Jenačković pays special attention to the influence of the education factor on the demographic behavior of

[a] https://orcid.org/0000-0003-2526-7652
[b] https://orcid.org/0000-0002-0635-3187
[c] https://orcid.org/0000-0002-1100-423X
[d] https://orcid.org/0000-0001-6300-9174
[e] https://orcid.org/0009-0007-0973-0017

young people (Jenačković, 2022). The work of Australian researchers Paula P. Sheppard, D. A. Coall (Sheppard, 2022) is interesting. They analyzed the role of ontogenesis in understanding human demographic behavior. Ontogenesis, the development of an organism from conception to maturity, is, according to the authors, one explanation that allows us to understand "why we do what we do." The authors note that in addition to genetic inheritance, the development environment, to which parents make a major contribution, is crucial for shaping a child's life. It affects not only their physical and psychological development, but also their reproductive strategy as an adult child and, ultimately, their lifespan. Demographers are concerned with fertility and mortality, which, when understood within the framework of evolution, are two intertwined processes that influence and, in turn, are influenced by the trajectory of human development. The authors use a life history approach, focusing on how early developmental influences have long-term consequences for mortality and fertility (Sheppard, 2022).

Russian researchers Yu. Frantsuz and E. Potanin are studying the impact of socio-political instability on demographic behavior. The authors have developed a model linking instability at the macro level with its perception of uncertainty at the micro level and its impact on decision-making and fertility outcomes. This model is based on a modified version of the uncertainty reduction theory. The authors believe that higher birth rates may reflect people's efforts to reduce uncertainty during periods of increased instability. They test and partially confirm this model using an analysis of fertility data in Soviet and post-Soviet Russia from 1959 to 1998. The model helps explain some sudden short-term fluctuations in fertility during the period of research interest that other social and demographic theories have failed to interpret (Frantsuz, 2020).

It should be noted that in modern turbulent conditions characterized by a state of risk and uncertainty caused by the special military operation in its economic and geopolitical terms, the subject of scientific interest of Russian researchers has become the study of the influence of the uncertainty factor on demographic behavior, as well as the study of demographic behavior as a factor of national security (Merenkov, 2021). D. M. Loginov's research is devoted to the analysis of the adaptation practices of the Russian population in the conditions of instability in the early 2020s, as well as the parameters of socio-demographic differentiation of its reproduction (Loginov, 2023).

Thus, a significant number of works by foreign and domestic researchers are devoted to the issue of demographic behavior. However, interest in the further development of this area of research in modern conditions is only increasing.

2 MATERIALS AND METHODS

The methodological basis of the project is a set of demographic and sociological concepts and theories that contribute to a full understanding of the analysis of the demographic behavior of the population of rural areas as a necessary element of overcoming depopulation and reproduction of Russian society:

– the concept of demographic transition (A. Landry, R. Lestag);

– the concept of rural networks (Van der J.D Ploeg). Within the framework of the proposed concept, scientists identify several conceptual blocks in the structure of rural networks (among them: endogeneity, sustainability, social structure of the population, social capital, etc.) that are in dynamic interaction. In relation to Russian conditions, it is advisable to include 3 blocks in the structure of rural networks, in particular: 1) human resources in rural areas (main demographic indicators); 2) the nature of the local economy and features of the infrastructure of rural areas; 3) socio-cultural characteristics of rural areas (values, specifics of forms of human communication and interaction, etc.);

– the theory of rural areas proposed by F. Tönnis (Tonnis, 1887), according to which two polar types of social connections are considered: community and society, which act as stages of social evolution. The concept of Tönnis allows us to describe the processes taking place within rural communities and influencing the worldview of rural residents.

3 RESEARCH RESULTS

Currently, the Russian Federation is experiencing changes in the size and composition of the population, serious in nature and consequences. A scientific digest prepared by the Center for Interdisciplinary Research of Human Potential in 2022 notes that: "Russia is characterized by demographic waves - fluctuations in the number of births and individual age groups, due to both demographic and socio-economic reasons. In some years, they soften, as, for example, in Russia in the 2000s, and in others, as in the 2020-s, on the contrary, they strengthen these trends" (Demographic changes ..., 2022). According to Rosstat, “the resident population of Russia as of January 1, 2023 amounted to 146.425 million people, having decreased by 555 thousand over the year (minus 0.38%). This follows from the preliminary estimate of the resident population posted by Rosstat on January 31" (Population of Russia..., 2023).

Currently there is an objective need to develop an interdisciplinary and systematic approach to the analysis of demographic behavior, its structural elements, clarification of the methodological foundations, as well as the theoretical justification of the mechanisms for regulating this process. This task is especially relevant for rural areas, where the steady process of depopulation is most acutely observed.

Rural areas in many regions of the world are in a state of demographic imbalance, and the Russian Federation is no exception. “The rural population in Russia is rapidly declining in both absolute and relative terms. Long-term trends towards a progressive (without returning to the indicators of previous years) decline in the rural population began to take shape in the RSFSR by the end of the 50s of the 20th century” (Bezverbny, 2022).

The demographic behavior of the population of rural areas is influenced by specific factors, primarily related to the characteristics of rural areas as a unique social organization. The specific features of rural areas in the context of demographic behavior include economic, infrastructural and social features:

Economic and infrastructural features include:

– weak diversification of rural employment;
– decline in the standard of living of the rural population;
– high share of poor people in rural areas;
– poor development of social infrastructure in sparsely populated areas.

Social features include:

– closer (in comparison with urban areas) family and neighborhood ties that ensure interaction between individuals;
– the greater severity of the factor of attachment to place, identity;
– the greater role of traditions, customs and rituals;
– the severity of social control over individual behavior, especially from the older generation;
– significant influence of public opinion on the behavioral attitudes of the individual.

The presence of specific features affecting the development of rural areas determines the diversity of theoretical and methodological approaches to the analysis of the demographic behavior of rural areas.

As a rule, the category of demographic behavior of the population of rural areas is based on the characteristics of the place of permanent residence. For example, N. A. Shchitova, V. S. Belozerov and N. V. Sopnev define the demographic behavior of the population of territorial communities as "a set of real or mental actions and relationships that develop under the influence of the natural, economic and socio-cultural characteristics of their places of permanent residence and affect the course of demographic processes. The change in population size depends on the nature of people’s demographic behavior” (Shitov, 2022).

Demography as a science that analyzes and reveals patterns of numerical development of the population, by definition, involves the widespread use of interdisciplinary and multifactorial study of complex and dynamic processes such as demographic behavior. Over the years, scientists have tested various research methods (modeling of demographic processes, comparative analysis, sociological research and monitoring, etc.).

M. G. Nosova and A. V. Fedorov, systematizing methods of demographic analysis, note: “Among the methods of demographic analysis, the following main groups are distinguished: statistical methods, sociological methods, graphic-analytical and cartographic methods, metamathematical modeling. Statistical methods and methods of mathematical modeling are popular in population projection" (Nosova, 2021).

Demographic methods have evolved since the advent of demography in response to changes in the content of research and theoretical orientations of the field. The early core mission of discovering patterns underlying demographic phenomena at the macro level, as well as the later interest in explaining demographic change, inductively facilitated the development of formal demographic methods. A more radical methodological shift occurred after the 1960s, when the availability of survey data at the micro level increased and the theoretical focus shifted towards causal mechanisms, which led to the widespread adoption of regression-based models and methods from other disciplines of the social sciences.

Future development of demographic methods will likely continue to incorporate new methods developed in other disciplines, including methods for analyzing unstructured "big" data, but formal demographic methods will continue to play a role in population forecasting, improving measurements, and correcting erroneous data.

In modern foreign and Russian science, there is an active development of new methods for studying demographic processes, as well as optimization of already proven technologies. Let's consider the most promising of them from the point of view of analyzing the demographic behavior of the population of rural areas.

British researcher Martin Clarke sees *micromodeling* as one of the promising methods for studying the demographic behavior of the population of rural areas. The author notes that the processes of reproduction of the population of rural areas, their formation, change and collapse are complex and often interdependent. The author discusses how to synthetically generate samples of individual and generalized statistical data and use them to develop practical recommendations and forecasts for long-term demographic development (Clarke, 2023).

Turkish demographer H. Yaprak Civelek points to a growing trend in the *use of online data collection* tools in both quantitative and qualitative demographic research methodologies. The author highlights the effectiveness of incorporating observations and contextual information in eliminating potential limitations and disadvantages associated with the preference for online data collection methods. Through critical research, which intertwines narratives and theoretical foundations from the fields of statistics, sociology and demography, the author seeks to achieve a comprehensive understanding of the positive consequences of using online demographic information collection tools. He highlights multifaceted issues, including sample representativeness, data quality, validity, reliability, objectivity, analysis (Civelek, 2023).

Czech researchers José Ignacio Sánchez-Vergara, Marko Orel, Valeria Ferreira, Andrej Rus developed the *concept of rural coworking*, which allows them to study rural communities from an in-depth point of view, determine their values, attitudes, patterns of self-organization and behavior. The authors form an understanding of rural coworking as a driving force of relationships between different groups in rural territorial space, as well as the influence of coworking on the attitudes and behavior patterns of rural residents (Sánchez-Vergara, 2023).

Chinese demographer Yuheng Li studies the demographic behavior of rural residents through the prism *of the concept of rural sustainability*. "Sustainability is at work in this process as rural communities respond to risks and shocks to maintain the stability of the system and minimize losses. Rural sustainability consists of the ability to resist, adapt and transform. To improve rural sustainability, it is proposed to promote multifunctional transformation, implement bottom-up planning, increase social capital, and improve demographic development technologies (Li, 2023).

One of the newest methods of demographic research today is the *use of artificial neural networks*. "Artificial neural networks do not require a lot of information about the area under consideration and are suitable for modeling dynamic systems such as population in real time. Neural networks are a mathematical model and are capable of perceiving information like a biological neuron. The main components of neural networks include architecture and functional properties. The architecture determines the structure of the network, that is, the number of artificial neurons in the network and their interconnection. The functional properties of the network determine the method of learning and obtaining a forecast" (Nosova, 2021).

Russian researchers D.S. Zhukov and V.V. Kanishchev see the use of the *cluster analysis method* as promising for studying the demographic behavior of the population of rural areas. The researchers note that: "Multidimensional cluster analysis is an effective tool for identifying stable groups of typologically homogeneous objects. The use of several indicators provides a comprehensive picture of the geographical distribution of demographic types. Moreover, in this case, the attention of researchers is not fixed on any one criterion. In addition, cluster analysis makes it possible to identify types based on empirical data, and not on criteria formulated a priori" (Zhukov, 2022).

Cluster analysis allows to consider demographic behavior at the meso-level (territory, region, republic) and micro-level (rural settlements, villages, auls, etc.).

In the context of analyzing the demographic behavior of the population of rural areas, cluster analysis makes it possible to identify rural areas of the same type in terms of demographic indicators in some chronological sections, as well as to trace how different types of demographic behavior transformed over time and were distributed geographically.

The current level of development of information technology makes it possible to use various software products for clustering. One of them, for example, is Statistica 12 - "a software package that provides convenient tools for analyzing statistical data, various studies, forecasting and visualization of the studied array of information. The application is characterized by close integration with advanced query tables and plug-in databases, allowing complex actions of SQL dialects to be carried out by simply dragging and dropping objects" (New Possibilities..., 2023).

When considering demographic behavior as a complex category, the *use of a cognitive approach* seems promising in its study.

Yu. G. Tkachenko emphasizes: "cognitive modeling is currently an effective means of studying complex socio-economic systems by simulating their properties and behavior. To carry out cognitive modeling, as is known, it is necessary to develop a model of the structure of a complex system in the form of a cognitive map, the mathematical form of which is a signed oriented graph G, which is a visualized picture of the cause-and-effect relationships E between the vertices V (concepts) of the cognitive map - expression" (Tkachenko, 2023):

$$G = \{V E\},$$

"In the process of cognitive modeling, the properties of the model are studied and, after analyzing the results obtained, which make it possible to make a decision about the adequacy of the G model, various projected scenarios are modeled on it. Based on these scenarios, it is possible to propose a system of measures to improve the management of a complex system," Yu. G. Tkachenko (Tkachenko, 2023) writes.

When considering demographic behavior as a complex category, the *use of a cognitive approach* seems promising in its study.

In our opinion, the *cognitive approach can be successfully applied to solve the problem of analyzing the demographic behavior of the population of rural areas*. This approach seems especially relevant in conditions of high dynamics of social change, in the context of which the subject of analysis is constantly faced with new, increasingly complex environmental requirements and unpredictable consequences of both their own actions and environmental changes. In these conditions, it seems necessary to take into account difficult-to-formalize factors ("black swan events").

Describing the current demographic situation in Russia, Doctor of Political Sciences Ildus Yarulin notes: "As for the demographic situation in our country, it can be described as "a flock of black swans." This is a whole layer of various events that, for some reason, no one wants to bring together and analyze" (Black Swans..., 2023).

A cognitive approach allows us to solve this problem, however, when *studying rural areas, cognitive maps should be modernized* by adding such factors (mainly of a subjective nature) as:

– the nature of the social environment and the level of its stress and negative impact on physical health;

– satisfaction of the population with the infrastructural, economic, and social conditions of living in rural areas;

– assessment of value-semantic dispositions (dominant values, norms, rules) of rural residents;

– self-assessment of the state of physical and psycho-emotional health, the presence of chronic diseases that significantly reduce the quality of life;

– satisfaction with family relationships, fulfillment of family functions by family members, compliance of their descriptive status with the normative one, self-assessment of the financial situation of the family, acting as subjective factors of family behavior;

– willingness and motivation for marriage/divorce.

The presented factors, as a rule, are subjective in nature and can be studied by applying qualitative and quantitative methods of sociological research.

Thus, the fact that the problem of demographic behavior is interdisciplinary and is located at the junction of many scientific disciplines leads to the appeal to a wide range of theoretical and methodological approaches.

4 DISCUSSION

Currently, there is a wide discussion among scientists and practitioners about approaches and tools of demographic policy that would change the difficult demographic situation and have a significant impact on demographic behavior. Some researchers and practitioners point to the need for a flexible approach aimed at regularly studying the opinions of citizens, their attitudes and, based on their analysis, the impact on reproductive behavior (A. O. Makarentseva, S. S. Biryukova, E. V. Korobko).

Some researchers are looking for the dependence of birth rates on factors of a different order, for example, economic or religious (E. V. Prutskova, I. V. Pavlyutkin, O. N. Borisova, S. A. Sukneva, A. S. Barashkova, K. Yu. Postnikova).

In general, it can be noted that at present, the established paradigm and approaches to the implementation of demographic policy are being destroyed, an active search is underway for the most effective tools for demographic development, relevant to the current situation of risk and uncertainty in which society is immersed.

4 CONCLUSIONS

Thus, the theoretical justification and development of a methodology for analyzing the demographic behavior of the population of rural areas as a necessary element of overcoming depopulation and reproduction of Russian society allows us to draw a number of conclusions:

1. Demographic behavior is a complex category of scientific knowledge, which includes such elements as: marital and family (matrimonial) behavior; reproductive behavior; migration behavior; self-preservation behavior. Modern studies of demographic behavior are predominantly of a narrow factorial nature.

2. In modern science, various theories are used to explain trends in demographic behavior, the most extensive of which are: the economic theory of fertility; socio-psychological theory and the demographic transition theory.

3. Within the framework of the theoretical justification of the demographic behavior of the population, researchers analyze various factors that have a dominant influence on this process, among them, for example, such factors as income, education, genetic characteristics, etc. In modern turbulent conditions characterized by a state of risk and uncertainty caused by the special military operation in its economic and geopolitical terms, the subject of scientific interest of Russian researchers has become the study of the influence of the uncertainty factor on demographic behavior, as well as the study of demographic behavior as a factor of national security.

4. The theoretical analysis of modern research and statistical information has shown that currently there is an objective need to develop an interdisciplinary and systematic approach to the analysis of demographic behavior, its structural elements, clarification of the methodological foundations, as well as the theoretical justification of the mechanisms for regulating this process. This task is especially relevant for rural areas, where the steady process of depopulation is most acutely observed.

5. In modern foreign and Russian science, there is an active development of new methods and concepts for studying demographic processes, as well as optimization of already proven technologies. The most promising are: the method of micromodeling, the use of online data collection tools, the concept of rural coworking, the concept of rural sustainability, the use of artificial neural networks, the method of cluster analysis, the cognitive approach, the concept of rural networks.

ACKNOWLEDGEMENTS

The study was carried out within the framework of the State Task project FZWG-2023-0006 “Regulation of the demographic behavior of the population of rural areas of the Central Black Earth Economic Region as the main mechanism of social reproduction in conditions of depopulation.”

REFERENCES

Aref'eva, E.A., Ryleeva, A.S., 2010. Regulirovanie demograficheskih processov s pomoshch'yu kognitivnyh kart. In Izvestiya Tul'skogo gosudarstvennogo universiteta. Ekonomicheskie i yuridicheskie nauki. 2-1: 195-200.

Bezverbnyj, V.A., Maksimov, A.N., 2022. Tendencii depopulyacii sel'skih territorij Rossijskoj Federacii po dannym Vserossijskoj perepisi naseleniya 2020. Nauka. Kul'tura. Obshchestvo. 28(4): 150-161.

Bekker, S., 2003. CHelovecheskoe povedenie: ekonomicheskij podhod. Izbrannye trudy po ekonomicheskoj teorii, Moskva. «GU VSHE».

Demograficheskie izmeneniya i predlozhenie rabochej sily v regionah Rossii. URL: https://www.hse.ru/data/2022/05/30/1872644620/Human_Capital_NCMU_Digest_10_Demographic..Ssupply_in_Russian_Regions_2022.pdf (data obrashcheniya: 23.11.2023).

Drepa, E.N., 2012. Teoretiko-metodologicheskie podhody k issledovaniyu demograficheskih processov. Sovremennye issledovaniya social'nyh problem. 9.URL: www.sisp.nkras.ru (data obrashcheniya 12.12.2023).

ZHukov, D.S., Kanishchev V.V., 2022. Klasternyj analiz kak sredstvo vyyavleniya tipov demograficheskogo povedeniya (russkoe sel'skoe naselenie, evropejskaya chast' Rossii, nachalo XX - XXI v.). Novejshaya istoriya Rossii. 12(2): 454-476.

Ivanov, S.F., 2022. Central'nyj mekhanizm demograficheskogo perekhoda. Demograficheskoe obozrenie. 9(3): 4-23.

Kvasha, A.YA., 1995. Sovremennaya demografiya. Moskva. Izd-vo MGU.

Krot, N.S., 2022. Demograficheskoe povedenie russkogo naseleniya Respubliki Tatarstan: tradicii i sovremennost' : special'nost' 07.00.07 "Etnografiya, etnologiya i antropologiya" : dissertaciya na soiskanie uchenoj stepeni kandidata istoricheskih nauk.

Loginov, D.M., 2023. Adaptacionnye praktiki rossijskogo naseleniya v usloviyah nestabil'nosti nachala 2020-h godov. Moskva, Vserossijskij centr izucheniya obshchestvennogo mneniya.

Merenkov, A.V., 2021. Vliyanie neopredelennosti budushchego na demograficheskoe povedenie molodezhi. Ekaterinburg. Institut ekonomiki Ural'skogo otdeleniya RAN.

Naselenie Rossii za god sokratilos' na 555 tys. chelovek. URL: https://www.rbc.ru/economics/01/02/2023/63da428b9

a7947e741363c53?from=copy (data obrashcheniya: 23.11.2023).
Narodonaselenie: enciklopedicheskij slovar'. 1994. Moskva. Bol'shaya Rossijskaya enciklopediya.
Nosova, M.G., Fedorov A.V., 2021. Metody demograficheskogo analiza i prognoza. Colloquium-Journal. 15-2(102): 24-26.
Novye vozmozhnosti Statistica 12 URL: http://statsoft.ru/resources/support/new-features-statistica-12.php?ysclid=lqinz7tm9b123578175 (data obrashcheniya: 23.09.2023).
Rudakova, E.K., 2023. Obespechenie demograficheskoj bezopasnosti Rossii v usloviyah kognitivnyh ugroz. Diss. dokt. polit. nauk. Nizhnij Novgorod.
Tkachenko, YU.G., 2023. Kognitivnyj analiz regional'nyh demograficheskih problem (Rostovskaya oblast'). Sankt-Peterburg. POLITEKH-PRESS
«CHernye lebedi sbivayutsya v stayu»: ekspert o demografii Rossii. URL: https://dzen.ru/a/ZR0CTXwZX35ZWFy0?experiment=931375 (data obrashcheniya: 11.10.2023).
SHCHerbakov, A.I. 2017. Demografiya. Moskva. INFRA-M.
SHCHitova, N.A., Belozerov, V.S., Sopnev, N.V., 2022. Sravnitel'nyj analiz demograficheskogo povedeniya territorial'nyh obshchnostej lyudej v gorodskih aglomeraciyah raznogo tipa. Tyumen'. TyumGU-Press.
Alexander, J. C., 2011. Morality as a Cultural System: On Solidarity Civil and Uncivil. Perspectives: Newsletter of the ASA Theory Section. 33(2): 1-11.
Clarke, M., 2023. Demographic processes and household dynamics: a microsimulation approach. Population structures and models. Routledge.
Civelek, Y., 2023. Exploring Digital Context and Its Limitations in Social Sciences: A Concentration on Demographic Research. Migration and Diversity. 2(3): 367–381.
Easterlin, R.A., 2004. The reluctant economist : perspectives on economics, econ. history a. demography. Cambridge. Cambridge univ. press.
Frantsuz, Y., Ponarin, E., 2020. The impact of societal instability on demographic behavior (The case of Soviet and post-Soviet Russia). Population Research and Policy Review. 39(6): 1087-1117.
Jenačković, D.P., 2022. Implications of educational origin on demographic behavior of young people in south-east Serbia. Employment, education and entrepreneurship. P. 60.
Li, Y., 2023. A systematic review of rural resilience. China Agricultural Economic Review. 15(1): 66-77.
Sánchez-Vergara, J. I., 2023. Bracing community in rural coworking: emerging trends and categories. Journal of Place Management and Development.
Sheppard, P., Coall, D.A., 2022. The role of ontogeny in understanding human demographic behavior.

Analyzing the Feasibility of Using the Sylvan Information System and Drones in Forest Fire Suppression in Yakutia

Valeriy A. Yakovlev[a]

Department of Technosphere Safety, North-Eastern Federal University, 58 Belinsky Street, Yakutsk, Republic of Sakha (Yakutia) 677000, Russia

febra.t@yandex.ru

Keywords: ecology, fire, forest, environment, information, drones, Yakutia.

Abstract: Special attention in the article is paid to the relevance of IT-technologies in the field of forest fire prevention and localisation. The author of the paper justifies the use of the forest fire countermeasures system "Sylvan" and the use of unmanned aerial vehicles. He considers them as a way to monitor and record forest fires. This paper will validate the effectiveness of using drones for forest fire suppression, which can determine the type of fire, its area and direction of fire development, as well as the area of the most intense burning. Determination of information needs of the system participants should be in the system of fire safety and fire suppression, because it is essential for the operation of the system. Insufficient information, its untimeliness, as well as falsehood increases the risk of loss of life and material objects, forces to act in conditions of uncertainty, and the decisions taken may be wrong. Improvement and introduction of the latest technical means make it possible to realise different forms of fire safety provision irrespective of the features of emergency circumstances.

1 INTRODUCTION

Yakutia is one of the most fire-prone regions of the country. The total area of forests is 256.1 million hectares (83.4% of the territory). According to the information, as of 20 October 2022, in 2022, 531 forest fires were registered in Yakutia on the area of 560 thousand hectares. Analysing this data with the indicators of the previous year, it becomes clear that in 2022 the number of fires decreased by 3 times, and the area covered by fire decreased by 14 times! As practice shows, such results have become possible, among other things, thanks to the use of information technology, which will be discussed in this article.

Modern information technologies have started to play an important role in ensuring fire safety. They provide a wide range of means for fire detection. Their process starts with detection and ends with fire extinguishing. Some of them, for example, the system from the company "Spark Cinema", work on the basis of artificial intelligence and are able to detect not only direct signs of fire, but also the preconditions for its occurrence, for example, overheating of electrical equipment.

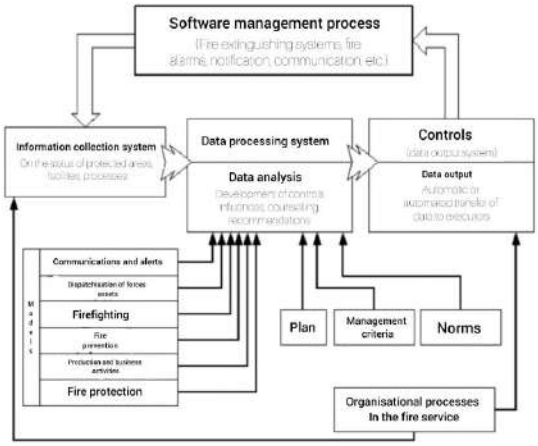


Figure 1: Structural diagram of automated software management.

IT technologies are already being used directly in firefighting. For example, modern automatic fire extinguishing systems can operate in an autonomous mode, analysing data from sensors and making decisions on the start of extinguishing.

[a] https://orcid.org/0000-0002-3765-5292

Large-scale projects in the IT industry are currently being implemented in Yakutia. The Far Eastern Federal District is a leader in high technology. It not only creates, but also implements promising, attention-grabbing projects that solve issues that exist not only in the republic, but also in the country itself.

In this article, I would like to make a special mention of a recent IT development by Yakut specialists. To create it and other control systems in the field of fire safety, the technologies discussed in Table 1 are used.

Table 1: Types of information technologies for creating control systems in fire safety.

Types of information technology	
System analysis	It identifies the characteristics of the facilities where fire safety must be assessed. The analysis helps to formulate the criteria for fire safety assessment and the main functional tasks to be performed by the control system. It includes computational experiments to simulate various scenarios of fire development, provides an opportunity to reproduce various calculated fire scenarios, etc.
Mathematical modelling	The emergence of powerful and affordable computing systems and the expansion of knowledge in the field of physics and chemistry of processes have made it possible to carry out modelling of processes occurring in fires with sufficient accuracy for practical activities. For modelling the development of fire hazards and determining the time of блокирования путей эвакуации используется combination of integral and zonal methods, or a bank of ready-made calculation models, and in case of analytical mode of system operation - field method. Decision support systems are implemented on the basis of mathematical modelling of CFP and evacuation development taking into account the evacuation conditions of the facility and analysis of calculation results using a database.
Database management systems	On the basis of DBMS the block of analytical processing is built, with the help of which reports are formed: on the process of evacuation of people, on blocking of evacuation routes, on getting evacuees into zones with maximum permissible values of fire hazards. Comparative tables of evacuation time and stages of fire development are also built to identify the danger of exposure of people to PFPs.
Operational analytical processing of data	The technology of operational analytical processing of multidimensional data (OLAP) provides high speed of work with data when performing analytical operations, visual presentation of results and prompt construction of reports. Multidimensional model allows to adequately represent the process of working with information objects, visually describe the main analytical operations and optimally build a physical data model for storing and processing queries.
Geographic information systems	Integration of geographic information systems (GIS) and OLAP-systems is possible. Such a combination contributes to increasing the visibility of presentation of the results of analytical data processing. As a result of integration OLAP-system acquires additional possibilities of visual representation of multidimensional data on geographical maps, GIS-tool for forming analytical queries for building thematic maps. The mechanism of dynamic connection of multidimensional data of OLAP-system to spatial information of GIS is based on cartographic data binding, which allows to establish correspondence between the results of operational analytical modelling and geographical objects.

2D and 3D graphics	2D - graphical environment is necessary to generate input data on fire hazardous objects. 3D - graphic environment helps to visualise the results of modelling, e.g. the process of evacuation of people and the spread of fire hazards.

2 SYLVAN SOFTWARE FOR FIGHTING FOREST FIRES

The Sylvan system, developed by Smart Unit LLC with the participation of employees of the State Budgetary Institution of the RS(Ya) "Avialesookhrana", the Ministry of Emergency Situations and volunteer movement, in 2022 helped Yakutia to detect new fire hotspots and extinguish forest fires twice as quickly. The advantages of using the forest fire information system include:

1. Reduction of response time by 5 times.
2. rapid detection of thermal anomalies (within 30 minutes).
3. Generation of over 30 types of reports, analytics and dashboards in automatic mode.
4. Possibility to create a register of citizens' appeals.
5. Calculation and tracking of readiness of means and forces.
6. Data update every 30 minutes.

This unique kind of programme combined mapping services for wind direction, deployment of forces and means, as well as climate services and accounting systems that were previously used by operational firefighting services such as EDDS, EMERCOM, 112, Avialesokhrana, municipalities and the operational headquarters of the district management. For comparison, previously, seven different applications were used to detect a natural fire in Yakutia, but now there is only one system.

The hardware and software complex, which consists of many modules, provides a complete picture of the current forest fire situation. It contains information on the area of fires, the number of resources involved, access to analytical data for the day/past dates, the register of aerodromes, records of air raids, readiness of forces and means. This data allowed to halve the response time to fires of any complexity and five times reduce the time to analyse the situation and actions. In addition, the system maintains the dynamics of each fire by day: changes in fire class, area, edge, human resources and equipment involved. The programme is available to all interested agencies - the operational headquarters, the Ministry of Ecology, the Ministry of Emergency Situations, the prosecutor's office, and municipal administrations. Compared to 2021, which was the most difficult year in history, forest fires in 2022 became 6.5 times less, and the area covered by fire decreased by 30 times. The downward trend continues in 2023. For example, on 21 June 2023, there were two forest fires on the territory of the Republic of Sakha covering an area of 1903 ha (Table 2).

Table 2: Types of information technologies for creating control systems in fire safety.

Region	Number of fires		
RS(Ya)	2022	2023	%
	199	217	+8,3

The mapping subsystem is implemented on the SMART software platform and was introduced in May 2022. After successful implementation, today it is used by more than 150 organisations, including specialists from the Aviaforestry, Ministry of Ecology, and municipalities of the republic. The development solved a problem of many years - it enabled agencies of different levels to interact with each other.

After the programme detects by satellite thermal spots with suspected fires, a ground unit or an air monitoring group immediately goes to the place. For its successful operation, data from six different sensors is collected. Today, the Smart Unite team is working on updating the programme, namely on the introduction of a lightning detection system and monitoring of thunderstorms.

The mathematical model of forest fire forecasting from the Synet Spark Foundation has small similarities with the development of Smart Unite. It can predict the development of an active fire for a certain period of time, taking into account the type of landscape, relief, and wind direction. The principle of its work is based on satellite observations, as well as data from international monitoring and scientific services. To build the forecast, the OpenWeather service is used, which receives information on wind speed and direction from a convolutional neural network.

The declared accuracy of the data is from 90 to 100% with an error of 1%. Even the darkness of a particular area is taken into account. On the map you can compare the forecast and already active fires with the help of a layer of actual "forecast" perimeters, which reflect the areas occupied by thermal points, from the beginning of the fire season to three days ahead of the selected date. Archived forecasts for 2020-2022 are publicly available. Figure 2 shows archived data for 12 July 2023.

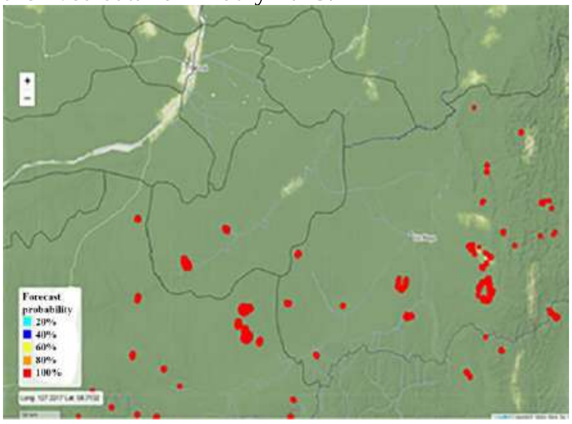


Figure 2: Archived data from the start page of the Yakutia Forest fire forecast website.

In the test version of the Yakutian service, current and forecast wind speed values are collected at 40 points evenly distributed across central Yakutia with a time step of 3 hours. Local authorities highly appreciated the project and intend to support its further development. According to project manager Timur Alekseev, in the future it is planned to make the system more accurate and also provide forecast data on fires in other regions of Russia.

3 USE OF UNMANNED AERIAL VEHICLES IN FIGHTING FOREST FIRES

During the first 10 days of August 2023, 152 forest fires with a total area of 156,354.4 hectares were extinguished, including 14 forest fires with a total area covered by fire of 51,933 hectares. In order to preventively detect forest fires and eliminate them, the first flights of BAS drones were conducted in early July 2023. The experiments confirmed that the drones, which are equipped with thermal imaging cameras, help paratroopers and paratroopers to scout the situation as accurately as possible, as well as to build the most effective plan of action. At the same time, drones are used for systematic monitoring of territories. This is especially important during the time of year when fires are most possible - in summer during dry weather. UAVs for monitoring forest fires have a great advantage over large aircraft. Firstly, it is operational efficiency - reconnaissance can be launched as needed per day. Secondly, UAVs are able to "see" fire sources even through significant smoke screens. Thirdly, flights are hundreds of times cheaper than manned aviation. The use of drones is expected to be an alternative to aviation when aircraft are unable to go out on air patrols due to low cloud cover.

There is usually only a short period of time between when a fire starts and the loss of control of the situation. Drones provide an opportunity for firefighters to observe the area from a bird's eye view, further helping rescuers to understand where the fire is moving, predict the further development of the situation, and correctly assess the scale of the disaster. UAVs fly lower than helicopters and provide a more detailed picture of the situation, can manoeuvre in a limited or dangerous space, where no aircraft pilot would dare to go.

In some cases, drones and firefighting helicopters can even be used in tandem to cover as much terrain as possible. The 360-degree images from the scene provide invaluable information on property damage to more quickly assess the situation and expedite insurance payouts to victims. The GPS receiver and RTK stations, with which the vast majority of modern drones are equipped, present the overall picture down to centimetres of the sensing results in a special mapping system. Coordinates are determined, locations of emergency services, machinery, equipment are identified, general condition and changes in the concentration of substances in the air are calculated, external factors are assessed, taking into account weather and other changes. Computer systems and autonomous stations also make it possible to control unmanned systems from afar, promptly regulating the actions of fire and rescue services.

4 CONCLUSION

It is becoming evident that information technologies make it possible to quickly mobilise additional forces and resources to extinguish forest fires, which so often occur in Yakutia. Thanks to them, response times are reduced and losses are prevented.

Recently, neighbouring regions have shown interest in the Silvan system. The programme developers have held talks with representatives of Khabarovsk Krai, Primorye, Karelia, Magadan, Irkutsk and Amur Oblasts, as well as Egypt, Madagascar, Mongolia and Turkey. Representatives of industrial, energy, communications and agricultural enterprises have also actively started to join in for continuous monitoring of their facilities -

industrial territories, communication lines, gas and pipelines. The Republic also signed an agreement with the Skolkovo Institute of Science and Technology on the use of models for predicting the direction of fire based on artificial intelligence. There are plans to introduce such a complex throughout the entire territory of the Far Eastern Federal District. The Yakutia Innovation Development Fund and Rostelecom will provide support in scaling up the IT development.

The authorities of the Sakha Republic are actively promoting the improvement of competences of UAV operators and training of new ones. In January this year, a special training centre was opened in the republic, where 1,060 students will be trained between 2023 and 2025. It should be said that Yakutia is included in the number of regions where the all-Russian strategy for the development of unmanned aviation will be developed in pilot mode.

After analysing the fire danger of forests, it turns out that IT in fire safety in Yakutia is an integral part of modern life, which help to save forests and reduce the cost of fire suppression. Drones, different information systems, some of them discussed in this article, not only improve the quality of fire supervision, but also reduce the number of accidents, loss of life at fires. They can be used to further prevent the spread of fire in forest areas, as well as to improve the efficiency of communication, signalling, special equipment, etc.

A number of activities aimed at developing the sphere of information technologies within the Republic of Sakha are planned for today in order to successfully pass the next fire seasons. The main conclusion of this work suggests that the perennially burning forests of Yakutia are one of the country's problems that need the help of IT specialists and all those who care about them.

REFERENCES

Mohan, A.T., Coyle, R.W., Hopkin, D., Yomaas, G., Caspil, R., 2021. Risk tolerance limits in fire engineering design: methodology and benchmark case study, Fire Technol., 57: 2235-2267.

Ovcharenko, G.V., 2018. Actual problems of fire safety. abstracts of the XXX International Scientific and Practical Conference 289-291.

Danilova, S.S., Nikolaeva, V.M., 2018. Alley of Science, Vol. 3. No. 10: 380-383.

Timofeeva, A.V., 2020. StudNet. 2020, T. 3. №12: 581-585.

Khabirov, T.R., Maltsev, S.V., Kosovet,s M.A., 2018. Actual problems of fire safety. abstracts of the XXX International Scientific and Practical Conference 394-397.

Automation of the Preliminary Assessment in the Design of Commercial Roads

Shestakova A.O.[1][a], Glukhikh I.N.[1][b], Chistyakov I.V.[1][c], Pavluk I.E.[1][d] and Dolgodvorov R.E.[2][e]
[1]*Tyumen State University, 6 Volodarsky str., Tyumen, 625003, Russia*
[2]*Gazprom Neft Scientific and Technical Center, 50 Let Oktyabrya str., 14, Tyumen, 625048, Russia*
a.o.shestakova@utmn.ru

Keywords: Automation, preliminary assessment, officesuit, software solution, productivity.

Abstract: The research article is devoted to the problem of automating the estimation of cost and labor in the road construction process, given the complexity of influencing factors such as soil type, weather conditions and resource costs. The article discusses the importance of accurately determining these parameters in the context of road design, emphasizing the high qualification of engineers. Particular attention is paid to the importance of automating preliminary assessment, identifying its key benefits: data analysis, rapid generation of estimates, decision optimization and risk management. As a result, automated systems are becoming an integral part of successful completion of road projects, minimizing financial and time costs. The paper further focuses on the description of the developed software solution aimed at automating the preliminary determination of embankment design, geomaterial strength characteristics, resources and construction cost in road construction projects.

1 INTRODUCTION

The estimation of cost and labor in road construction is a complex task due to numerous influencing factors. Factors such as soil type, weather conditions, material and labor costs represent only a fraction of the parameters that need to be considered for a reliable estimate. Additionally, the complexity of road design, including technical aspects such as alignment geometry and pavement stability, adds to the complexity of cost estimation.

In light of the factors described above, accurate cost and labor estimation in road construction requires consideration of many variables and possible changes in conditions, making the process difficult and highly demanding on the skills of engineers and specialists. In this context, automating the preliminary estimation of cost and labor for road construction is of paramount importance.

The importance of this process is justified by a number of key advantages of automation. First of all, automated systems have the ability to analyze vast amounts of data and parameters, increasing the accuracy of estimates. Second, they are able to generate estimates quickly based on input data, significantly reducing time costs. Third, automated systems perform cost and labor analysis at various stages of design and construction, which helps identify optimal solutions for efficient use of resources. Finally, automated systems facilitate risk management by providing the ability to identify potential problems and risks early in the project.

In this context, the automation of pre-assessment becomes an integral part of successful completion of road construction projects, resulting in minimization of financial and time costs. The following paper will describe the developed software solution aimed at automating the preliminary determination of embankment design, geomaterial

[a] https://orcid.org/0000-0003-4779-4285
[b] https://orcid.org/0000-0002-0683-6138
[c] https://orcid.org/0009-0005-0531-7941
[d] https://orcid.org/0009-0003-2743-6939
[e] https://orcid.org/0009-0002-0169-5222

strength characteristics, resources and construction cost in road construction projects.

2 MATERIALS AND METHODS

2.1 Requirements elicitation

There are many methods for requirements elicitation. BABOK lists nine, but there are many more methods, such as protocol analysis (Berezovik, 2024.), job application development (Khasanov, Prokofiev, Ushmaev, Gilmanov, Margarit, 2016), and the like.
It is unlikely that any one elicitation method will always work for all projects. "While some may advocate ... only one method of elicitation... it is generally recognized that a method or approach to identifying individual requirements may not be appropriate for all projects."

The structure of the organization, the political climate, the nature of the project, and your personal strengths and preferences will largely determine which methods will work best for the project. Having said that, here are five methods that analysts with almost any experience or skill level can use and that almost always yield a great return on investment.

Table 1: Basic requirements elicitation methods.

Method name	Brief description	Benefits
Observation	Capturing what already exists. As one analyst notes, "We have found that informal use cases provide the best return on invested effort in the early stages of discovery - they are easier to repeat and provide less risk of getting tangled up in the details of early thought processes." (Hidellaarachchi, Grundy, Hoda, Mueller, 2023)	The ability to accurately identify the users' position at the beginning of a project.
Brainstorming	A way to find solutions without frameworks and constraints using collective intelligence. Multiple ideas and information provide a rich knowledge base to choose from to understand the direction of the project.	Helps avoid potential pitfalls in the future by enlisting others to help uncover unknown data. Allows a large amount of information to be absorbed simultaneously to help understand the direction of the project.
Interview	Individualized elicitation of requirements from a stakeholder. One author notes: "Interviews provide an efficient way to collect large amounts of data quickly."(Khannur, Hiremath, 2023)	In-depth exploration of the stakeholder's needs. The author adds: "The results of interviews, such as the usefulness of the information gathered, can vary considerably depending on the skill of the interviewer." (Khannur, Hiremath, 2023)
Requirements workshops	A gathering of key stakeholders to elicit requirements in an open conversation. "A requirements workshop is a highly productive, focused event that brings together carefully selected key stakeholders and subject matter experts over a short intensive period." (Sehlhorst, 2012)	Rapid requirements elicitation. Possibility of attracting inventory into the project.
Prototype	Creating a visual example of a future	The ability to validate the correct vision of a future product or solution.

	solution or product. One analyst notes: "Users and business owners should not be expected to be able to visualize new software. Users usually don't know what they want until they see what they don't want." (Bochkareva, 2015)	Analysts state: "The advantage of using prototypes is that they encourage stakeholders, more specifically users, to play an active role in requirements development. this method is extremely useful when developing new systems for completely new applications."

In order to identify requirements for a software product, it is important to have an effective interaction with interested stakeholders. Examples of typical questions asked of stakeholders are:

- 1. Functional Requirements:
  - What functions and capabilities do you expect from the software product?
  - What basic operations or tasks would you like the product to perform?
- 2. Non-Functional Requirements:
  - What performance requirements (e.g., speed of operation, responsiveness) are important to you?
  - Are there special requirements for security, reliability, or scalability of the product?
- 3. User Experience:
  - What are user expectations for the interface and usability of the product?
  - What additional features could enhance the user experience?
- 4. Integration and Compatibility:
  - Is integration with other systems or programs necessary?
  - Are there specific compatibility requirements with operating systems, browsers, and other technologies?
- 5. Data Requirements:
  - What data needs to be considered or processed within the product?
  - Are there specifics regarding data storage, processing, and protection?
- 6. Business Objectives:
  - What business goals and outcomes do you expect from using the product?
  - What key performance indicators (KPIs) should be considered?
- 7. Budget and Time Constraints:
  - What budget constraints exist for the project?
  - Are there deadlines that need to be met?
- 8. Change Management and Development:
  - What opportunities for future development or product changes might be important?
  - What change management processes do you favor?
- 9. Training and Support:
  - What are your requirements for training users or staff on how to use the solution?
  - What support do you expect from the development team once the solution is implemented?
- 10. Expected Results:
  - How will you measure the success of the product?
  - What specific results or benefits do you expect to realize?

It is important to consider that the questions should be tailored to the specific project context and stakeholder needs. In addition, active listening and open dialog are also important elements in the requirements elicitation process.

2.2 Calculation of Productivities

Bulldozer productivity formula:

$$P = amount * \frac{3600 * T * Q * kb}{tc}, \tag{1}$$

where P - operational productivity in m3/shift; T - shift duration in h; Q - volume of soil in dense body, moved by bulldozer, in m3; kb - time utilization factor; tc - cycle duration in sec.; amount - number of bulldozers.

The volume of soil in a dense body, moved by bulldozer is determined by the formula:

$$Q = \frac{ho^2 * I * \sin(\beta)}{2 * kr * tang(\varphi)}, \tag{2}$$

where ho - dump height in m; - angle of natural slope of soil in deg; l - dump length in m; kp - loosening factor; - angle of inclination in plan between the longitudinal axis of the bulldozer and the dump line.

$$tc = \frac{lr}{V1} + \frac{lp}{V2} + \frac{lr+lp}{V3} + tm + 2 * ts + t0, \tag{3}$$

where lr - length of cutting path in m; lp - length of soil movement in m; V1 - speed of bulldozer movement during soil cutting in m/sec.; V2 - speed during moving in m/sec.; V3 - speed of reverse (empty) bulldozer movement in m/sec.; tm - duration of gear shifting in sec.; ts - duration of bulldozer turning in sec.; t0 - duration of blade lowering in sec.

Dump truck productivity formula:

$$P = Qp * np, \tag{4}$$

where Qp - load per trip; np - number of trips. Formula for calculating the load per trip:

$$tc = \frac{lr}{V1} + \frac{lp}{V2} + \frac{lr+lp}{V3} + tm + 2 * ts + t0, \tag{5}$$

where Pk - verification calculation of voyage load; Yt - curb weight of the vehicle; f - specific resistance of the road; i - guiding elevation.

Formula for calculating the number of trips:

$$np = \frac{(480 - tpz) * K}{l * (T1 + T2 + T3)}, \tag{6}$$

where l - hauling distance; T1 - travel time per 1 km in both directions; T2 - loading time; T3 - unloading time; tpz - preparation and stopping time; K - time utilization factor.

Formula for verification calculation of voyage load:

$$Pk = \frac{Me * ipk * ikn * ian * Npnm}{PK}, \tag{7}$$

where Me - operating torque on the engine flywheel; ikn - number of gears in the gearbox; ipk - number of gears in the transfer gearbox; ian - number of gears of the main transmission; Npnm - efficiency factor; PK - dynamic wheel radius.

The formula for the productivity of the roller:

$$P = \frac{Vp * (B - C) * Kv}{n}, \tag{8}$$

$$Ph = T * P * hy, \tag{9}$$

where Vp - operating speed of the trailed roller; C - width of the overlapping zone; B - width of the roller; Kv - coefficient of utilization of working time; hy - thickness of the compacted layer; n - number of passes.

The formula for the thickness of the compacted layer for the cam roller is:

$$hy = 0.65 * (L + 2.5 * b - hp), \tag{10}$$

where hp - thickness of the loosened layer; L - height of the cam; b - width of the support surface of the cam.

Motor grader productivity formula:

$$P = \frac{3600 * (B - b) * L * kb}{m * \left(\frac{L}{v} + t\right)}, \tag{11}$$

where kb - coefficient of working time utilization; L - length of the planned area in m; B - width of the blade in m; b - width of the overlapping strip in m; V - working speed of the motor grader in m/s; t - time for turning in s.

2.3 Calculation of shifts

Calculating the number of shifts of work depends on the specific situation and working conditions. Here are some methods for calculating the number of shifts:

- Production Calendar:
  - Consider the production calendar, which determines the number of working days in a month or year.
  - Divide the total number of hours worked by the length of one shift (usually 8 hours) to determine the number of shifts.
- Load Factor:
  - Consider the Load Factor, which accounts for planned and unplanned work interruptions (e.g., lunch breaks, technical downtime).
  - Multiply the total number of hours worked by the Load Factor to determine the actual hours worked.
- Labor Productivity and Intensity:
  - Evaluate the productivity and intensity of labor on each shift.
  - Consider what tasks are performed on each shift and how long it takes to complete them.
- Production Requirements:
  - Consider the requirements of the production or service you provide.
  - Determine how much time is required to complete specific tasks or handle a certain volume of production.
- Performance Standards:
  - Use the performance standards established for your industry or specific type of work.
  - Consider regulations and standards to determine the optimal number of shifts.
- Volume of Orders or Tasks:
  - Estimate the volume of orders, tasks, or projects that need to be completed.

- Allocate the workload between shifts, taking into account time constraints and deadlines.
- Load Forecasting:
  - Forecast labor load based on historical data or estimated workload.
  - Determine how many shifts will be required to handle the expected workload.

The specific method chosen depends on the nature of the work, working conditions, production requirements, and other factors considered in a particular situation.

The formula for calculating the number of shifts per stage is:

$$shift = \sum_{i=1}^{g} \left(\frac{V_i}{\sum_{j=1}^{eq_i} pr_j * k_j} \right) \quad , \tag{12}$$

where shift - number of shifts per stage; K - number of techniques; G - group of techniques per stage; Pr - productivity, V - volume of brought soil.

Formula for calculating the total number of shifts:

$$shifts = \sum_{i=1}^{n} shift, \tag{13}$$

where n - number of stages, shift - number of shifts per stage.

Formula for calculating the cost of shifts per stage:

$$cost = \sum_{i=1}^{m} t_i * c_i \quad , \tag{14}$$

where cost is the cost of shifts per stage; t is the number of shifts; c is the cost of a shift.

Formula for calculating the total number of shifts:

$$costs = \sum_{i=1}^{n} cost, \tag{15}$$

where n - number of stages, - cost of shifts per stage

2.4 Drawing a timeline

Drawing calendar schedules, also known as gantt charts, is essential in various fields where it is important to visualize and manage project timelines and dependencies. Here are a few aspects of the importance of rendering calendar schedules:

1. Visualization of timelines:

- Gantt charts are an effective tool for presenting project timelines. They allow you to clearly see the sequence and duration of tasks.

2. Managing tasks and dependencies:

- Gantt charts help to identify dependencies between tasks, which helps to better manage the temporal and logical relationships in the project.

3. Resource Planning:

- Building timelines makes resource planning easier. Project managers can see which tasks require more time or resources and make decisions accordingly.

4.Progress Tracking:

- Gantt charts provide a tool to monitor and track the progress of tasks. This allows you to respond quickly to changes and problems in the project execution process.

5. Communication and Stakeholder Involvement:

- Calendar charts are an effective means of communicating with team members and other stakeholders. Visualization helps all participants to better understand the progress of the project.

6. Schedule Optimization:

- Gantt charts allow you to explore different scheduling options, which can help optimize timelines and achieve better results.

7. Decision making:

- Drawing timetables facilitates the decision-making process because all participants see the big picture and can work together to solve problems.

Gantt charts have become a standard tool in project management due to their simplicity, efficiency and ability to effectively represent and manage the time aspects of projects.

The construction of Gantt Diagrams involves the following methodology steps:

- Defining Tasks and Time Frames:
- Developing the Diagram Structure:
- Visualization of Tasks:
- Accounting for Dependencies:
- Use of Colors and Design:

Total construction days = (end-start)/(1000 * 3600 * 24 * 365);

$$end\ of\ stage = \sum_{stage=1}^{n} end\ of\ stage_{stage-1} * \frac{difference\ of\ days}{total\ construction\ days} \tag{16}$$

For j=startJ through (endJ+1), execute:
Shade cell(i-1, j) in RGB(118,190,39) color

3 RESULTS

3.1 Requirements for the software solution

The software solution shall solve the problem of automating the preliminary determination of embankment design, geotextile material strength characteristics, resources, construction cost and work steps.

Requirements for the solution:

- realization of the possibility of design and embankment selection;
- calculation of soil volume and geomaterial area taking into account the embankment geometry with the possibility of user editing;
- calculation of settlement value;
- determination of the amount of resources required;
- construction of calendar schedule;
- realization of the possibility of performance editing;
- output of the results of calculation of material volumes, resources and calendar schedule.

The technical requirement for the software solution is implementation in p7-office.

R7-Office is a Russian cross-platform application package for collaborative work with office documents. It is included in the unified register of Russian programs for computers and databases. It is available in cloud, local and mobile versions, supports private cloud deployment and a range of collaboration solutions.

3.2 Architecture of the program solution

To solve the problem of automation of preliminary assessment of feasibility of construction of a field road, a document of a special page structure and macros for working with the excel document were created.

Since the software solution should work in p7-office, the programming language for writing macros is JavaScript.

The software solution is divided into 2 components: macros for realizing the logic of actions for solving tasks and the sheets of the document that perform the necessary calculations. Such division was chosen for scalability of the software solution - the software product will continue to work correctly even if the calculation formulas are changed or new types of influencing parameters appear.

The sheets of the document are divided into 3 types:

- sheets with which the user actively works;
- sheets with which the user cannot interact. Such sheets have an introductory character;
- auxiliary sheets, with which the user interacts when it is necessary to change parameters for calculation or to enter new data.

3.3 Implementation of the software solution

For preliminary assessment of feasibility of field road construction with the help of the software solution the user should fill in active sheets (see Figure 1).

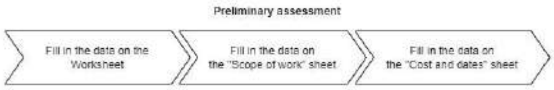


Figure 1: Filling sequence.

When filling in each sheet it is necessary to confirm and update the values using special buttons. These buttons are linked to the corresponding macros.

Filling in the initial data. The first step for preliminary estimation is the input of data by the user on the worksheet.

By receiving data on the estimated dimensions of the road and the type of soil on which the road will be laid, the LoadData macro determines the road design, the depth of settlement and the amount of resources required (see Figure 2).

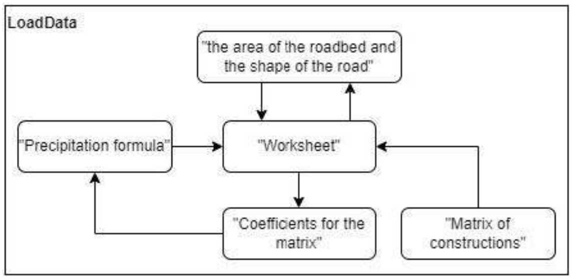


Figure 2: Structure of the LoadData macro worksheets.

Possible road constructions are listed on a separate sheet and can be added or changed if necessary. The data on structures has a certain structure:

- Strength entry: Strength - *value* *units*,

- Material entry: *Material name*,

- Enter the number of cages: Number of cages - *value*,

- Geomaterial shape input: Shape - *cell name of the row with the formula from the sheet "road surface area and shape "*.

In are entered variable values by the user, outside the template words for the program operation.

When new structures are added because of a new value of embankment height, new rows must be added to the matrix. If the addition of new structures is due to the presence of a new soil type, the structures must be added to a new column.

The standard calculation of the volume of material to be brought in is done taking into account the trapezoidal shape of the road. The calculation formulas are entered according to a defined structure and defined on a separate sheet, which will allow the user to modify or add a new formula if necessary.

The calculation of the depth of settlement is placed in a separate sheet that accesses the sheet with the values to be calculated.

In this case the gauge calculation function has 2 auxiliary sheets. For the possibility to change both the calculation formula and to change or add parameters for the calculation.

After clicking on the macro button the result with the main data necessary for further calculations is displayed.

Determining the amount of work. The table for entering the quantity of equipment is filled in automatically when the "Update table" button is pressed on the "Scope of work" sheet. The macro builds the table for distribution of the quantity of equipment by stages (see Figure 3).

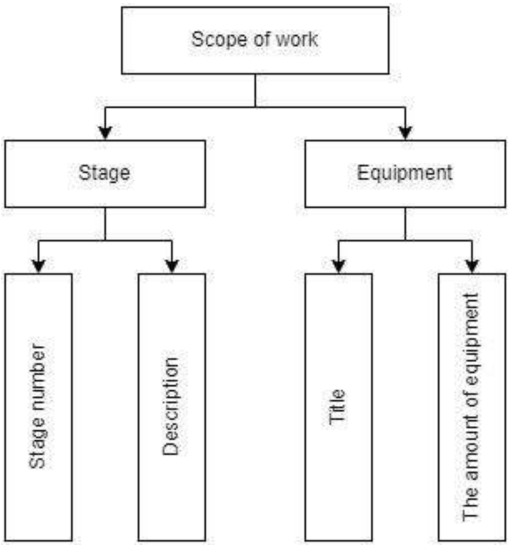


Figure 3: Structure of the sheet with the scope of work.

The macro correlates the technique and the stage, as well as the amount of material to be brought to each stage from a separate sheet (see Figure 4).

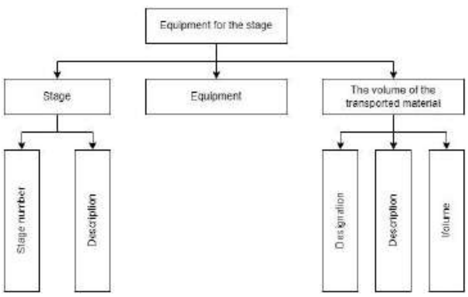


Figure 4: Structure of the sheet with technique per stage.

On a separate sheet there are alternatives of the technique for the possibility of calculating shifts, taking into account the replacement of the technique with an alternative one.

FillTablesWorks and Smeta macros interact with the same list of sheets of the document (see Figure 5).

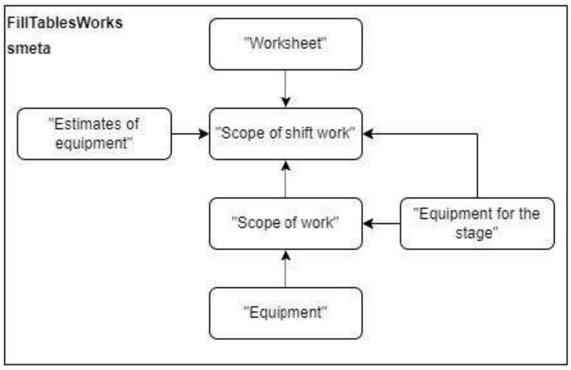


Figure 5: Structure of worksheets of FillTablesWorks and Smeta macros.

When calculating shifts of equipment for each stage of work, the macro collects data on stages, the volume of brought material and the number of equipment for each stage from the corresponding sheets. After the calculations have been performed, the user gets the results on the cost, number of shifts and volume of brought resources for each stage of works (see Figure 6).

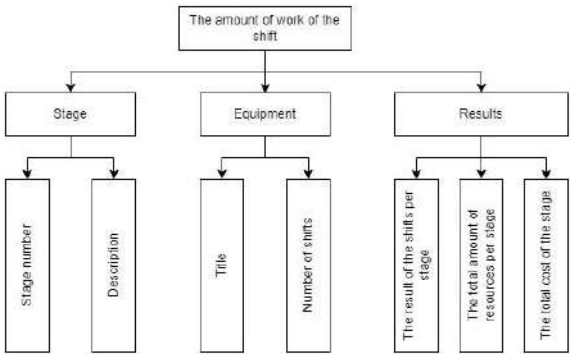


Figure 6: Sheet structure with work volume shifts.

Calculation of productivity and cost of equipment work per shift are placed on a separate sheet for the possibility of adjusting values and adding new data (see Figure 7).

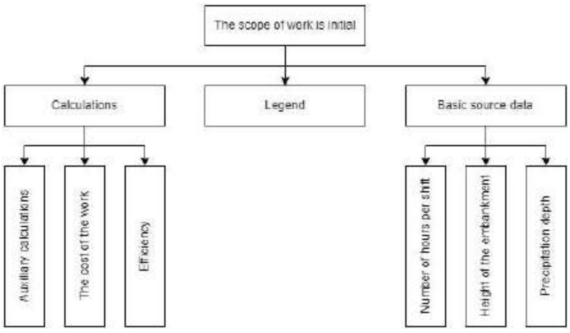


Figure 7: Sheet structure with productivity and cost of machinery work.

The sheet contains machinery and parameters for calculating its productivity. When hovering over a parameter, its description or name is displayed. The macro uses the values from the green and yellow cells, the values of other cells can be used as auxiliary for calculations:

- Summa (green cell) - the cost of equipment, manpower per shift, as well as the designation of the resource cost.
- Pr (yellow cell) - productivity of equipment, manpower.

Building a schedule of work stages and displaying the final cost. On the sheet "Cost and dates" when activating the macro with the help of the button the final cost of works for each stage, the dates of the beginning and end of each stage, the number of days per stage and the final price for materials are displayed (see Figure 8).

Figure 8. Structure of the sheet with the cost of works and dates per stage.

After reading data from the auxiliary sheets, the user enters the start date of the first stage, following which the macro is restarted.

After recalculation of the start and end dates of the stages, a schedule of the stages of work is built.

The size of each stage is proportional to the number of days for its execution relative to the total number of days for all stages.

4 DISCUSSION

The discussion of the current software solution highlights its ability to automate the calculation and design selection processes, which is a meaningful step towards the preliminary assessment of field road construction.

An important aspect is the fact that the macros are currently optimized to work exclusively with the P7-office product. This ensures that calculations can be performed directly on the document sheets without the need to use third-party office programs such as Microsoft Office. However, it should be noted that adapting the program to other office products will require reworking the macro code to match the programming language used in those products.

Regarding the calendar, it should be noted that it is currently capable of building simple sequential tasks, but there is a need for improvement when working with tasks that start simultaneously. Duplication of dates in such cases is a potential improvement that could be introduced in future versions of the software solution to enhance its functionality and meet the diverse needs of users.

5 CONCLUSION

It can be emphasized that, in the present context, the automation of pre-assessment plays a key role in ensuring the successful completion of road construction projects, reducing both financial and time costs.

At the end of this phase of the study, which focused on the development of a software solution for a digital technical solution album for road construction, the key findings and conclusions are as follows:

1. The developed software product provides the user with the ability to select the optimal design and embankment for a road facility.

2. The software product successfully performs the calculation of settlement value, which is an important parameter in the design of road structures.

3. The user is able to perform editing of parameters such as soil volume and geotextile area with respect to embankment geometry, which provides flexibility in planning.

4. The software product successfully determines the required quantity of resources, which helps to manage the budget and material resources of the project efficiently.

5. The ability to create and edit the schedule, including machine and mechanism performance parameters and the amount of resources to be utilized, is provided.

6. The results of material, resource and schedule calculations are output by the software product in a convenient format, providing complete information for decision making.

These conclusions underline the importance and efficiency of the developed software solution in the field of road construction, providing engineers and specialists with all the necessary tools for successful and optimized planning, pre-estimation and execution of projects.

REFERENCES

Berezovik, E., 2024. Automation of Supplier Management as a Trend in 2023. Available at: https://kontur.ru/market/spravka/37708-avtomatizaciya_raboty_s_postavshchikami, last accessed 04/01/2024.

Khasanov, M., Prokofiev, D., Ushmaev, O., Gilmanov, R., Margarit, A., 2016. Perspektivnye tekhnologii Big Data v neftyanom inzhiniringe: opyt kompanii «Gazprom neft'». Neftyanoe Khozyaystvo 12, 76–79.

A Guide to the Business Analyst's Body of Knowledge, Version 2.0, International Institute of Business Analysis, Toronto, Ontario, Canada, ©2005, 2006, 2008, 2009

Hidellaarachchi, D., Grundy, J., Hoda, R., Mueller, I., 2023. The Influence of Human Aspects on Requirements Engineering-related Activities: Software Practitioners' Perspective. ACM Transactions on Software Engineering and Methodology. 32(5), 1-37.

Wiegers, K, Beatty, J., 2013. Software Requirements, 3rd Edition.

Khannur, A., Hiremath, M., 2023. Requirements Engineering Framework using Contextualization, Profiling, and Modelling. Conference: 8th International Conference on Software Engineering.

UTS ePRESS, http://epress.lib.uts.edu.au, last accessed 2023/12/29.

Sehlhorst, S., 2012. Top Five Requirements Gathering Tips. Available at: https://tynerblain.com/blog/2006/01/14/top-five-requirements-gathering-tips/, last accessed 2012/12/05.

UTS ePRESS, http://epress.lib.uts.edu.au, last accessed 2023/12/29.

Bochkareva, T.M., 2015. Tehnologija planirovochnyh i zemlerojnyh rabot [Technology of Planning and Earthworks]. Perm', Perm. nac. issled. politehni. univ., 2015. 132 p.

UTS ePRESS https://r7-office.ru/, last accessed 2024/01/14.

Banker, R.D., Charnes, A., Cooper, W.W., 1984. Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management science 30 (9): 1078–1092.

Potential and Risk Identification of Solar Generation Development in the Republic of Tatarstan

Gainullina Leysan Raisovna[1][a], Farida Mizhatovna Filippova[2][b]
and Averyanova Yulia Arkadyevna[3][c]
Kazan State Energy University, st. Krasnoselskaya, Kazan, Russia
gainullina7819@mail.ru, filippovafer@yandex.ru

Keywords: Solar generation, solar insolation, Republic of Tatarstan, Delphi method, forecast, risk factors

Abstract: The relevance of this work is associated with the entry into force of the federal law of 02.07. 2021 № 296 "On limiting greenhouse gas emissions" and the need for a partial transition to affordable and environmentally friendly sources of power supply. One of such sources is solar energy. The purpose of the work is to determine the potential of solar energy in the Republic of Tatarstan, identification and risk assessment of projects for construction of solar generation facilities. The work determines insolation in the region as a whole and districts, in particular. Also identified the potential power output of generation facilities of different levels with the calculation of conventional crystalline silicon (C-Si) modules as the most common technology in the market of solar photovoltaic systems. The factors influencing the development of solar power generation are considered. A SWOT analysis has been conducted in view of the research findings on the potential for realization of different level of solar power generation projects. Identification and assessment of risks was carried out with determination of the degree of damage and probability. Risk management opportunities were identified for the identified risks: training of specialists abroad and in Russia (opening of new educational programs), the need and possibility of developing autonomous stations, long-term guarantees from manufacturers of equipment components, localization of PV module production.

1 INTRODUCTION

In recent years, solar energy has been actively developing. New technologies are being developed to increase the efficiency of solar panels, expand the range of operating temperatures (for different regions). The advantages of solar energy, in addition to renewability and environmentally friendly operation, include silence, the possibility of autonomous use of power plants, application in various spheres. The disadvantages of solar energy are high cost of solar panels, use of rare-earth metals for their production, irregularity of power generation, as well as problems of utilization of spent solar modules.

Currently, solar energy is not so widespread in Russia, but modern technologies in this field and their rapid development suggest the possibility of further development of this type of generation in our country.

The purpose of the work is to determine the potential of solar energy in the Republic of Tatarstan, identification and risk assessment of projects for the construction of solar generation facilities. Design and construction of solar power plants are long and complex processes with a large number of surveys for site selection, consideration of climatic conditions and equipment selection, feasibility studies, etc. All these items require financial investments. Consequently, before the financial investment phase, it can be very useful to get a first idea of the future energy output at the beginning of the process in order to consider the risks and make sure that the project is profitable (Kou, Pamucar, Dinçer, Yüksel, 2023; Strielkowski, Civín, Tarkhanova, Tvaronavičienė, Petrenko, 2021).

Solar atlases are often used for this purpose. A solar atlas is a dataset that provides at a particular location an estimate of the solar resource, average daily amounts of solar radiation, direct normal

[a] https://orcid.org/0000-0001-5414-7647
[b] https://orcid.org/0000-0003-3138-7212
[c] https://orcid.org/0009-0000-4552-4228

irradiance, horizontal irradiance, optimal angle oblique irradiance, etc. (Wald, 2019). In recent years, the use of solar atlases has accelerated with the development of open access datasets such as Global Solar Atlas.

The estimation of solar resource generation for a particular area by Global Solar Atlas are suitable for preliminary studies because they consider default values for many factors that are important for the selection of solar power plant sites.

2 MATERIALS AND METHODS OF RESEARCH

The paper uses general scientific methods of comparative analysis, study of information sources, SWOT-analysis.

The source materials for the analysis are the data obtained from Global Solar Atlas. In the work direct normal irradiation, global oblique irradiation under the optimal angle of day and year for the Republic of Tatarstan are determined. The results are given in the form of a histogram. Also the existing technologies in solar energy were analyzed with determination of the acceptable ones for this region.

Identification of risks of projects for construction of solar energy facilities was carried out according to the results of SWOT-analysis. The list of the most significant risk factors was determined using the Delphi method.

3 RESEARCH RESULTS

3.1 Solar insolation of the Republic of Tatarstan

For preliminary assessment of the insolation level of the Republic of Tatarstan and potential power generation, data were obtained from literature sources and Global Solar Atlas (Torres, Petrakopoulou, 2022).

Average values of indicators for April 2024 from the Global Solar Atlas for Tatarstan are given in Table 1.

Direct normal irradiation and global oblique irradiation at an optimal angle for the Republic of Tatarstan during a year are shown in Fig. 1 and 2.

According to the radiation maps it can be seen that insolation of the territory of Tatarstan is almost uniform. There is a slight decrease in insolation against the general background of the northern and northeastern part of the Republic.

Table 1: Map data.

Indicator	Meaning	Unit of measurement
Specific photovoltaic output power	1094,9	kWh/kWp
Direct normal irradiation	1079,1	kWh/m^2
Global horizontal irradiation	1092,0	kWh/m^2
Diffuse horizontal irradiation	518,4	kWh/m^2
Global oblique radiation at an optimal angle	1293,9	kWh/m^2

Figure 1: Direct normal exposure in the Republic of Tatarstan.

Figure 2: Global oblique radiation at an optimal angle.

Values of direct solar radiation and inclined radiation at an optimal angle (W/m²) by districts of the Republic of Tatarstan are given in Table 2.

Table 2: Insolation by districts of Tatarstan.

Municipal districts (urban districts)	Specific photovoltaic power output PVOUT, kWh/kWp	Direct normal irradiation DNI, kWh/m^2	Diffuse horizontal irradiation DIF, kWh/m^2	Global tilted irradiation at optimum angle GTI opta, kWh/m^2
Agryzsky	1090,1	1070,6	515,1	1285,0
Aznakaevsky	1118,0	1108,3	522,7	1315,8
Aksubaevsky	1108,1	1092,4	524,8	1310,8
Aktanyshsky	1107,4	1101,9	513,9	1306,5
Alekseevsky	1122,7	1113,4	520,1	1323,7
Alkeevsky	1119,8	1096,7	528,4	1324,6
Almetyevsky	1115,6	1099,5	520,6	1316,0
Apastovsky	1111,4	1089,5	524,0	1313,2
Arsky	1097,9	1068,1	517,9	1292,7
Atninsky	1096,1	1071,2	517,1	1291,5
Bavlinsky	1137,7	1126,2	523,4	1339,3
Baltasinsky	1100,0	1077,1	514,7	1297,1
Bugulminsky	1125,5	1113,2	523,4	1325,6
Buinsky district	1113,7	1093,1	527,8	1316,9
Verkhneuslonsky	1110,2	1098,8	520,6	1313,6
Vysokogorsky	1095,8	1071,0	517,9	1291,7
Drozhzhanovsky	1111,4	1084,3	532,2	1315,1
Yelabuzhsky	1095,2	1080,4	517,2	1294,3
Zainsky	1094,2	1071,1	519,2	1291,2
Zelenodolsky	1098,2	1073,1	518,6	1297,3
Kaibitsky	1101,9	1077,9	523,4	1302,1
Kamsko – Ustinsky	1111,3	1091,5	523,2	1312,8
Kukmor	1096,2	1069,5	515,3	1290,6
Laishevsky	1026,0	1116,6	519,0	1329,2
Leninogorsk	1132,2	1124,9	520,1	1331,3
Mamadyshsky	1118,9	1102,1	516,5	1315,3
Mendeleevsky	1098,0	1076,3	512,9	1295,2
Menzelinsky	1104,1	1099,4	512,3	1303,9
Muslyumovsky	1097,8	1077,5	516,9	1295,8
Nizhnekamsk	1115,3	1112,0	515,8	1316,9
Novosheshminsky	1118,0	1104,5	524,4	1321,4
Nurlatsky	1131,4	1126,0	525,0	1338,9
Pestrechinsky	1104,4	1078,2	522,5	1303,4
Rybno-Slobodsky	1118,3	1101,3	520,1	1316,5
Sabinsky	1105,7	1083,6	517,9	1302,7
Sarmanovsky	1101,8	1077,5	520,0	1303,2
Spassky	1129,0	1119,0	522,7	1335,4
Tetyushsky	1118,4	1104,5	520,5	1321,6
Tukaevsky	1093,4	1076,6	517,4	1290,5
Tyulyachinsky	1102,9	1081,1	519,8	1303,1
Cheremshansky	1118,0	1100,6	524,8	1318,5
Chistopolsky	1111,5	1094,8	521,6	1314,1
Utazinsky	1124,5	1100,3	523,3	1325,0
Kazan	1087,2	1074,4	510,2	1284,4

Insolation in the Republic of Tatarstan differs insignificantly. Slightly lower indicators in the northern and northeastern part of the Republic. It is also necessary to take into account air pollution, especially in large cities, as it affects the accuracy of measurement.

To identify potential electricity generation in the Republic of Tatarstan, it is necessary to determine the average insolation by month, taking into account the optimal angle of inclination of stationary PV modules towards the equator (Table 3, Fig. 3). This will allow to calculate the maximum efficiency for any time of the year. To control the tilt angle, trackers can be used or the angle can be moved independently using special fasteners (Torres, Petrakopoulou, 2022).

Table 3: Solar insolation with regard to optimal tilt angle (Torres, Petrakopoulou, 2022)..

Month	Solar insolation, кВт•ч/m^2	Optimal tilt angle, °
Jan	1,45	71
Feb	2,47	63
Mar	3,85	50
Apr	4,92	35
May	5,77	20
Jun	6,19	11
Jul	5,99	17
Aug	4,79	29
Sep	3,49	44
Oct	2,25	57
Nov	1,68	69
Dec	1,39	74
Annual average	**3,69**	**44,9**

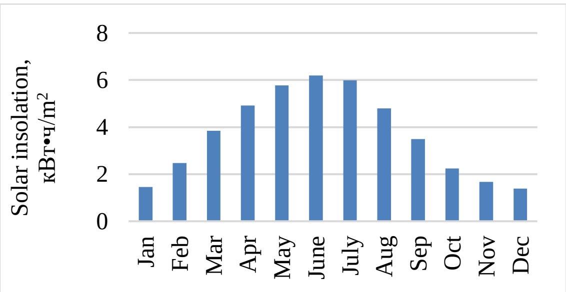


Figure 3: Solar insolation of the Republic of Tatarstan by months.

It is also of interest to determine the total photovoltaic power output for different levels of solar generation. In Fig. 4 shows the monthly average values of the total photovoltaic power output for a large scale project with an installed capacity of 1000 kWp. Fig. 5 shows the monthly average values of total PV power output for a medium-sized commercial facility with an installed capacity of 100 kWp. Fig. 6 shows the monthly average values of the total PV power output of the installation for a small residential building (installed capacity of 1 kWp).

In the Global Solar Atlas modeling, the calculation is based on conventional crystalline silicon (C-Si) modules as the most common technology in the solar PV market.

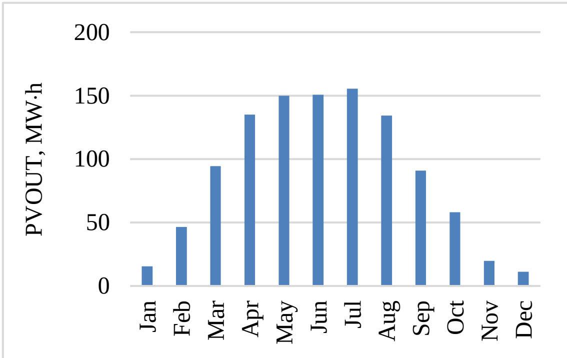


Figure 4: Total photovoltaic power output of an industrial plant with an installed capacity of 1000 kWp.

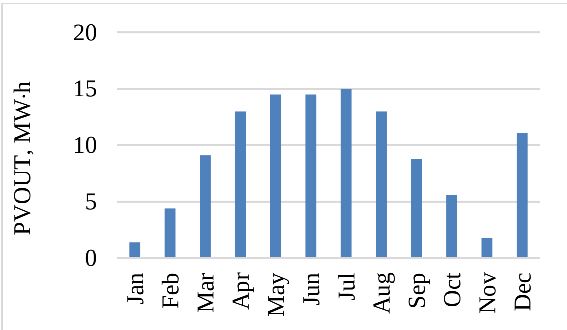


Figure 5: Total photovoltaic output of a commercial facility with an installed capacity of 100 kWp.

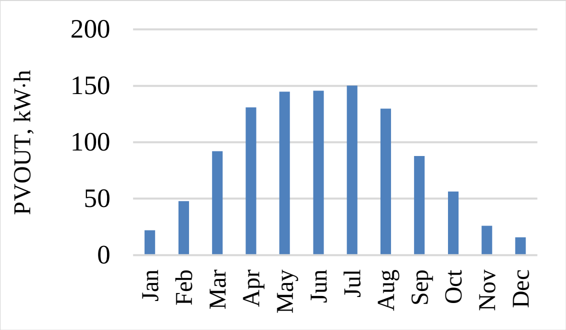


Figure 6: Total photovoltaic output of the installation for a small residential building (with 1 kWp installed capacity).

Solar modules produce electricity even when there is no direct sunlight. Therefore, even when the weather is cloudy, the PV system will generate electricity. However, the best conditions for electricity generation will be when the sun is bright and the panels are oriented perpendicular to the sunlight (Platonova, Toropov, Tulikov, 2019).

3.2 Availability of modern technologies

Scientists all over the world are working on increasing the efficiency of photovoltaic modules. Currently, the efficiency of such technologies is 15-30%. It is assumed that the theoretically possible limit of efficiency factor for semiconductor technology is 85-88 % (Kochmarev, Malozyomov, Kuznetsova, Ignatev, 2020).

The efficiency factor of solar cells depending on the material is shown in Figure 7.

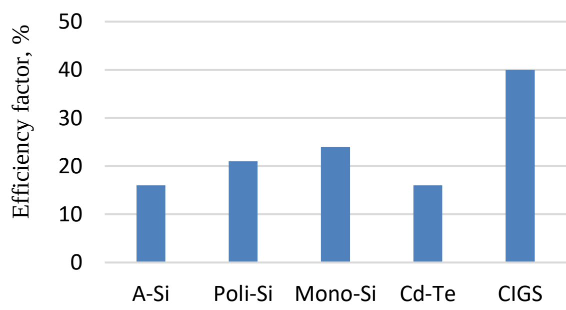


Figure 7: Efficiency factor of different semiconductor materials (Baiju, Yarema, 2022).

Amorphous silicon, thanks to thin-film technology, has raised the efficiency to 16%, and it is able to absorb even weak and diffuse light. The multidirectional arrangement of polycrystalline silicon crystals also maintains performance even when light conditions deteriorate. Monocrystalline silicon can give the highest energy yield, however, changing conditions such as temperature (high temperature) or position relative to the sun affects a significant reduction in efficiency. Cadmium telluride with average efficiencies is popular due to its low price. The most efficient and most expensive is rare earth copper-indium-gallium sulfide, which is only used in aerospace applications (Baiju, Yarema, 2022; Chatzipanagi, Jaeger-Waldau, Cleret de Langavant, Letout, Latunussa, Mountraki, Georgakaki, Ince, Kuokkanen, Shtjefni, 2022; Mustafa, Gomaa, Al-Dhaifallah, Rezk, 2020).

Other materials and technologies are also in development. But in this paper we consider the currently available ones for solar power plant design.

3.3 Economic situation in the country

Russia and Tatarstan, in particular, have large areas for solar energy development. The state supports clean generation despite a surplus of electricity generation in some regions of the country. There are benefits for producers and consumers of clean energy in accordance with Federal Law No. 42 of April 5, 2003. Also, solar generation can be very profitable under affordable conditions in some industries and remote communities as an autonomous source of energy (Guskov, Kolesnichenko, Korotkov, 2019).

3.4 Infrastructure

Tatarstan is one of the most developed regions in the country with a well-developed power grid infrastructure, which means that potential solar power plants can be connected to the grid in any region of the republic. However, the high level of gasification in the republic does not stimulate the development of solar energy.

Since the program of carbon footprint reduction is still relevant, there are prospects for solar generation both for the construction of new production facilities and for the private sector.

Tatarstan has long been using autonomous solar power plants to maintain road equipment (traffic lights, cameras) and street lighting. Since March 2021, microgeneration facilities have started to connect to the electric grid (Suslov, Doroshin, Kabanov, Pereverzev, 2023).

3.5 Risk identification and analysis

To make a decision on the development of solar energy in the Republic of Tatarstan we applied SWOT-analysis. At the first stage, strengths and weaknesses, opportunities and threats were identified (Fig. 8). For the objectivity of the analysis we used the Delphi method, which consists in expert evaluation of a group of people according to a questionnaire. It identified the items in the SWOT analysis and decision groups. The results are summarized in a new questionnaire and so on until complete consensus.

Taking into account the results of the study, the Delphi method was used to identify and assess the risks of solar energy construction projects.

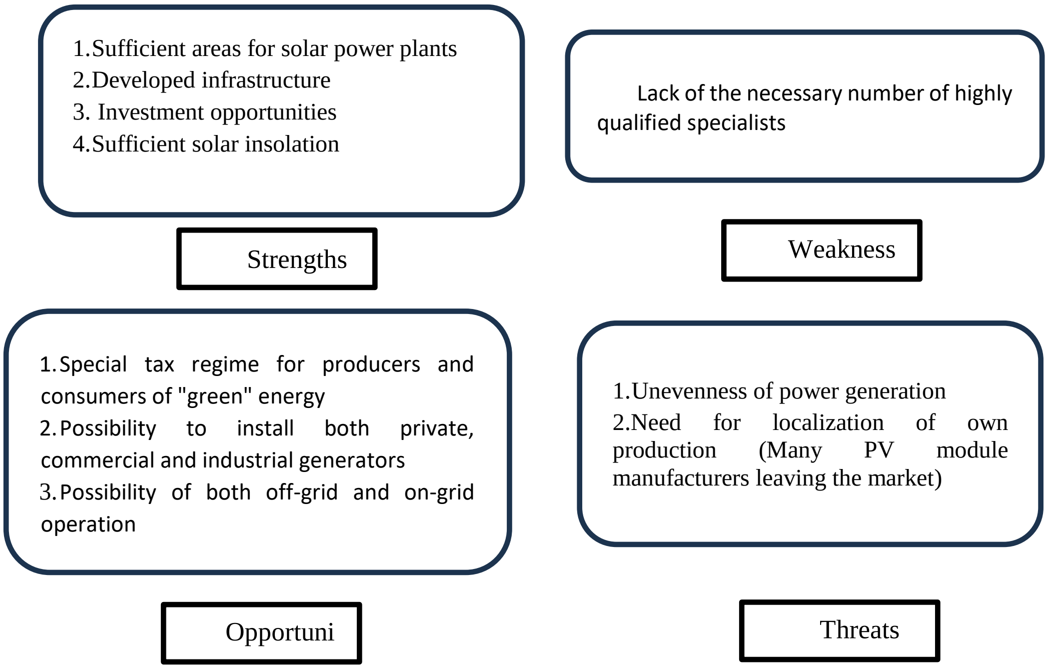


Figure 8: SWOT analysis.

The risk factors, degree of damage and probability obtained as a result of expert assessment are summarized in Table 4.

Table 4: Risk factors.

Risk factors	Probability/damage
Lack of the necessary number of highly qualified specialists	40%, low
Uneven power generation	70 %, high
Necessity to localize own production (Many PV module manufacturers leaving the market)	60 %, middle

Risk management opportunities obtained as a result of SWOT-analysis include: Training of specialists abroad and in Russia (opening new educational programs), necessity and possibility of development of autonomous stations, long-term guarantees from manufacturers of equipment components, localization of PV module production.

4 CONCLUSIONS

Insolation studies for the Republic of Tatarstan in general and for municipal districts in particular showed good values from March to August inclusive. A calculation of specific photovoltaic power output for a conventional crystalline silicon (C-Si) module, as the most common technology on the market of solar PV systems, was carried out. The results are given for Tatarstan by month, for districts - annual average value.

Factors affecting the development of solar energy and its assessment using SWOT-analysis were also considered.

SWOT analysis was used to assess the risks in planning the construction of solar generation facilities taking into account various factors, which showed the degree of damage and probability of these risks. Based on this assessment, the risk management opportunities are given.

The data obtained shows sufficient potential for realization of different level of solar power generation projects.

REFERENCES

Kou, G., Pamucar, D., Dinçer, H., Yüksel, S., 2023. From risks to rewards: A comprehensive guide to sustainable investment decisions in renewable energy using a hybrid facial expression-based fuzzy decision-making approach. Applied Soft Computing,Volume 142.

Strielkowski, W., Civín, L., Tarkhanova, E., Tvaronavičienė, M., Petrenko, Y., 2021. Renewable Energy in the Sustainable Development of Electrical Power Sector: A Review. Energies. 2021; 14(24):8240.

Wald, L., 2019. Basics in solar radiation at earth surface - revised version #2.

Global Solar Atlas. https://globalsolaratlas.info.

Torres, J., Petrakopoulou, F., 2022. A Closer Look at the Environmental Impact of Solar and Wind Energy. Glob Chall. 2022 Jun 22;6(8):2200016.

Betaenerdzhi. https://www.betaenergy.ru/company/

Platonova, E., Toropov, A., Tulikov, A., 2019. Simulation of Energy Input to Solar Panels. International Ural Conference on Electrical Power Engineering (UralCon), Chelyabinsk, Russia, 2019, pp. 133-137.

Kochmarev, K., Malozyomov, S., Kuznetsova, Y., Ignatev, I., 2020. Theory and practice of positioning a solar panel to obtain peak power points at weather stations. Journal of Physics: Conference Series. 1661, 012098.

Baiju, A., Yarema, M., 2022. Status and challenges of multi-junction solar cell technology. Frontiers in Energy Research. 10.

Chatzipanagi, A., Jaeger-Waldau, A., Cleret de Langavant, C., Letout, S., Latunussa, C., Mountraki, A., Georgakaki, A., Ince, E., Kuokkanen, A. and Shtjefni, D., 2022. Clean Energy Technology Observatory: Photovoltaics in the European Union – 2022 Status Report on Technology Development, Trends, Value Chains and Markets, Publications Office of the European Union, Luxembourg.

Mustafa, R., Gomaa, M., Al-Dhaifallah, M., Rezk, H., 2020. Environmental Impacts on the Performance of Solar Photovoltaic Systems. Sustainability. 2020; 12(2):608.

Guskov, V., Kolesnichenko, I., Korotkov, K., 2019. Investigation of the effect of heating solar modules on the efficiency of radiation conversion. Izvestiya SPbGETU "LETI", No. 1, pp 10-16.

Suslov, A., Doroshin, V., Kabanov, D., Pereverzev, A., 2023 Analysis of the development of solar energy in Russia. Energy policy.

A place in the sun: a Tatarstan family saves on electricity with the help of solar panels. 28.03.2022.https://m.realnoevremya.ru/articles/245399-kak-tatarstanskaya-semya-ekonomit-elektrichestvo-s-pomoschyu-solnechnyh-batarey

Aylin, A., Ali Ç., Dağdeviren, M.. 2018. An integrated model using SWOT analysis and Hesitant fuzzy linguistic term set for evaluation occupational safety risks in life cycle of wind turbine. Safety Science, Volume 106,2018, pp. 184-190.

Development of a Software Solution for Scheduling for Individual Learning Trajectory

Shestakova A.O.[a], Sbrodov S.O.[b] and Glukhikh I.N.[c]
Tyumen State University, 6 Volodarsky str., Tyumen, 625003, Russia
a.o.shestakova@utmn.ru

Keywords: Schedule, efficiency, constraints, requirements, genetic algorithm, scheduling, artificial intelligence, module, Telegram bot, website, neural network.

Abstract: This paper deals with the actual problem of creating efficient schedules in various spheres of human activity such as education and transportation. The difficulties in creating optimal schedules are related to a variety of constraints, requirements and constantly changing conditions. The paper discusses the main problems associated with scheduling and proposes approaches and methods to solve them using modern technologies and artificial intelligence techniques. A developed module for integration with an educational institution and a Telegram bot for scheduling classes are presented. The process of generating schedules based on the entered information about students, classes, time and location is described. A genetic algorithm was used to minimize the target function considering all requirements. Plans for further development are presented, including the creation of a website for constraint and requirement selection, the development of a neural network to evaluate the quality of the generated options, and the creation of a mobile version for user-friendliness. Tests of the program on data from Tyumen State University were conducted, showing its potential for efficient schedule creation.

1 INTRODUCTION

In today's world, one of the key management and organizational challenges is to produce efficient schedules that optimally allocate resources and take into account a variety of constraints and requirements. Despite significant technological breakthroughs and availability of computational resources, the task of scheduling remains relevant and challenging, especially in the context of today's dynamically changing environments and requirements (Brucker, Knust, 2000; Baker, 1974).

The practical importance of developing optimal schedules is enormous, as they are applied in various spheres of human activity. For example, in the educational sphere, an effective schedule can ensure optimal utilization of teaching time and resources, improving the quality of learning and the satisfaction of students and teachers (Pinedo, 2016). In the transportation domain, a well-planned schedule can reduce delays and congestion, optimizing vehicle utilization and improving service quality (Graham, Lawler, Lenstra, Rinnooy Kan, 1979.).

However, creating effective schedules faces a number of challenges, including a large number of schedule options, a variety of constraints and requirements, and the need to accommodate changing conditions and preferences (Blazewicz, Lenstra, Rinnooy Kan, 1983).

In this paper, we discuss the main problems associated with scheduling and propose approaches and methods to solve them using modern technologies and artificial intelligence techniques.

2 RESEARCH METHODOLOGY

The generation of efficient schedules is a key task in management and organization, which requires optimal resource allocation and consideration of

[a] https://orcid.org/0000-0003-4779-4285
[b] https://orcid.org/ 0009-0006-3120-5780
[c] https://orcid.org/0000-0002-0683-6138

various constraints and requirements. Despite significant technological advances and availability of computational resources, the task of scheduling remains challenging (Li, Aloulou, 2020), especially in today's dynamically changing environment and requirements.

The practical significance of developing optimal schedules is extensive as they are applied in various fields of human activities including healthcare (Belmeziti, Benyettou, Boukachour, 2019), education (Li, Wang, He, Zhu, 2019; Klašnja-Milićević, Vesin, Ivanović, Budimac, Jain, 2018), transportation, manufacturing, and others (Ibrahim, Elkateeb, Ahmed, Kowalczyk, 2018). An efficient schedule promotes optimal utilization of resources and time, improving efficiency and quality of services.

However, creating efficient schedules faces a number of challenges such as a huge number of schedule options, diverse constraints and requirements, and changing conditions and preferences. Thus, it is necessary to solve an optimization problem with constraints involves determining the target function to be minimized or maximized and the set of constraints to be satisfied. For the posed problem domain, the target function f(x) determines the degree of satisfaction of the planning objectives and includes various factors: task completion time, resource cost, space selection, daily load constraint, etc.

Constraints that must be satisfied in scheduling tasks include:

Resource constraints - the amount of time, personnel, equipment, etc., and total resource utilization should not exceed available resources.

Time constraints - the time available for the activity, as well as the time to accomplish the activity.

Dependency constraints - the performance or execution of an activity depending on the status of another, related activity.

Quality constraints - measurable value of quality indicators of resources.

The formalization of this problem in the form of an optimization problem can look as follows:

$$\min f(x), \tag{1}$$

under the conditions:

$$\begin{aligned} g_i(x) &\le 0, \qquad i = 1, 2, \dots, k \\ h_j(x) &= 0, \qquad j = 1, 2, \dots, l, \end{aligned} \tag{2}$$

where:

- x – vector of variables that represents resource and time allocation.
- f(x) – the target function to minimize.
- $g_i(x)$ – resource and time constraint functions.
- $h_j(x)$ – dependency and quality constraint functions.

To solve this problem 2 variants of solution were used: using genetic algorithm and annealing method.

2.1 Genetic Algorithm

Genetic algorithm (Goldberg, 1989) is a heuristic optimization method inspired by the processes of biological evolution. It utilizes the mechanisms of natural selection and genetics to find optimal solutions in the search space. The algorithm is based on the idea that a population of solutions evolves towards more suitable solutions by applying genetic operators such as crossbreeding, mutation and selection.

The main steps of the genetic algorithm are:

1. Initialization of the population.
2. evaluation of adaptability.
3. Selection of parents
4. Inbreeding.
5. Mutation.
6. Replacement of a population.
7. Estimation of the stopping condition.

An initial population of solutions is generated using heuristic methods with the substitution of the first matching parameters. Such a set of parameters called genes that form the genotype. Each solution from the population is evaluated using a target function. Solutions from the current population are selected for crossbreeding based on their fitness. The selected parents are crossed to create offspring. This process involves combining genes from both parents to create a new solution. Some genes in the offspring undergo mutations that allow for random changes in the genotype. The new offspring replaces a portion of the old population depending on the performance of the target function. The algorithm continues to run until some stopping condition is met: reaching the maximum number of generations or reaching the desired value of the target function.

2.2 Annealing Algorithm

The annealing algorithm (Kirkpatrick, Gelatt Jr, Vecchi, 1983) is an optimization method that is inspired by the annealing process of metals in metallurgy. In the context of optimization, the annealing algorithm is applied to solve the problem of finding the global minimum (or maximum) of a target function in the state space. The search process starts from some initial state, and then the algorithm gradually explores the neighboring states and decides to move to a new state based on certain probabilistic criteria.

The main stages of the annealing algorithm:

1. Initialization.
2. Energy estimation.
3. Iterative process.
4. Temperature reduction.
5. Stopping the criterion.

The initial state of the system is set randomly. Then the energy of the current state of the system is estimated using the target function to be optimized. After the estimation, an iterative state search process takes place: selecting a random neighboring state, making a transition decision, and updating the state.

The current state is changed by applying some random operation, such as moving to a neighboring point in the state space. Next, the energy of the new state is calculated using the target function. The decision whether the system stays in the new state or returns to the previous state is made based on a probabilistic criterion that depends on the change in energy and the current temperature of the system. If the decision to transition is made, the current state of the system is updated with the new state.

As time passes, the temperature of the system decreases, which corresponds to the cooling process in the physical analog. This is done in order to reduce the probability of accepting transitions with increasing iterations, allowing the algorithm to focus on finding the optimal solution. The algorithm terminates when a certain stopping criterion is met: when the maximum number of iterations is reached or when the required optimization accuracy is reached.

3 RESULTS

A module for possible integration with an educational institution and a Telegram bot for scheduling classes were developed. The application takes as input information about students, class, time and location. Then the program generates an initial set of schedules satisfying the user's requirements.

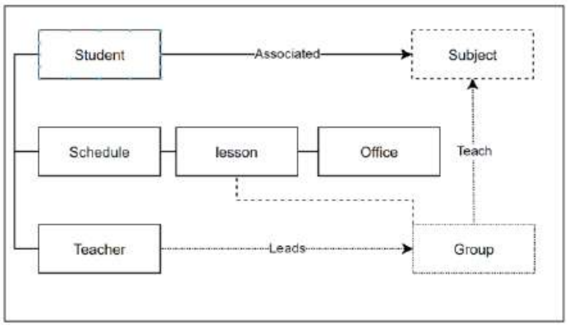


Figure 1: Simplified ER diagram.

The requirements are listed in Table 1, where each requirement is assigned a weight.

Table 1: Requirements.

Condition	Value	Weight (w)
time spent per day going between buildings	integer [0, +∞)	2/2*k
more than four pairs on the same day	True / False [0, 1]	10/10*k
there's a window between classes	True / False [0, 1]	30/30*k
there's not a day in the week without couples	True / False [0, 1]	40
more than two couples on Saturday	True / False [0, 1]	20*k

The goal function is to minimize f(x) given all the requirements. Testing the genetic algorithm and the annealing algorithm on simplified data it is decided to use the genetic algorithm. The justification of this decision is a lower value of the target function taking into account the increase of the program duration.

For each constructed variant the value of the target function is determined, then five variants with the lowest value of the target function are selected and crossed among themselves. Five variants with the lowest value of the target function are selected from the crossed variants, as well as parent variants. These variants become the parent variants. Iterations are repeated until the limit on the number of generations is reached or until the target function is zero. The user is offered to choose the most suitable variant, which will be generated and uploaded to a JSON file. An example of filling such a file is shown in Figure 2.

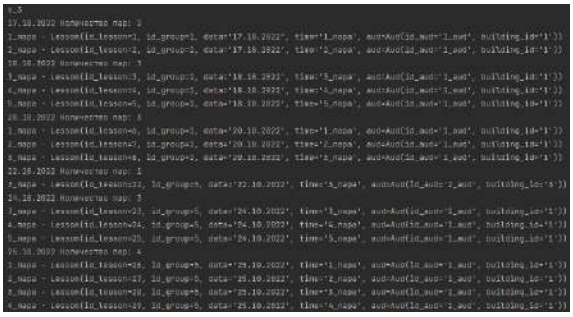


Figure 2: Example of filling such a file.

To test the scalability of the program, a Telegram bot was created. In it, users are divided into two categories: students and teachers. A special link is created to unite students into groups. Teachers enter initial data for schedule generation. Users define a convenient time for them to hold a class, the program correlates time cells and generates a schedule.

4 DISCUSSIONS

In the future, it is envisioned to develop a web site where the user can select constraints and requirements for creating a schedule from a suggested list with the ability to filter and rank them by importance. The web site assumes the possibility of integration into social networks. A standalone mobile version is envisioned for user convenience.

To improve the quality of the proposed options, it is proposed to develop a neural network to assess the quality of the generated options and adjust the weights depending on the user's choice.

5 CONCLUSIONS

Two algorithms for scheduling individual educational trajectories were written: genetic algorithm and annealing method. Having compared two methods for scheduling, it was decided to use the genetic algorithm, which had a disadvantage in the form of speed of operation and had a closer value of the target function to the desired value. The written program forms JSON file with ready schedule on the basis of initial data. The program is implemented as a module to connect to the university API, an important criterion of which is compliance with the pre-formatted format, and as a Telegram bot.

The developed program was tested on the provided data of Tyumen State University. Due to the limitation of the technical characteristics of the system used, a restriction on the number of generations equal to 150 was introduced. At the first stage of schedule creation 20 unique variants were created. The process of creating a schedule for one semester for five academic groups of the university took 7 minutes.

ACKNOWLEDGEMENTS

If any, should be placed before the references section without numbering.

REFERENCES

Brucker, P., Knust, S., 2000. Complexity results for simple assembly line balancing and simple sequencing problems.

Baker, K. R., 1974. Introduction to sequencing and scheduling.

Pinedo, M., 2016. Scheduling: Theory, algorithms, and systems.

Graham, R. L., Lawler, E. L., Lenstra, J. K., Rinnooy Kan, A. H., 1979. Optimization and approximation in deterministic sequencing and scheduling: A survey.

Blazewicz, J., Lenstra, J. K., Rinnooy Kan, A. H. G., 1983. Scheduling subject to resource constraints: Classification and complexity

Li, R., Aloulou, W., 2020. A personalized approach for solving the nurse rostering problem. *Computers & Operations Research*, 104, 104974.

Belmeziti, F., Benyettou, A., Boukachour, J., 2019. A personalized genetic algorithm for nurse scheduling problem. *Journal of Healthcare Engineering*.

Li, W., Wang, J., He, Y., Zhu, J. , 2019. Personalized course scheduling for universities using modified genetic algorithm. *Computers & Industrial Engineering*, 127, 568-578.

Klašnja-Milićević, A., Vesin, B., Ivanović, M., Budimac, Z., Jain, L. C., 2018. Personalized university course timetabling using a genetic algorithm. *Information Sciences*, 450, 185-200.

Ibrahim, R., Elkateeb, A., Ahmed, N. M., Kowalczyk, R., 2018. Personalized learning path generation for adaptive educational hypermedia systems. *Computers in Human Behavior*, 85, 10-22.

Goldberg, D. E., 1989. Genetic algorithms in search, optimization, and machine learning. Addison-Wesley.

Kirkpatrick, S., Gelatt Jr, C. D., Vecchi, M. P., 1983. *Optimization by simulated annealing. science,* 220(4598), 671-680

The Role of Cinema in Creating a Tourist Atmosphere and Promoting Historical and Cultural Heritage Objects of Tatarstan

Sattarova Adelya Ilhamovna[1] and Kadyrov Ramil Vasilievich[2]
Kazan (Volga Region) Federal University, Kazan, Russian Federation
satadel@inbox.ru, kind2002@mail.ru

Keywords: destination, film industry, historical and cultural heritage, movie tourism, filming location, tourism, promotion.

Abstract: Cinematic tourism is a relatively new direction in tourism and is very popular in many countries. In cities where cinematic tourism is well developed, we can notice that the interest of tourists increases after the first excursions in a particular location, and the profit from new tourist flows significantly increases. In Tatarstan, there are no actively promoted cinema tours by local travel agencies. However, having analyzed numerous films shot in the territory of Tatarstan, it can be assumed that a cinema tour would be popular because it would be a new tourist product. The Republic of Tatarstan has significant resource potential for developing such a relatively new form of cultural and educational tourism as cinematic tourism here. The article, using the example of famous films of the Republic of Tatarstan, analyzes the prospects for the development of film tourism as a journey into the world of culture and traditions of the Tatar people.

1 INTRODUCTION

The end of the XX - beginning of the XXI centuries became important stages in the formation of a new type of tourism, which was fixed under the name of “cinema tourism”. Unfortunately, for Russia, this type of tourism is still at the initial stage of its development. The love of Russians for domestic films opens up certain prospects for development. Moreover, the rich history of Soviet and Russian cinema can potentially become one of the factors for the development of domestic tourism.

An important factor for modern tourism has become people's desire for cultural and civilizational identification, connection with the history of their ancestors, and studying culture within the global system of coordinates (Abdel Wahed, 2021). And the cinema industry is also very close to the theme of dialogue between cultures, peoples, and civilizations.

Movies are an integral part of our society and are easily accessible compared to other sources of information. Movies can influence the viewer and his choice of travel destinations. Sources of information may vary from advertising sources to recommendations from friends and family.

The place and setting of a film affects how viewers perceive a potential tourist destination. The influence of a film on a viewer depends on several factors such as the importance of the location in the plot line and duration. Most viewers tend to believe that a fictional story is a real event when watching a film (Spears, Josiam, Kinley, Pookulangara, 2013).

Films that showcase a country, its regions and territories, as well as cities, are viewed by millions of viewers. Such a display can be a good advertisement, the results of which are usually not achievable through traditional tourist campaigns.

People who are eager to watch movies and are actively interested in the film industry are more likely to participate in promoting tourist destinations.

An important role in promoting cinematic tourism can be played by television series, which are sometimes more popular than feature films. The involvement of TV series viewers is usually higher because more people watch TV than go to the cinema and follow the latest news in the film industry. An example of a successful television series is the project "The Magnificent Century," which was filmed in

[1] http://orcid.org/0000-0003-1060-3393
[2] http://orcid.org/0000-0003-2238-2604

Istanbul. Istanbul is very popular among tourists. Consequently, motivation and perception of the destination are constantly strengthened.

Television series are often watched on a regular basis, so viewers are more likely to be exposed to the target image over a longer period of time. Thus, such plots increase the viewers' motivation for travel.

2 RESEARCH METHODOLOGY

The topic of «cinema tourism» is quite popular in the academic community, but all materials are sometimes descriptive and analytical, telling about the problems and perspectives of cinema tourism development in the world.

To understand the significance of developing such a type of tourism, it is necessary to delve deeper into the history of cinema. One of the main sources on the history of cinema is Georges Sadoul's book «General History of Cinema» (Butenko, Berkasova, 2021). In this edition, for the first time, an attempt is made to consider the history of cinema art as the history of the collective labor of film workers from all over the world.

To explore the prospects for the development of cinema tourism, it was necessary to refer to the current state of the tourism industry in Russia. The development of tourism in the context of international sanctions is considered in the work of E. A. M. Abdul Wahed «Development of Tourism in Russia in the Context of International Sanctions and Their Reflection in the Media» (Abdel Wahed, 2021), Tourism is considered an important component of national economic growth, and the introduction of sanctions against Russia in 2014 led to structural changes and a change in the direction of tourist flows.

In the article by M. S. Barsov and I. F. Ignatieva «Prospects for the Development of Cinema Tourism», the film industry is presented as one of the leading elements of modern culture and its wide potential for economic promotion of various brands. The depth of the film industry in terms of spectacle and impact on human feelings and emotions generates interest and motivation for consuming a product or service (Udeneieva, 2019).

In the scientific research by N. V. Udeneeva and A. I. Saiedzh, modern trends in the development of global cinema tourism have been studied. The study notes the favorable role of movie fans clubs in the development of cinema tourism (Sadoul, 1958). In the article by L. F. Habibullina and L. L. Stepanova, South Korea is considered as a promising destination for the development of cinema tourism. In the article, factors are analyzed that prove that the country becomes a promising destination in the field of international cinema tourism due to increased interest in the Korean film industry around the world (Kabibullina, Stepanova, 2020).

Several studies are devoted to the history of the development of cinema tourism in Russia. The study by E. A. Petrov is devoted to the analysis of cinema tourism as a promising direction in the tourism industry, the author raises the question of the problems in forming such tours by tour operators. The author notes that the problem with popularizing this type of tourism in Russia lies in the insufficient number of special places to attract tourists, as well as the fact that many places cannot claim to be «exotic» and the insufficient popularity of Russian cinema on the international arena (Petrova, 2019).

In the work of D. A. Garbuz and A. Yu. Anokhin «Cinema Tourism as a Technology for Improving the Tourist Attractiveness of the Region», the results of an analysis of the tourist product in the field of cinema tourism formed in Russia, as well as the results of an analysis of filming in the Kaliningrad region by shooting dates and genres, are presented (Garbuz, Anokhin, 2020).

In the article by V. V. Anisimova and I. A. Romanov «Cinema Tourism in Russia: Concepts: Trends and Problems» issues related to the theoretical definition of this type of tourism are considered, trends and problems are revealed, and solutions to these problems will allow achieving effective results (Anisimova, Romanova, 2020). In the study by O. V. Virrt «Cinema Tourism in Russia» (Virt, 2016) it is noted that cinematic tourism can become one of the popular types of cultural and educational tourism, where a potential tourist can independently form a route and other details of the journey, taking into account their interests and capabilities.

In the scientific work by O. P. Butenko and L. V. Berkasova, cinematic tourism in St. Petersburg is considered. The authors note that St. Petersburg can rightfully be considered the center of Russian cinematic tourism, since the first cinema session was organized here in 1896. Also, filmmakers are attracted by the rich historical layer of attractions concentrated in St. Petersburg (Butenko, Berkasova, 2021).

The problem of using the potential of Russian cities is noted in the article by Yu. V. Preobrazhensky «Formation of literary and cinematographic chronotopes of cities for the purposes of tourism development» where the author notes the need for systematic and intellectual work to identify special artistic chronotopes within Russian cities (Preobrazhensky, 2019).

The review of modern scientific research shows that the topic of cinema tourism is very topical in the modern world and the potential of Russian history is quite high for the formation and organization of such programs within domestic and inbound tourism.

3 RESEARCH RESULTS

3.1 Analysis of the potential of Tatar cinema for the formation of cinema tours

Kazan, being the capital of the Republic of Tatarstan, has a rich multicentury history, amazing nature, architecture, and unique cultural heritage. Therefore, Kazan attracts many directors with its perfect location.

Many famous movies have been filmed both in Kazan and in Tatarstan. Among them:

1. «Blue Bird» (2009) is a movie filmed in Kazan and Sviyazhsk. It tells the story of love between art historian Svetlana Kolina and artist Gennady Arkhireyev.

2. «Emergency» (2002) was filmed entirely in the capital of Tatarstan, Kazan. The most recognizable moment in the film is the night Kremlin, against which an ambulance crew passes by. The multi-part film is dedicated to the daily life of Kazan doctors.

3. The eight-episode series «Zuleikha Opens Her Eyes» (2018) was filmed both in Kazan and Laishevo. The old mosque from the village of Maskara, Kukmorsky district of Tatarstan, was also filmed in the movie. The scene in the abandoned mosque, where the dekulakized people spend the night, was also filmed in Tatarstan, in the village of Maskara, Kukmorsky district. In the frame, you can also see the main building of Kazan University, Kazan Kremlin and the streets of Kazan. The leading role was played by the famous actress Chulpan Khamatova. The premiere of the film took place on October 20, 2020.

4. «Middle-aged Woman» (2014) used locations in Kazan such as School № 39, a restaurant, and the courtyard of a house on Karl Marx Street. The rocky shore of the Kamskoye Ustye in the village of Shuran, Laishevsky district, according to the director's idea, turned into the sea shore.

5. «Real Fairy Tale» (2011). Locations for filming were the «Vamin House», the building of the Central Office of the State Traffic Inspectorate of Tatarstan on the Orenburg Highway. In addition, the views of Kazan Kremlin, Park Kyraly, Bauman Street, Bulak embankment and the picturesque view at the entrance to the island of Sviyazhsk appeared in the frame.

6. The text «The Best Day» (2015) about the shooting of a karaoke comedy directed by Georgy Rodionov, who also turned to the help of Kazan residents, about the flash mob in 2015 when locals broke the record for the largest karaoke, about the participation of the finalist of «The Voice», Honored Artist of Tatarstan Elmira Kalimullina, and about how in the same year Kazan residents together with the whole country could appreciate the released film «The Best Day» with Dmitry Nagiyev in the lead role.

7. «Treasures of Lake Kaban» (2013) is an attempt to rethink the legend of the treasures of Lake Kaban. The film shows views of the Kamal Theater, Suyumbike Tower, Kazan Kremlin, and Lake Kaban.

Thus, we see that the most popular locations were the territories of the Kamsko-Ustyinsky district, the embankment of Lake Kaban, Kazan Kremlin, and others, while among the historical and cultural heritage of the region, the locations of the Kukmorsky district and the Laishevsky district aroused the greatest interest from filmmakers.

3.2 Research on the demand for cinema tours in Tatarstan

To determine the level of demand for a cinema tour in the Republic of Tatarstan, we conducted a study in which 115 respondents participated.

The research period was March-April 2024.

An online survey was conducted using a questionnaire consisting of 9 questions.

The results showed that cinema tourism aroused great interest among women. The ratio of male and female respondents was 20% to 80%.

In the next question, respondents were asked to choose a film or series from the listed ones that they had watched. Most of the respondents answered that they had not watched any of the mentioned films or series, namely 63.8% of the people. Among the options were the following: «Zuleikha Opens Her Eyes», «Blue Bird», «Emergency», «Middle-aged Woman», «Real Fairy Tale», «Baygal», «Treasures of Lake Kaban». Nevertheless, 31.9% of people watched the series «Zuleikha Opens Her Eyes».

When asked which of these films they liked the most, many answered nothing from the list. However, 24.1% said they liked the series «Zuleikha Opens Her Eyes». The least number of votes received the film «Middle-aged Woman».

Many in the cinema tour are attracted:

- the opportunity to walk around filming locations and see the film sites with their own eyes (71 person);

- the opportunity to experience the history of the film (24 people);

- The opportunity to feel like a hero (20 people);

However, it is worth noting that there are those who claim they do not know what a film tour is. This fact provides strong reasons to inform tourists about the fact that tourism now includes a new direction, known as «filmtourism», with the opportunity to purchase tours at filming locations.

It is important to note that most who traveled through Tatarstan found their trip enjoyable and have a desire to return again.

Based on the research conducted, we can hypothesize that the creation of a film tour in the Republic of Tatarstan could be a desirable venture. However, comprehensive work should be undertaken to develop film tourism in the region due to potential tourists not having enough knowledge about Russian films or the concept of «filmtourism».

3.3 Interconnection of historical and cultural sites, natural landscape, and movie plot in the formation of tourist spaces attractiveness

In recent years, the most popular TV series for cinema viewers in Tatarstan and other regions of Russia have been «Zuleikha» based on the play by Gaiaz Iskhaki (2005), and «Zuleikha Opens Her Eyes» (2019) based on the novel by Guzel Yahina. Both TV series tell the story of a tough life of a Tatar Muslim woman named Zuleikha who loses her husband and children and is forced to marry again. Finding herself on the verge of life and death, she does not give up thanks to her strong willpower and personal convictions.

The filming of the first movie took place in several districts of Tatarstan, including Chistopolsky, Tyulachinsky, Askubaevsky, Pestrechny, as well as in Kazan and the Republic of Chuvash.

The second movie was shot in the Kukmorsky and Laishevsky districts (the coast of Kamya), in the center of the city of Kazan, and in the ethnographic museum «Tatarian Village» under the open sky.

Many objects of historical and cultural heritage of Tatarstan and famous tourist locations were covered in the film for shooting:

Kremlin Street and May 1st Square. At these places, near the Spasskaya Tower of the Kazan Kremlin, they filmed the largest scenes of the film - the market and revolutionary theater. It was here, at the old square, that Zuleikha came together with the families of other dekulakized peasants. To make the scenes look atmospheric, they brought a ton of snow to the walls of the Kremlin and closed the road for several days.

Kazan Kremlin. In the basement of the Kazan Kremlin, they recreated a prison for filming, where Zuleikha and Professor Leibe waited their turn in one cell. From there, the characters went to hard labor in Siberia.

Building of Kazan Federal University.

In the series, the town of Kazan University in the XIX century was presented, near which the battles of the Civil War took place.

The building of the officers' assembly on Freedom Square was used for filming a scene with Nastya and Kuznetsov. In addition, on Freedom Square, there is the House of the Government of Tatarstan, the opera and ballet theater, and the majestic building of the Noble Assembly of the XIX century.

Black Lake. In the frames of the series, the window of the prison where one of the heroes was sitting looked out precisely at the lake located in this park.

Old Tatar settlement. In the historic quarter of Kazan, near the Marjani mosque, there is the very house in which, according to the plot, Yuusuf, the son of Zuleikha, settled with his family after moving to Kazan. Scenes shot in this authentic and picturesque place in Kazan conclude the final episode of the film. It was here, upon returning from Leningrad, that Yuusuf, the son of Zuleikha, settled.

Open-air ethnographic museum «Tatar village» (Isakovo, Zelenodolsky district) became the image of the Yubash village in the series, where the life and everyday life of a Tatar village, as well as ethnographic traditions, national cuisine, and crafts are recreated. This is Zuleikha's native village, where the action of the novel begins.

Sermuk settlement, built near the city of Laishovo under Kazan. It was here that the most interesting scenes taking place with the characters of the film in Siberia on the Angara River were filmed. Here are the wooden houses of settlers, a club building decorated with Soviet posters, and high water towers. Located at the edge of the forest right on the bank of the mighty Kama, they resemble lighthouses pointing the way for ship captains.

To make tours to the filming locations of «Zuleikha» and «Zuleikha Opens Her Eyes» popular, it is first necessary to draw tourists' attention to watching these films. When developing a tour, we believe that potential tourists should be involved in the history, way of life, and culture of Tatarstan through event tourism. For example, the annual national holiday «Sabantuy» can be taken as an example, which is celebrated on a large scale simultaneously at several venues in Kazan. During this celebration, it is possible to organize a film screening or help promote cinematic tours. Consequently, a potential tourist will fully immerse themselves in the culture and history of the Tatar people, want to watch the series «Zuleikha» and «Zuleikha Opens Her Eyes» and possibly purchase tours to the filming locations.

Thus, the proposed activities will contribute to attracting and engaging potential tourists in watching Tatar cinema and purchasing cinematic tours.

4 DISCUSSION OF RESULTS

As the main advantages of developing cinematourism within the Republic of Tatarstan, the following points can be identified:

1. Beautiful architecture of the city;
2. On the territory of Tatarstan, different nations live with their own traditions, customs, and culture, their combination in a certain sense is unique. This is serious advantage of developing cinematourism in the Republic of Tatarstan;
3. City residents themselves explore Kazan, because the city changes very quickly;
4. Living pulse of time, the fusion of ancient and modern city;
5. The intersection of Muslim and Christian religions.

The history of the Tatar nation can be brought to the world stage by emphasizing its connection with other well-known cultures. The problem is that representatives of Tatar culture often overlook this aspect.

The architecture of the streets and locations of Kazan is diverse. There are many historical and industrial heritage sites in the capital of Tatarstan, which can also become valuable filming locations.

Currently, individual industrial heritage buildings, with the support of entrepreneurs, have been converted into loft spaces where exhibitions, theatrical performances, bikers, creative youth, and tourists gather.

We believe that overall, the prospects for the development of cinematourism in the Republic of Tatarstan are positive. However, it is necessary to carry out a whole range of measures for its development.

To develop cinematic tourism in the Republic of Tatarstan, it is proposed to create a comprehensive program within the framework of event tourism, form and implement new tourist products, as well as create conditions for the development of new cinematic tourism products, taking into account the historical and ethnocultural features of the city and the originality of its culture. First and foremost, to develop cinematic tourism, one should develop cinema itself.

At present, as it seems to us, the attempt made by us to develop a movie route based on Guzel Yahina's novel «Zuleikha Opens Her Eyes» and the eponymous film is one of the most likely options for launching such a direction as cinematic tourism in the Republic of Tatarstan. One of the reasons is that the shooting of this series gave the town of Laishevo an object of material heritage - the film's decorations. The settlement Semyrok on the Angara River, where the novel's dekulakized characters were exiled, was built on the picturesque bank of the Kama River, at the site of an abandoned quarry. After the filming, the decorations were not dismantled, leaving the town with a new landmark. Now travelers and local residents come here to see the filming location.

However, «Semyrok» village is popular only for a single visit. In order for the place to become a tourist destination, it lacks historical spirit: the design, facade should remind of the distant past. These buildings should convey the feelings of that era described in the work. Since Tatarstan has a rich ancient history, the history of culture is not isolated in itself, but has a close connection with world cultures, uniting West and East. Initially, there was no intention for tourists to visit «Semyrok», since the place does not breathe culture and does not reveal the Tatar spirit. However, after the filming of the film, tourists began to be interested in this place more and more. And in order to attract more tourists at this stage and turn this place into a destination, we propose to carry out a number of activities:

1. To build a cafe with Tatar cuisine in order to attract tourists.
2. To expand the territory so that there is an imitation of the railway to Siberia, along which Zuleikha went to Siberia.
3. To decorate houses with ornaments of Tatar culture (the shape of a tulip, etc.).
4. To conduct a marketing campaign using the beach as an attraction tool, because tourism is primarily associated with recreation, but recreation must not only relax, but also enlighten with history, culture, and cuisine. If there is a complex like «Semyrok» nearby, it will have to be improved, since it is like raw dough from which you can make a decent product for tourists.

5. To hold master classes on how to bake triangles, chak-chak, gubadia, and other similar dishes within the complex.

6. To organize a festival of Tatar dances, in which tourists can participate.

7. To build a mini-hotel with a bathhouse and sauna within the complex, which would resemble the barracks from the series, where visitors could stay for a modest fee for a week, with the same rules, food, and mandatory work up to 3 hours a day.

8. To form a general style of Russian cinema, adhering to the idea that in order to develop cinematic tourism, it is necessary to develop the film industry and shoot high-quality films. The plots of Tatar cinematography are saturated with the idea of the value of family. This idea can also be traced in the TV series «Zuleikha Opens Her Eyes» in which the main character «Zuleikha» waits for her husband until the very end, etc.

5 CONCLUSIONS

In conclusion, based on the results of the conducted research, we can draw the following conclusions.

First of all, when studying the experience of developing cinematic tourism, it is worth noting that modern cinema is turning into an element of global cultural communication. In many countries (USA, India, France, etc.), cinematic tourism is actively developing, there are numerous movie tours offered by local tourist companies, which enjoy special popularity.

Secondly, the development of Tatarstan's cinema has its own peculiarities. It develops through the prism of history and the authenticity of Tatar culture. For this, Tatarstan really has everything it needs - a thousand-year history, a rich culture, unique traditions and way of life, kind people from the countryside, and beautiful nature.

Thirdly, in Russia there are many filming locations, however, the sphere of cinematic tourism is, unfortunately, underdeveloped. This is due insufficient popularity of domestic films abroad.

The development of cinematic tourism in the regions of Russia can become a positive element in promoting their image. For example, for the Republic of Tatarstan, as a national region of Russia, the goals of developing such tourism may include the following prospects:

- Introduce Russian tourists to the history, culture of the Tatar people, traditions and way of life of Tatars;
- Expand the perception of tourists about cinema and culture of the Republic of Tatarstan;
- Ensure the promotion of a positive image of the Republic of Tatarstan.

Thus, in order for not only cinematic tourism, but tourism as a whole to receive a boost towards dynamic development, it is necessary for the state to act as a coordinator in the development of tourism infrastructure. A balance must be found between the demand for tourist services and existing supply, as well as ensuring the necessary infrastructure, transport accessibility to objects of tourist interest, and guaranteeing the proper quality of services.

REFERENCES

Abdel Wahed, E.A.M., 2021. Tourism Development in Russia under International Sanctions and their Reflection in the Media. *Service in Russia and abroad.* T. 15. № 2 (94). C. 57-65.

Anisimova, V.V., Romanova, I.A., 2020. Cinematic tourism in Russia: concepts, trends, and problems. *Scientific Notes of the Vernadsky Crimean Federal University. Geography.* Geology. 2020. T. 6. № 2. C. 20-29.

Barsow, M.S., Ignatieva, I.F., 2020. Film Tourism Development Prospects. *Youth tourism in Russia: resources, trends, prospects. Saint Petersburg.* C. 275-281.

Butenko, O.P, Berkasova, L.V., 2021. Cinematic Tourism in St. Petersburg. Trends and Problems in the Development of the Tourism and Hospitality Industry. Ryazan, C. 32-34.

Virt, O.V., 2016. Cinematic Tourism in Russia. Youth. Science, Society. 270-272.

Garbuz, D.A., Anokhin, A.Yu., 2020. Cinematic Tourism as a Technology for Increasing Tourist Attractiveness of the Region. Tourist and Recreational Potential and Peculiarities of Tourism and Service Development. Kaliningrad, C. 49-58.

Kinopoisk. All the movies of the planet. [Electronic resource] - Access mode: https://www.kinopoisk.ru/ (date of reference: 15.04.2024).

Petrova, E.A., 2019. Cinematic Tourism as a Perspective Direction for the Development of the Tourist Market. *The Power of Systems*. № 1. C. 11-13.

Preobrazhensky, Y.V., 2019. Formation of literary and cinematic chronotopes of cities for the purposes of tourism development. *Geography and Tourism.* 2. C. 86-90.

Sadoul, J., 1958. The Universal History of Cinema 1832-1897. Pioneers of Cinema (from Melies to Pathe). 1897-1909. Volume 1. Invention of Cinema. – 644 c.

Udeneieva, N.V., 2019. Some Aspects of the Development of Global Cinematic Tourism. *Scientific Bulletin МГИИТ* №5 (61). C. 24 – 32.

Kabibullina, L.F., Stepanova, L.L., 2020. South Korea as a Promising Direction for Cinematic Tourism. *Modern Oriental Studies.* Т. 2. № 3. С. 84-90.

Bunakov, O.A., Eidelman, B.M., Terehina, Y.V., Kadyrov, R.V., 2019. Improving industrial tourism in the republic of Tatarstan through historical and industrial heritage: An investigation of the role of language functions and cultural familiarity. *Journal of Research in Applied Linguistics,* 10 (SpecialIssue), pp. 1427–1438.

Spears, D. L., Josiam, B.M., Kinley, T., Pookulangara, S., 2013. Tourist See Tourist Do: The Influence of Hollywood Movies and Television on Tourism Motivation and Activity Behavior," Hospitality Review: Vol. 30: Iss. 1, Article 4.

Managing the Sustainable Development of Regional Innovative Entrepreneurship Infrastructure

Alena Dyrdonova[a], Elena Andreeva[b] and Nikita Fomin[c]
Nizhnekamsk Chemical Technology Institute (Branch) of Kazan National Research Technological University, Stroiteley Street 47, Nizhnekamsk city, Russia
dan-home@yandex.ru, esandreeva-nk@rambler.ru, juventino@yandex.ru

Keywords: Sustainable development, innovative entrepreneurship, infrastructure, industrial park, performance efficiency.

Abstract: The article addresses the issues of managing the sustainable development of the innovative entrepreneurship infrastructure in a region. The essence of the innovative entrepreneurship and its role in the economic development are also considered. The study sets out an author's methodological approach that has been used as a basis to carry out an in-depth analysis of the entrepreneurship system advancement in the Republic of Tatarstan, as well as an evaluation of the sustainability and efficiency indicators in line with an assessment of the activities of the industrial parks (private and integral) located in the region. The postlude describes the innovative entrepreneurship infrastructure growth trends in the region along with the currently available instruments to support the small- and medium-sized businesses, as well as the prospects for advancement of the industrial parks operating in the Republic of Tatarstan.

1 INTRODUCTION

The status quo in terms of the sustainable development of the national economy in Russia calls for its large-scale re-industrialization in line with larger investments, higher industrial output, and imports phase-out. One of the effective mechanisms to address these tasks is to promote the industrial manufacturing in the innovative entrepreneurship structures. In this field, initiatives from the private sector are very well welcomed by the national government. However, an appropriate infrastructure would be needed in order to support and push through the private sector's initiatives involving the industrial segment of the national economy, as well as promote an inflow of investments into the said segment.

Degree of the investment potential of a region provides a background for forecast and regulation of an inflow of investments. For many years, the Republic of Tatarstan has been leading the pack in that respect. Industrial parks, special economic zones, areas of advanced social and economic development are considered to be effective mechanisms for creation of an infrastructure that would add attractiveness to the region from the investor's perspective [3]. In recent years, there has been a rapid increase in the number of the said structures. This allows the Republic of Tatarstan to be a leader among the Russian regions. In this regard, of particular importance and relevance are the issues related to assessment of the sustainability and performance efficiency of the infrastructure units as well as pathways of their development, when it comes to the innovative entrepreneurship.

The theoretical framework of management and analysis of a degree of maturity of the innovative entrepreneurship has been extensively contemplated by many authors, namely L.I. Abalkin (Abalkin, 2004), N.A. Adamov (Adamov, 2016), A. Crockett (Crockett, 1996), A.E. Karlik (Karlik and Platonov, 2016), S.M. Klevtsov (Klevtsov, Vertakova and Klevtsova, 2016), V.P. Meshalkin (Meshalkin, Dli and Kakatunova, 2013), F.S. Mishkin (Mishkin, 1999), V.M. Rodionova (Rodionova, 1995), Y.V. Vertakova (Vertakova, Babich and Bykovskaya, 2019), M.A. Zotov (Zotov, Ponikarova and Kadeeva,

[a] https://orcid.org/0000-0001-7144-7473
[b] https://orcid.org/0000-0003-1323-2524
[c] https://orcid.org/0000-0002-2410-0335

2020), and others. However, there is still a lack of researches related to the feasibility of setting up and effective functioning of potential technological parks, special economic zones and areas of advanced development. This is also due to the fact that most of the writings are mainly aimed at investigation of the activities of the existing and well-developed integrated entities.

The purpose of the study carried out within the scope of this article is to design a methodological approach to assessment of sustainability of the regional innovative entrepreneurship infrastructure, validate the said approach using as an example the activities of the industrial (production) parks located in the Republic of Tatarstan, as well as work out recommendations for improvement of their performance efficiency.

2 MATERIALS AND METHODS

In recent years, the advancement of the industries located in the Republic of Tatarstan has been largely dependent on successful implementation of the technopark projects, thus calling for an analytical investigation and science-based assessment of the sustainability and performance efficiency of the industrial parks.

The concept of "efficiency" can be defined as a set of metrics indicating a degree of attainment of project objectives during its execution, subject to an amount of consumed resources (Dyrdonova, 2016). In the course of an efficiency assessment, the indicators related to the manufacturing and process technology activities are reviewed. Taking into account the variety of quantitative and qualitative assessment criteria relating to the innovative entrepreneurship infrastructure development efficiency, we propose to identify five ones being of the utmost importance, from the author's perspective, namely:

– growth rate of a number of residents;

– growth rate of an average number of personnel (workplaces);

– growth rate of turnover of enterprises;

– growth rate of average wages;

– growth rate of an amount of tax payments.

With a view to assess an integrity level of the development efficiency of the infrastructure link making part of the innovative entrepreneurship, the specified values were introduced as input data for all of the indicators listed above, with a certain evaluation score assigned to each of them (from 0 to 1):

– a point equal to 1 is assigned to an infrastructure link (in this particular case it is an industrial park) if a growth rate of the metric is higher than 10%. Consequently, the level of development of the industrial park infrastructure can be regarded as high level ("A");

– a point equal to 0.5 is assigned to an industrial park if a growth rate of each of the indicators ranges within 5–10%, in which case the level of development of the innovative entrepreneurship infrastructure will be regarded as medium level ("B");

– a point equal to 0 is assigned to an industrial park if a growth rate is lower than 5% or below zero, in which case the level of development of the industrial park infrastructure will be regarded as low level ("C").

An integrity level of the development efficiency of the innovative entrepreneurship infrastructure will be determined by the mean value of the sum of points. Table 1 shows the specifics of the integrity levels of the development efficiency of the infrastructure links making part of the innovative entrepreneurship (industrial parks).

Table 1: Characteristics of the development efficiency integrity levels of the infrastructure links making part of the innovative entrepreneurship.

Level	Brief description
High	Infrastructure of an industrial park is well developed. The invested funds are used for their intended purpose. A positive effect is noticeable (there is an increase in the number of residents, in the turnover of enterprises etc.)
Medium	Infrastructure of an industrial park is developed, but the positive effect largely depends on changes in both the internal and external environment
Low	Infrastructure of an industrial park is not developed at all

Thus, the methodological approach contemplated in this study will help conduct a comparative analysis of the activities of industrial parks, determine an integrity level of the respective infrastructure's development efficiency, identify the strengths and weaknesses of technoparks, as well as shape the main pathways for their advancement.

3 RESULTS

The presented methodological approach has been tested on three industrial parks located in the Republic of Tatarstan, namely the Technopolis "Himgrad", the Kama Industrial Park "Master" and the Agroindustrial Park "Kazan".

– The Technopolis “Himgrad” is a state-of-the-art industrial chemical park that was set up in 2006 within the framework of the national program named "Creation of high-tech technoparks in the Russian Federation". The total industrial park area is 131 hectares, with a territory allotted for the buildings exceeding 500,000 square meters (Andreeva, Dyrdonova, Girfanova and Fomin, 2015). The main areas of activities include the low-tonnage chemistry, polymer processing, nanotechnology, biotechnology, resource conservation, energy efficiency, and medical technologies.

The Technopolis “Himgrad” is functioning on a public-private partnership basis. Over 2007–2022, the public investments totaled RUB 2.4 billion (the budget funds were allocated for a full-scale revamp of the heat and water supply networks, electric power system, road network, construction of industrial buildings). The private investments totaled RUB 24 billion (the funds were allocated for renovation of buildings and structures, construction of on-site facilities and process lines).

As many as 367 companies are the residents of the Technopolis “Himgrad”, with an aggregate number of personnel amounting to 10,000 people. In 2022, a commercial output produced by the residents of Himgrad amounted to RUB 68.1 billion (18% up vs 2021), the tax payments to the budgets of all levels amounted to RUB 7.6 billion (11% up vs 2021). Over 2007–2022, a commercial output produced by the residents of Himgrad amounted to RUB 382.5 billion, with the tax payments to the budgets of all levels amounting to RUB 46.3 billion.

– The Kama Industrial Park “Master” is strategically aimed at setting up an infrastructure for development of small- and medium-sized businesses, primarily operating in the manufacturing segment (focused on serving the machine-building cluster of the Republic of Tatarstan). By the end of 2022, the Kama Industrial Park “Master” achieved the following indicators: about 300 resident companies; created workplaces for more than 12 thousand people; the proceeds reached RUB 228 billion (as of year-end 2022).

The Kama Industrial Park “Master” accommodates as many as 11 manufacturers running their business in the advanced social and economic development area named "Naberezhnye Chelny City". Each of these eleven residents through their operations contribute to an inflow of the investments in the regional economy along with setting up new workplaces, improving the production potential and forming an additional tax base (Shinkevich, Dyrdonova, Barsegyan and Fomin, 2020).

– The Agroindustrial Park "Kazan" is the first multifunctional complex that was built for agricultural producers. The facility incorporates the entire technological chain "from the field to the counter" with the respective infrastructure. The overall territory is 8.5 hectares of which 50 thousand square meters is the useful area (3.5 thousand square meters are allotted for agricultural fairs). As many as 19 production units are located on a plot of land exceeding 6 thousand square meters, with a product yield of more than 7 thousand tons per year. Annual turnover of the Park "Kazan" is RUB 2.3 billion on average.

Using the methodology outlined above, a review of these industrial parks’ performance over a period of 2020–2022 has been carried out, as well as their growth rates and overall degree of maturity were assessed (Table 2-3).

Table 2: Growth rates of the indicators efficiency (based on a 3-year period) of the industrial parks located in the Republic of Tatarstan.

Indicator	Growth rates		
	2020	2021	2022
Technopolis “Himgrad”			
Number of residents	9.0%	10.1%	1.9%
Average headcount	4.8%	2.7%	6.1%
Operational turnover of the enterprises	20.2%	22.9%	17.8%
Average wages	4.9%	11.2%	16.9%
Tax payments	15.6%	23.4%	11.5%
Kama Industrial Park “Master”			
Number of residents	6.0%	-2.3%	-22.7%
Average headcount	16.1%	4.4%	1.1%
Operational turnover of the enterprises	16.7%	70.7%	-93.5%
Average wages	3.1%	3.2%	10.9%
Tax payments	16.7%	70.7%	-52.4%
Agroindustrial Park “Kazan”			
Number of residents	-4.7%	-3.3%	7.2%
Average headcount	0.0%	-33.1%	8.6%
Operational turnover of the enterprises	23.3%	-17.7%	-8.7%
Average wages	3.4%	28.3%	0.0%
Tax payments	21.1%	-46.7%	-15.8%

Taking into account the data analysis results, the following conclusions can be made concerning the three parks located in the Republic of Tatarstan, with a focus on their operational performance over 2020–2022. The best indicators have been achieved by the Technopolis "Himgrad" incorporating two facilities, namely an industrial park located on the Technopolis premises, and an innovative industrial park engaged in the high-tech sector. The development efficiency integrity level of the Technopolis "Himgrad" is considered to be high (Level A) in terms of "Operational turnover of the enterprises" and "Tax payments" throughout the period under review. With regard to such indicators as "Average headcount" and "Average wages" over the same period (2020–2022), the efficiency development integrity level of the Technopolis "Himgrad" is considered to be medium (Level B). Growth rates of the first and the second of the said indicators did not exceed 6.08% and 4.86% over 2020, respectively. However, over the period of 2021–2022, the growth rate of "Average wages" already exceeded 10% suggesting a high integrity level in terms of assessment of the development efficiency of an industrial park.

Table 3: Integrated assessment of the development efficiency level of the industrial parks located in the Republic of Tatarstan.

Indicator	Assessment levels			
	2020	2021	2022	Total over three years
Technopolis “Himgrad”				
Number of residents	B	A	C	B
Average headcount	C	C	B	C
Operational turnover of the enterprises	A	A	A	A
Average wages	C	A	A	B
Tax payments	A	A	A	A
Kama Industrial Park “Master”				
Number of residents	B	C	C	C
Average headcount	A	C	C	C
Operational turnover of the enterprises	A	A	C	B
Average wages	C	C	A	C
Tax payments	A	A	C	B
Agroindustrial Park “Kazan”				
Number of residents	C	C	B	C
Average headcount	C	C	B	C
Operational turnover of the enterprises	A	C	C	C
Average wages	C	A	C	C
Tax payments	A	C	C	C

Medium-level performance indicators have been achieved by the Kamsky Industrial Park "Master" located in the city of Naberezhnye Chelny. The dynamics of such indicators as "Operational turnover of the enterprises" and "Tax payments" shows a medium integrity level of the development efficiency of the said facility. During 2020–2021, these indicators suggested a high degree of development, while in 2022 the dynamics went down reaching a low level of the facility’s development efficiency. When it comes to such indicators as "Number of residents", "Average headcount” and "Average wages", the values represent various growth rates over the period under review. According to the 3-year performance indicators, the Kamsky Industrial Park "Master" is rated as a low integrity level in terms of the development efficiency. It would also be worth mentioning that by 2022 the said three indicators, namely "Number of residents", "Average headcount” and "Average wages" demonstrated a negative dynamics of their growth rates.

The negative trend has also affected the Agroindustrial Park "Kazan". Most of the indicators assessed over the period under review suggest a low development efficiency level of the facility, signaling its ineffective operation.

Next, it would be necessary to look into the development trends of the innovative entrepreneurship infrastructure in the region, specifically by assessment of the existing measures aimed at supporting the small- and medium-sized businesses, as well as by outlining the prospects for the functioning of the industrial parks set up in the Republic of Tatarstan (Dyrdonova, Shinkevich, Fomin and Andreeva, 2019).

It should be noted that the times we are living in are marked by the high uncertainty of the economic development, mainly due to the geopolitical factors. Therefore, the period of 2022–2023 seems to have been very difficult for the regions and Russia as a whole. The ongoing sanctions substantially constrain the advancement of the Russian national economy, among which are:

– import and export restrictions, as well as transport blockade – these have a negative impact on the foreign trade activities;

– technological restrictions on various investment projects – these slow down the implementation and development of the same;

– escalation of the inflation rates amid the imbalance between the supply and demand in addition to the Russian Ruble volatility – these worsen the operations of all the entrepreneurs;

– restricted access of the Russian companies and banks to the global financial system – this has led to a cost escalation in transactions with overseas counterparties, and so on.

However, the Cabinet of Ministers of the Republic of Tatarstan by Decree No. 1464 of December 30, 2022 approved a list of high priority investment projects planned to be executed in the regional special economic zones of the industrial and production and technical innovation types. There are as many as 140 largest investment projects on the list, with the scope including allotment of plots of land for construction, setting up of new industrial (manufacturing) parks intended to localize all the innovations of the region, etc.

So far, all the residents and management companies operating in the industrial parks of the Republic of Tatarstan have been able to take advantage of the tax incentives so as to improve the labor conditions at the production facilities and upgrade the infrastructure.

According to the data of the first half of 2023, sixty-six industrial parks have been registered in the Republic of Tatarstan that comply with all the applicable requirements and are ready to accept new residents. However, most of them are not even half built-up. This is a critical point calling for further study.

4 CONCLUSIONS

Following the review of the industrial parks' performance and assessment of the degree of their development efficiency and sustainability, a conclusion can be made that at the moment the prospects for the advancement of the industrial parks located in the Republic of Tatarstan are questionable.

Firstly, the number of residents and number of personnel in the industrial parks goes down. This is due to the following factors that (negatively) contribute to the situation:

– remoteness of a park from a place of residence or residential area having a well-developed infrastructure;

– reduced number or absence of sales channels for the manufactured products and, as a result, inability to make adequate payments for labor, as well as the lack of benefits from the status of residence in an industrial park.

Secondly, amid the complicated military and political situation in Russia, there is a noticeable downward trend in the turnover of the enterprises operating in an industrial park and, consequently, in the amount of tax payments. This is because many Russian producers depend on imported components and availability of export outlets for their products.

Thirdly, despite the decline in the turnover of the enterprises, the average wages of the personnel in the industrial parks have been kept at a good level (over the past three years under review), which, of course, is a positive factor (unlike the first two ones).

Hence, the prospects for the advancement of the industrial parks operating in the Republic of Tatarstan will depend on improvement of the external political environment, presence of foreign companies and access of the parks' resident companies to the domestic markets for the materials necessary for the manufacturing of products but currently being in short supply. Besides, the growing rates of the import substitution, the production of domestic analogues of the imported materials currently being in short supply will contribute to a sizable increase in the turnover of the enterprises operating in the industrial parks and, as a result, to a higher percentage of the resident companies there. As such, enhanced economic efficiency and sustainability of the infrastructure links of the innovative entrepreneurship will have a positive effect on the economy of the entire region, giving it a significant boost.

REFERENCES

Abalkin, L. I., 2004. Economic security of Russia: threats and their reflection. *Issues of Economics*, *12*, 4-13.

Adamov, N. A., 2016. *Strategy for sustainable development of industries, complexes and regions of Russia*, Moscow, Russia: Professor.

Andreeva, E. S., Dyrdonova, A. N., Girfanova, E. Y, Fomin, N. Y. 2015. Enhancement of performance of infrastructural assets built through a public and private partnership. *Mediterranean journal of social sciences*. *6* (5), 311-316.

Crockett, A. 1996. The theory and practice of financial stability. *De Economist*, *144* (4), 531-568.

Dyrdonova, A. N. 2016. Methodological approach to evaluation of clustering potential and efficiency improvement management for development of the regional industry clusters. *International Journal of Economics and Financial Issues*, *6* (1S), 243-248.

Dyrdonova, A. N., Shinkevich, A. I., Fomin, N. Y., Andreeva, E. S. 2019. Formation and development of industrial clusters in the regional economy. *Revista Espacios*, *40* (01), 21-28.

Karlik, A. E., Platonov, V. V. 2016. Cross-industry spatially localized innovation networks. *Economy of Region*, *12* (4), 1218-1232.

Klevtsov, S. M., Vertakova, Y. V., Klevtsova, M. G. 2016. *Sustainable development of industrial complexes based on the modernization of the mechanism of spatial distribution of economic resources*. Moscow, Russia: Rusains.

Meshalkin, V. P., Dli, M. I., Kakatunova, T. V. 2013. Analysis of the effectiveness of innovation in regional industrial complexes of Russia. *North and Market: the formation of an economic order*, *4*, 66-70.

Mishkin, F. S. 1999. Global financial instability: framework, events, issues. *Journal of Economic*

Perspectives, *13* (4), 3-20.
Rodionova, V. M. 1995. *The stability of the enterprise in conditions of inflation*. Moscow, Russia: Publishing house “Perspective”.
Shinkevich, A. I., Dyrdonova, A. N., Barsegyan, N. V., Fomin, N. Y. 2020. Key directions of automation of petrochemical production. *Journal of Physics: Conference Series*, *1515* (2), 022016.
Vertakova, Y., Babich, T., Bykovskaya, E. 2019. Factors enhancing strategic technological competitiveness of industrial companies. *Proceedings of the 33rd International Business Information Management Association Conference, IBIMA 2019: Education Excellence and Innovation Management through Vision 2020*, Granada, Spain: IBIMA.
Zotov, M. A., Ponikarova, A. S., Kadeeva E. N. 2020. Balanced management of innovative sustainable development of the petroleum and gas chemical complex. *IOP Conference Series: Materials Science and Engineering. 971* (5), 052023.

Historical Truth and Artistic Texture in the Novels of Prosper Merime and Abdullah Qadiri

Jurayeva Shalolakhan Khusanboyevna[1]
Fergana State University, Fergana, Uzbekistan
shalolajurayeva123@gmail.com

Keywords: historical novel, historical truth, artistry, artistic composition, historical period.

Abstract: This article delves into the historical events, truths, and artistic nuances found in the novels "Mehrobdan Chayan" by the Uzbek writer Abdulla Kadiri and "Chronicle of the Sultanate of Charles IX" by the French writer Prosper Merimee, offering insightful commentary on these literary works.

1 INTRODUCTION

An essential criterion for historical literature is to vividly depict the pivotal events that significantly impacted the life of the nation and its people, encompass a genuine socio-historical portrayal of the era described, and align them with scholarly insights on that historical epoch. The nature of the portrayed period and events dictates the selection and portrayal of characters within the literary piece. It necessitates showcasing the universal essence of revolutionary life changes, the collective efforts undertaken by the masses, and the communal jubilation accompanying the establishment of a new societal order.

2 ANALYSIS OF THE LITERATURE ON THE SUBJECT.

In his monograph "The Creative Journey of Abdullah Qadiri," Oybek commented on historical novels, stating that attaining historical accuracy through artistic depictions and presenting an authentic tapestry of life's intricacies lost to time demands a vibrant portrayal. It is crucial to imbue the artistic renderings with the concrete historical essence of the era, veritably displaying past realities, the events' significance, and depicting the social dynamics through character portrayals. A fundamental criterion for crafting historical novels is to depict historical truths in accordance with scholarly findings. (https://literature.islamonline.uz/)

Hence, the socio-political issues, historical events, and figures spotlighted in historical works must harmonize with the historical veracity of the characters involved. Consequently, assuming that historical works should strictly adhere to documented facts alone would be an oversimplification. Even within historical narratives, authors can illuminate the zeitgeist and its socio-political dilemmas based on their interpretations. (Ganiyeva T. 2022.)

Among Uzbek historical works, some eloquently capture the essence of a specific era through intricately woven narratives and imagery, offering a precise depiction of historical realities.

For example, Abdulla Qadiri also traversed this path in crafting Uzbek historical novels, showcasing exemplary artistic prowess. One notable work in this vein is the novel "Mehrobdan Chayan," which serves as a natural progression from Qadiri's earlier piece, "O'tkan Kunlar," delving into the historical narrative surrounding Khudoyar Khan and his adherents. Completed in February 1928 and published the following year, this novel represents the writer's second major literary endeavor.

At the outset of the novel, the author articulates: "Khudoyar Khan, the subsequent representative of Turkestan's feudal lords, ruthlessly subjugated peasant families and artisans to fulfill his desires, imposing merciless punishments on those who dared oppose him." This thematic core elucidates the novel's essence, aiming to delineate the character,

[1] https://orcid.org/0009-0005-3148-1403

aims, ethics, and lifestyle of the scholars and scribes underpinning Khudoyar Khan's realm, capturing as much depth as the narrative allows. Furthermore, a juxtaposition highlighting the morals, societal strata, family lives, and authenticity of the impoverished masses standing in opposition to these oppressive forces is discernible. Qadiri's endeavor to portray the unsung heroes of Uzbek history without shying away from life's harsh realities is evident in his words: "I endeavored to vividly portray the forgotten heroes until the essence of Uzbek history stirs." (Abdulla Qadiri, 1994.)

While the novel primarily revolves around 19th-century events - the era of the Khans, it's imbued with a contemporary vigor reflective of the times in which it was penned. The title "Scorpion from the Altar" symbolizes the critique of individuals advocating Islamic ethics and engaging in unsavory deeds. Historical narratives often embody the essence of two eras - the period under scrutiny and the backdrop of the writer's contemporary milieu. Qadiri deftly juxtaposes the interactions between the "Tuban class" representatives and the impoverished families, encapsulating profound messages about societal structures and power dynamics.

The novel deftly portrays a panorama of characters representative of the 19th-century Uzbek society, enlivening the narrative with figures like the callous Salih Makhdum, his submissive wife Nigor Ayim, and the timid yet resilient Rana. These character sketches intricately weave a tapestry of national chronicles from that epoch, bringing to life a vivid portrayal of societal archetypes. Qadiri's adept portrayal of these characters as vibrant, sentient beings mirrors a crucial aspect of historical novels - breathing life into fictional personas to encapsulate the zeitgeist authentically.

The narrative of Qadiri further showcases his skill as a novelist with the intricate details he includes regarding Salih Makhdum's lineage. Delving into the tale of Salih Makhdum's father, the author cleverly intertwines real historical events linked to the Kokhan Khanate's history. The conflicts among the Turkestan emirates are subtly woven into the storyline through the thread of a concubine.

This concubine, whose marriage to Umar Khan's son Madali Khan led to treachery by certain mullahs within the horde, initiated a sequence of events that altered the course of history. The demand for a significant fatwa, despite the true circumstances not being heard, set the stage for deception and betrayal. This deception extended to Emir Bahadir Khan (Nasrullah Khan) of Bukhara, who, entranced by the concubine, sought validation through a biased fatwa from unlettered scholars, ultimately launching a religiously-motivated yet avaricious attack on Ferghana. This ill-fated endeavor resulted in the massacre of numerous innocents and the execution of Madali Khan.

The aftermath of this tragedy saw the implicated scholars and teachers, depicted as "scorpions from the altar," facing repercussions. Amir Bahadir Khan held these individuals accountable, stripping them of their positions, religious rights, and subjecting them to persecution. Among the scholars involved in the issuance of the fatal fatwa was Salih Makhdum's father, whose entanglement in this grim affair further deepens the layers of complexity within Qadiri's narrative.

Qadiri's prowess as a novelist shines through his depiction of Salih Makhdum's ancestry. By introducing Salih Makhdum's father into the narrative, Qadiri intricately weaves historical events from the Kokhan Khanate into his tale. The internal conflicts among the emirates of Turkestan find their place within the storyline due to the intriguing presence of a concubine. This concubine's marriage to Madali Khan, the son of Umar Khan, after betraying Umar Khan, catalyzed a series of events steeped in deception and power play. A pivotal moment arises when a significant fatwa - issued without a fair hearing - ignites a chain of tragic consequences, culminating in the ruthless execution of Madali Khan and the bloodshed of countless innocents. The aftermath sees a reckoning for the scholars and teachers involved in this nefarious scheme, dubbed "scorpions from the altar," who face retribution at the hands of Emir Bahadir Khan (Nasrullah Khan) of Bukhara. This narrative twist underscores the intricate interplay of power, betrayal, and divine authority within the historical context evoked by Qadiri.

Contrary to the traditional complacency within the Uzbek society towards religious scholars and Khan rule, Qadiri injects a revolutionary fervor influenced by Russian and global literary masterpieces into his work. By sculpting dynamic and spirited characters embroiled in the tumult of the era, he imbues the narrative with a revolutionary essence akin to the real-life uprisings depicted in Prosper Mérimée's novel, "Chronicle of the Reign of Charles IX." (Prosper Mérimée, 1890.)

Mérimée's deliberate articulation of his narrative purpose mirrors the evolving romanticism of the epoch, signaling a departure from conventional historical storytelling. By prioritizing anecdotes imbued with authentic representations of customs and heroes from a specific era, Mérimée challenges the conventional idealism espoused by classical historians of the 17th and 18th centuries. His preference for unembellished truths over polished narratives underscores his commitment to authenticity and unvarnished storytelling.

Against the backdrop of France's tumultuous 16th century, characterized by religious conflicts between Catholics and Protestants, Mérimée's novel explores the reign of Charles IX amid the cauldron of religious turmoil and political machinations. The narrative delves into the intricacies of this fractured era marked by bloodshed, intolerance, and intricate power dynamics, bringing to life the struggles and tribulations of its characters against the backdrop of a nation in turmoil.

Seeking to offer his unique perspective on the historical era, Mérimée delved into a scarce collection of memoir-like sources. In Chapter 8 of his historical novel, he intriguingly sets up a whimsical dialogue between the reader and the author, taking a satirical jab at the Romantics for their penchant for idolizing individuals, scrutinizing their actions, and delving into their supposedly profound philosophical musings. Mérimée, however, criticizes such approaches as distorting historical truths, advocating for a broader examination of the moral underpinnings across different societal strata to unearth the drivers of historical transformations. His "yearbook," as he terms it, delves deeply into the moral fabric of court nobles, Huguenots, and Catholic Church representatives. Mérimée skillfully navigates through the customs of the clergy, the influence of German assessors, and the daily lives of the common bourgeois and soldiers, painting a vivid portrait of the social milieu of the time.

In Mérimée's interpretation, the infamous St. Bartholomew's Night emerges as a calculated coup orchestrated from the upper echelons and actualized with the backing of the broader French populace. The deep-rooted religious conflicts between Catholics and Huguenots in 16th-century France set the stage for power struggles among the Protestants led by Admiral Gaspard de Coligny, the royalist faction, and the ultra-royalist clan of the Dukes of Guise. Amidst this backdrop, King Charles IX employs a strategy of division and manipulation, fomenting animosity among the factions, unwittingly entangling a significant portion of the populace in the melee. (Kattabekov A. 1972)

Throughout his life, Mérimée harbored disdain for the Restoration regime, lambasting its religious sanctimony, monarchical opulence, and aristocratic superstitions within his literary works. Unapologetically articulating his convictions, Mérimée distanced himself from political entanglements, encapsulating his beliefs within his literary oeuvre.

The artistic allure of Mérimée's "Chronicle of the Reign of Charles IX" lies in its meticulous and impartial portrayal of the socio-political milieu steeped in the throes of religious warfare. The novel's namesake, "chronicle," underscores its aspiration to objectively document the unfolding events throughout the annals of France, eschewing a narrow focus on key episodes or political figures for a holistic depiction of the era.

Interwoven within the narrative fabric, the populace's sentiments and attitudes towards authority are vividly captured, as exemplified in an early scene near Paris before the tumultuous events of Bartholomew's Night. Mérimée masterfully encapsulates the societal mood, illustrating the divide between Catholics revering a new Virgin Mary statue and Huguenots taking aim with arquebuses, showcasing the simmering tensions and polarized sentiments prevalent amongst the people. (Reizov B. 1958)

Baron de Vaudreuil responded, "Oh, he tallies them by the dozen!" - However, what transpired next was beyond belief! On a whim, he decided to engage in a duel himself; he dispatched a challenge to a courtesan, fully attired in his regimental dress, just because she happened to cross his path!

- Pure fabrication! Bernard interjected vehemently.

To capture the authentic essence of society, he includes dialogues between common folk, nobility, and courtiers. Crude jokes regarding faith, discussions about women - both in jest and malice, gossip about deaths, and scandals filled the crux of their conversations. They are willing to stain the reputation of a friend who believes in his lover's fidelity with the most salacious insinuations:

"- Ever since the unfortunate Lannoy's demise near Orleans, Mrs. Turgy has not entertained any suitors," remarked George, steering away from the religious debacles that ensue.

- Who would dare assert that a lady in Paris remains unattached? Bevil interjected, "Comminge must have held her very dear."

"That is why young Navaret kept his distance," Vaudreuil chimed in, "he must have dreaded such a fearsome adversary."

"Is that why Comminges is possessive?" inquired the captain.

"He is as possessive as a tiger," retorted Bevitle, "determined to eliminate any admirers of the enchanting countess; hence, to avoid falling for her charms, he had to secure Comminge." (Prosper Mérimée 1890)

3 ANALYSIS AND OUTCOME

Merimée underscores that appraising the actions of 16th-century individuals should not be scrutinized through the lens of 19th-century sensibilities. The moral standards vary not only across nations but also across epochs, necessitating a nuanced approach to historical judgment. At first glance, Merimée's narrative and Qadiri's novel appear reminiscent. Anwar, akin to Bernard, emerges as the adopted son of Salih Makhdum, a destitute noble of his time. Salih Mahmood aspires for Anwar to serve in the Khan's court, mirroring Bernard's familial expectations. Facilitated by the assistance of Nasim's late father, Anwar ascends to prominent roles within the Khan's domain. By entwining the life trajectories of their protagonists like a delicate thread, both authors deftly blend historical actualities with the artistic tapestry of an epic era. They adeptly elucidate the socio-political and ideological landscapes of their respective societies during epochs characterized by transition.

4 CONCLUSIONS AND SUGGESTIONS

A comparative analysis between "Mehrobdan Chayan" and "Days of the Past" reveals a more pronounced, lucid, and transparent party conflict in the former. This conflict emerges authentically from historical roots, heralding the awakening and evolution of social consciousness. Life's authenticity and historical veracity are elevated to an artistic realm, infusing dynamism, growth, and confluence into the narrative, transitioning the struggle into a realm of "two classes." Realism permeates the work, depicting the inexorable clash between conflicting factions as new forces triumph over antiquated ideologies. This metamorphosis of society's social struggle underscores the epic nature of "Mehrobdan Chayan," positioning the novel as a beacon of socio-historical narrative excellence. The epic narrative approach coupled with the creation of enduring epic characters validates the genre's narrative breadth and depth. Epic destinies and character essences assume paramount significance within such expansive works, heralding the formidable stature of the heroes within the narrative archetype.

REFERENCES

Qadiri, A., 1994. Scorpion from Mehrob (Historical novel by Khudoyor Khan and his followers) Tashkent: Gafur Ghulam Publishing House of Literature and Art, 149p.

Ganiyeva, T. T., 2022. Leading elements in the illumination of the character of the period in the historical novel. *Analytical Journal of Education and Development.* Volume: 02 Issue.

Prosper, M., 1890. Auteur du texte. Chronique du règne de Charles IX / par Prosper Mérimée. 1890. - P.6

Boboyev, T., 2002. Basics of Literary Studies".T., Uzbekistan.

Kattabekov, A., 1972. Historical truth and artistic skill.-T., Science.

Oybek, 1966. Literature, history, modernity. "Culture of Uzbekistan".

Balakin, Yu. V., 2002. Istoricheskiy roman v sovremennom svoem vyrajenii. Piligrim. Omsk. No. 4. S. 4-7.

Bakhtin, M., 1967. Problemy poetiki Dostoevsky, Moscow, Sov. Pisatel, 364 p.

Reizov, B.G., 1958. French historical novel and era of romanticism. M.: Gosudarstvennoe izdatelstvo khudojestvennoy literatury (Goslitizdat), C.352

https://adabiyot.islamonline.uz/adabiyotshunoslik/adabiy-suhbatlar/402-tarihiy-suyjet-tarihiy-manzara.html

Analysis of the Dynamics of Activity and Factors Determining the Investment Climate in Different Regions of the Russian Federation

Olga Nikolaevna Anokhina[1][1], Elmira Failovna Amirova[2][2]
and Louiza Tagirovna Eskerkhanova[3][3]

[1]*associate Professor Department of Food Technology Candidate of Technical Sciences, Associate Professor Kaliningrad State Technical University, 1 Sovetsky Prospekt, Kaliningrad, Russia, 236022*
[2]*PhD, Associate Professor Department of Digital Technologies and Applied Informatics, Kazan State Agrarian University, Associate Professor Department of Production Economics, Kazan (Volga Region) Federal University*
[3]*PhD, Associate Professor Department of Theory and Technology of Social Work, Chechen State University named after A.A. Kadyrov, Grozny, Russian Federation*
olga.anohina@klgtu.ru, elmira_amirova@mail.ru, lu-69@yandex.ru

Keywords: investment climate, dynamics, activity, factors, analysis, regions of the Russian Federation, political stability, economic infrastructure, institutional environment, market access.

Abstract: This article is dedicated to the analysis of the dynamics of investment activity and the factors determining the investment climate in various regions of the Russian Federation. The investment climate plays a crucial role in attracting capital, fostering business development, and ensuring sustainable economic growth. The author provides an overview of investment activity dynamics in different regions of the Russian Federation, identifying a variety of factors influencing this process. The article discusses political stability, economic infrastructure, institutional environment, market access, and human capital as key aspects shaping the investment climate. The analysis aims to identify major trends, challenges, and potential opportunities for improving the investment climate in Russia's regions.

1 INTRODUCTION

Investment activity serves as a driving force for economic development, determining the competitiveness and stability of regions in the modern market economy. In the Russian Federation, with its diverse geographical, economic, and socio-cultural landscape, the dynamics of the investment climate and its factors vary from region to region.

The aim of this article is to conduct an analysis of investment activity dynamics and identify key factors influencing the investment climate in various regions of the Russian Federation. Understanding these factors will help identify major trends, issues, and effective strategies for stimulating investment activity and attracting capital to Russia's regions. Within this analysis, various aspects of the investment climate will be examined, including political stability, economic infrastructure, institutional environment, market access, and human capital. Analyzing these factors will identify key problem areas and potential opportunities for improving the investment climate in different regions of Russia.

This analysis is of great importance for the development of targeted strategies for regional economic development, enhancing the competitiveness of regions, and ensuring sustainable economic growth at the national level.

The presence of developed infrastructure, access to resources, and markets also significantly influences the investment climate. Regions with well-developed transportation, energy, and communication

[1] https://orcid.org/0000-0003-1918-4690
[2] https://orcid.org/0000-0002-1528-5219
[3] https://orcid.org/0000-0002-1528-5219

infrastructure usually attract more investments, as it facilitates business operations and reduces operational costs. For example, regions with access to seaports have competitive advantages in international trade, while regions with limited access to transportation routes may encounter difficulties in delivering goods (Smith, 2019, p. 107).

Additionally, the presence of natural resources such as oil, gas, minerals, etc., can be an important factor in attracting investments. Regions rich in natural resources often attract investments in extractive industries and related infrastructure projects. However, for sustainable development, it is necessary to diversify the economy and invest in other sectors, such as innovative technologies, education, and services.

The quality of the institutional environment, including the judicial system, anti-corruption measures, and the efficiency of public administration, significantly affects the investment climate. Regions with transparent and efficient institutions usually attract more investments as it reduces risks and increases investor confidence. Conversely, regions with unstable political situations or high levels of corruption may face difficulties in attracting investments, even with other attractive conditions. The openness and transparency of government institutions, as well as the effectiveness of mechanisms for protecting investors' rights, are key factors contributing to the formation of a favorable investment climate.

Over the past decade, Russia has seen diverse dynamics in investment activity in different regions. Some regions demonstrate stable and dynamic investment growth, indicating a favorable investment climate, the presence of promising projects, and government support. These regions are often characterized by a developed industrial base, access to markets, qualified personnel, and a stable political environment (Jones, 2020, p. 109).

Analysis of investment climate dynamics in different regions of Russia shows that success in attracting investments depends on a variety of factors. Economic development, political stability, infrastructure, and the institutional environment play a crucial role in shaping a favorable investment climate. To improve the investment climate in regions, it is necessary to develop comprehensive strategies aimed at eliminating obstacles and creating conditions for attracting capital.

However, there are regions where the dynamics of investment activity leave much to be desired. This may be due to various factors, including inadequate infrastructure development, weak institutional environment, administrative barriers, as well as political instability or negative investor perception of risks and prospects.

Supporting investment activity in regions plays a crucial role in ensuring sustainable economic growth at the national level. Both state and regional authorities actively work on improving the investment climate, implementing investment programs and projects, as well as enhancing the business environment for investors. However, to increase investment activity in regions, it is essential not only to provide financial support but also to create favorable conditions for doing business, ensure transparency and stability of legislation, actively attract investors, and develop prospective investment projects. Only in this way can we ensure equitable and sustainable development of Russia's regions and create a favorable environment for attracting capital and investments. The investment climate in each region depends on a multitude of factors, including political, economic, socio-cultural, and institutional aspects. Here are some key factors influencing the investment climate:

1. Political stability: Political stability involves not only the absence of political crises and conflicts but also the effectiveness of governance, predictability of legislative and tax policies, as well as the level of corruption. Instability in these areas can create risks for investors and lead to capital outflows from the region. Therefore, the presence of transparent and stable political institutions is a key factor in creating a favorable investment climate. Furthermore, it is important to consider the opinions of the business community and other stakeholders in shaping political decisions to ensure a balanced approach to regional economic management and create conditions for long-term development.

2. Economic infrastructure: The presence of developed transportation, energy, communication, and other types of infrastructure significantly facilitates doing business and investing. The quality of infrastructure affects production costs, logistics, and market access. Moreover, economic infrastructure includes not only physical but also digital infrastructure. The development of digital technologies and access to high-speed internet are becoming increasingly important for successful business operations in the modern world. The digitization of the economy contributes to increased production efficiency, improved access to information and services, and provides new opportunities for innovation and development of new industries. Thus, the development of both physical and digital infrastructure plays a crucial role in

shaping the investment climate and attracting capital to Russia's regions.

3. Institutional environment: In addition to the legal system and anti-corruption measures, the institutional environment also includes the efficiency of governance and mechanisms for supporting business. Transparent and predictable procedures for interaction with government agencies, as well as mechanisms for investment support, such as incentives, grants, and investment funds, create favorable conditions for investors. Moreover, the degree of involvement of local authorities and communities in decision-making processes is also important, as it promotes investment localization and creates a favorable business environment in the region.

4. Market access and trade integration: Regions with access to large markets, both national and international, often attract more investments. Participation in international trade and integration into the global economy also contribute to improving the investment climate. Presence in international trade unions or free trade zones can provide regions with access to larger markets with greater potential for exporting their products. Broader markets usually mean more opportunities for growth and business development, attracting investor attention. Additionally, participation in international trade can facilitate technology transfer, exchange of experience, and strengthening of the region's innovative potential, which also positively affects the investment climate.

5. Human capital and labor market: The presence of qualified professionals and the development of human capital are critical factors for attracting investments. Regions with high levels of education and access to professional training are often preferred by investors, especially in high-tech and innovative industries. The development of the education system and scientific research, as well as measures to support innovation and develop technical skills, contribute to the formation of the region's competitive advantages and attract investments in promising sectors of the economy. Furthermore, a flexible and efficient labor market that promotes labor mobility and adaptation to changing market conditions is also an important factor for the investment climate.

6. Tax and regulatory policies: Tax and regulatory policies are key instruments of state economic regulation and have a direct impact on the investment climate. Tax rates, tax system, and tax incentives affect the profitability of investments and the attractiveness of the region for investors. High tax burdens or unjustified complexity of the tax system can deter potential investors and hinder capital attraction. Regulatory policies, including licensing, certification, and other types of administrative restrictions, also affect business conditions and investment decision-making. Transparency, predictability, and efficiency of tax and regulatory policies play a crucial role in shaping a favorable investment climate.

These factors are interconnected and collectively determine the investment climate in a specific region. Understanding and considering these factors help develop strategies to attract investments, improve business conditions, and stimulate economic growth.

Different regions of Russia face various challenges that may hinder the development of the investment environment and impede investment attraction. The main problems encountered by regions are listed below:

1. Political instability: Unpredictability in the political environment and legislative changes can create risks for investors and decrease trust in the region. Political instability may lead to changes in investment policies and increased administrative barriers, making it difficult to make long-term investment decisions.

2. Insufficient infrastructure development: The absence of developed transportation, energy, and communication infrastructure can significantly limit business opportunities and investments. High transportation costs, unreliable energy supply, and inadequate communication networks can deter potential investors.

3. Lack of transparency and efficiency in government institutions: Lack of transparency and efficiency in government institutions, as well as high levels of corruption, can create risks for investors and reduce trust in the region. The unpredictability of government actions and bureaucratic procedures can also discourage potential investors.

4. Tax and regulatory burden: High tax rates, a complex tax system, and excessive regulatory burden can significantly increase costs for businesses and reduce the attractiveness of the region for investments. The unpredictability of tax and regulatory policies can also create risks for investors and hinder investment project planning.

5. Shortage of qualified workforce: The shortage of qualified specialists and underdeveloped education system can be significant obstacles to the development of innovative and high-tech industries. The lack of qualified workforce can limit opportunities for the implementation of new

technologies and innovations, making it difficult to attract investments in these sectors.

6. Environmental problems and security threats: Environmental issues such as pollution and security threats can create risks for businesses and reduce the attractiveness of the region for investments. Unfavorable environmental conditions can lead to additional costs for companies and negatively affect their reputation.

The main problems hindering the development of the investment environment in different regions of Russia include political instability, insufficient infrastructure development, lack of transparency and efficiency in government institutions, high tax and regulatory burden, shortage of qualified workforce, as well as environmental problems and security threats. To address these problems, comprehensive strategies need to be developed to improve the investment climate, including measures to enhance political stability, infrastructure development, quality of governance, reduction of tax and regulatory burden, education development, and environmental responsibility.

2 CONCLUSION

The analysis of the dynamics of investment activity and the factors determining the investment climate in different regions of the Russian Federation allows for several important conclusions. Firstly, the diversity of factors influencing the investment climate emphasizes the need for an individualized approach to the development of each region. Secondly, political stability, developed infrastructure, transparent institutions, and market access play a key role in attracting investments. Thirdly, active attention to the development of human capital and support for innovation contribute to sustainable economic growth.

To improve the investment climate in the regions, it is necessary to continue efforts to create a favorable business environment, improve infrastructure, enhance institutional frameworks, and support the development of human capital. Only in this way can sustainable investment attraction be ensured, economic growth stimulated, and the quality of life improved for the population in various regions of Russia.

REFERENCES

Blagov, Y. N., Belkin, A. V., 2018. Economic growth and investments in the regions of Russia. Moscow: Delo Publishing. 224 p.

Grebennikova, T. A., Mikhailova, I. V., 2015. Investment climate of the regions of Russia: theory and practice of assessment. Moscow: INFRA-M Publishing. 240 p. 0.

Davydova, E. M., 2016. Investment climate as a factor in attracting investments to the regions of Russia. Moscow: Nauchny Mir Publishing. 176 p.

Erofeeva, L. S., Guryanova, A. V., 2017. Factors influencing the investment climate in the regions of Russia. Moscow: Ekonomika Publishing. 192 p.

Zaitsev, N. N., Popov, S. V., 2019. Investment climate and economic growth in the regions of Russia. Moscow: Economics and Life Publishing. 208 p.

Korotayev, A. V., Malevany, V. V., 2018. Investment climate and development of regions in Russia. Moscow: Economics and Statistics Publishing. 256 p.

Makarov, V. L., Nikolaeva, N. S., 2017. Investment climate and attraction of investments in the regions of Russia. Moscow: Finances and Statistics Publishing. 184 p.

Nikolaev, D. V., Ivanova, O. A., 2016. Formation of investment climate in the regions of Russia. Moscow: Economics and Society Publishing. 216 p.

Orlova, E. I., Petrov, A. V., 2019. Investment climate and economic development of regions in Russia. Moscow: INFRA-M Publishing. 240 p.

Stepanova, L. G., Loginov, A. V., 2018. Investment climate in the regions of Russia: problems and prospects. Moscow: NORMA-INFRA-M Publishing. 208 p.

Monitoring of Degraded Agricultural Lands of the Arid Agro-Climatic Zone of the Stavropol Territory

Alexandr V. Loshakov[a], Marina S. Melnik[b]
Stavropol State Agrarian University, Zootechnical lane, Stavropol city, Russian Federation
alexandrloshakov@mail.ru, mariushka0013@yandex.ru

Keywords: Monitoring of agricultural landscapes, agroclimatic zone, land degradation, types of degradation.

Abstract: Monitoring, assessment and analysis of the qualitative state of degraded agricultural landscapes within the arid agroclimatic zone of the Stavropol Territory and development of proposals for their further use. Monitoring of agricultural landscapes was carried out on the basis of modern remote and ground-based methods of territory survey and identification of degraded land. Zoning of all agrolandscapes of the agroclimatic zone was carried out on the basis of monitoring studies and the distribution of land according to their suitability for agricultural production. In the course of monitoring studies, it was found that the area of agricultural landscapes of the arid agroclimatic zone exposed to water, wind and joint erosion increased by 46039 ha during the study period and in 2020 is 577758 ha or 24.3% of the territory. At the same time, more than 152 thousand hectares of land have an average degree of degradation, and more than 73.5 thousand hectares have a strong degree. The use of degraded agricultural landscapes in agriculture should be based on their quality condition. The results of long-term monitoring studies and their cartographic support will allow us to preserve and improve agricultural land through the implementation of agrotechnical, hydrotechnical and agroforestry reclamation projects.

1 INTRODUCTION

The land fund of the arid (II) agro-climatic zone of the Stavropol Territory includes nine administrative districts with a total area of 2377675 hectares, of which more than 93% are occupied by agricultural land, represented by 94% agricultural land (Klyushin, 2016). Thus, the use of the land fund is intensive, which affects its quality condition. In some areas, the percentage of agricultural land reaches 96% (Blagodarnensky, Novoselitsky and Ipatovsky districts). During the research period, the land area of this category increased by 33727 hectares. The area of agricultural land is increasing in all districts of the arid zone, except for the Soviet municipal District. The increase in the area was also due to the reserve lands, which for the most part are not suitable or unsuitable for agriculture (Klyushin, 2017). Farming in this area is risky, since the hydrothermal coefficient is 0.7 – 0.9. Summer is dry and very hot. The average monthly winter temperature is -3.5... -5.0 0C, but the minimum January temperatures can reach -32... -34 0C. Precipitation, as a rule, is of a short-term and stormy nature, which can favor the development of erosion and flooding of land, especially in the spring and autumn periods (Dubrovsky, 2017). The soil cover of the arid agro-climatic zone is represented by chestnut, dark chestnut and chernozem soils, as well as salt marshes. On a significant area there are salt marshes with chestnut saline and meadow-chestnut soils. The content of nutrients in soils corresponds to the general trend of the Stavropol Territory (Shapovalov, 2018).

2 MATERIALS AND METHODS

When carrying out monitoring studies on degraded agro-landscapes of the arid agro-climatic zone of the Stavropol Territory, modern methods were used: remote sensing of agricultural lands (using satellite images and unmanned aerial vehicles), ground surveys using precision instruments, modern computer programs. In the course of the research, the

[a] https://orcid.org/0000-0002-0897-3099
[b] https://orcid.org/0000-0001-9576-5230

following were recorded: the area of agricultural landscapes subject to water, wind and joint erosion by type of agricultural land, the causes of their occurrence, the degree of development of degradation processes and the possibility of their further use in agriculture. Based on the results obtained, the zoning of agricultural landscapes was carried out according to the author's method-ology.

3 RESULTS

Analyzing the distribution of agricultural lands of the arid (II) agroclimatic zone by land, we note that agricultural lands predominate in all administrative districts in their composition. So in the Alexandrovsky district, they account for 93.26% of the lands of this category, in Blagodarnensky 94.15%, Budennovsky 95.02%, Ipatovsky 93.3%, Kursk 94.55%, Novoselitsky 95.02%, Petrovsky 94.62%, Sovetsky and Stepnovsky 94.16%. Thus, the use of the land fund is very intensive, which contributes to the development of all types of degradation processes (Yesaulko, 2015).

From the data presented, it can be seen that the intensity of the use of agricultural land in the II agro-climatic zone increases sharply, as the plowing of the territory increases significantly. The maximum areas of arable land are observed in the Soviet (86.11%), Novoselitsky (83.68%), Budennovsky (83.36%) and Blagodarnensky (83.18%) districts and these values are twice higher than the calculated norms. Also, significant areas used for arable land were identified in the Petrov (74.92%) and Stepnovsky (74.54%) districts, and the smallest in the Kursk district - 50.98% [6]. At the same time, during the analyzed period, there was an increase in the area of arable land in five districts, and a decrease in four districts. A large percentage of the plowed area negatively affects the condition of the land, since arable land is not a stable element. Pasture lands belong to stable landscape elements and their areas by administrative districts do not change significantly during the research period, which correlates with changes in the area of arable land. The largest shares of pastures in the composition of agricultural land are noted in Kursk (42.96%) and Alexander (23.68%) districts, and the smallest in the Soviet District – 7.65%. There are no hayfields on the territory of four districts, in other districts their share ranges from 0.07% to 3.37%.

Perennial plantings are available on small areas and in districts they occupy from 0.1% to 1.3%. Their largest areas are concentrated in the Budyonnovsky district (3690 hectares), where they are represented by vineyards, the area of which has grown by 282 hectares over the period of research.

Water erosion of agricultural landscapes is widespread on the territory of the arid zone of the Stavropol Territory and monitoring of lands that are subject to this negative process is carried out to determine these areas with mandatory setting of boundaries and calculating areas. An important point of monitoring is to determine the degree of degradation and the reasons why this process occurs. The dynamics of the areas of erosion processes provides grounds for assessing and eliminating the consequences on agricultural land (Trukhachev, 2018). With the development of technology and technologies, monitoring of erosion processes can be done with high accuracy and operativeness. It is necessary to carry out methodological improvement of the process of monitoring agricultural landscapes on the basis of remote sensing of the Earth and GIS technologies.

Many factors contribute to the development of water erosion, deflation and other negative processes. The main ones, of which is the large plowing of the territory, which in some areas exceeds the recommended norms by 30%, as well as a significant amount of pure vapor in crop rotations (Pavlova, 2016).

The area of eroded agricultural land in the II agro-climatic zone during the research period has a discontinuous shape. Thus, the maximum area of degraded land was identified in 2000, but this indicator is only 3887 hectares higher than in 2020. The minimum area of lands degraded by water erosion was discovered in 2006, and it amounted to 214268 hectares, after which their stable increase is noted. At the same time, there is a constant growth of lands subject to an average degree of erosion, the minimum area in 2006 (39527 ha), and the maximum in 2020 (55516 ha). The dynamics of the area of heavily eroded lands fully corresponds to the dynamics of the total land area of the II agroclimatic zone exposed to water erosion. The largest total area of eroded sites was found in the Blagodarnensky (51912 ha), Novoselitsky (51136 ha) and Petrovsky (46771 ha) districts. At the same time, the number of lands subject to medium and severe water erosion in these areas is one of the lowest, except for the Petrovsky district. The smallest areas of eroded lands were found in the Kursk (9807 ha) and Stepnovsky (10798 ha) districts, and this applies to both medium and highly degraded areas. In many areas, over a twenty-year period, there has been a decrease in the area of erosive agricultural land.

For the arid zone of the Stavropol Territory, such a phenomenon as planar or linear water erosion is very frequent. This is due to the fact that precipitation in the warm season, as a rule, is of a downpour nature and, accordingly, this leads to the flushing of the fertile soil layer or the erosion of a certain part of the agricultural landscape, where the concentration of runoff occurs. Also, the development of water erosion is facilitated by the relief and the absence of perennial grasses in the structure of cultivated areas.

The results of monitoring of lands degraded by water erosion obtained by us during the research period give grounds to assert that the area of degraded lands is constantly increasing, and there is also an increase in the degree of degradation. In all administrative districts of the arid zone, there is a tendency to increase the areas of eroded lands with a medium and strong degree of erosion (Fig. 1).

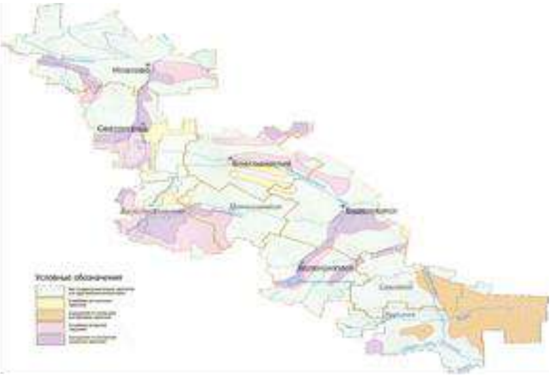


Figure 1: Eroded agricultural landscapes of the arid agroclimatic zone of the Stavropol territory.

Wind erosion or deflation is the destruction of the soil cover under the influence of strong wind. Deflation can be natural (normal, geological) and accelerated (anthropogenic), which is caused by improper land use and a large anthropogenic load on agricultural land. The territory of the Stavropol Territory is characterized by a complex relief and the presence of a large number of wind corridors. The average maximum wind speed is 15 m/s, but in different parts of the region the wind speed can increase to 26-30 m/s. Of course, in such conditions, the risk of deflation is maximum and, as we have already noted, the area of deflation-prone lands in the region is about 4.5 million hectares. In addition, our region is characterized by such a phenomenon as dust storms, which can occur at almost any time of the year. Dust storms cause great damage to agriculture and especially to crops and soils.

Monitoring of agricultural lands during surveys showed an increase in the area of deflated lands during the research period. The minimum values of the total area of the areas subject to deflation were found according to the state of the land in 2000 (213060 ha), and the maximum values for 2006 (245715 ha), which is 8743 ha more than the area of land identified in 2020. The number of lands on which the average degree of deflation has been detected, since 2000, has increased more than 2.5 times, to 83571 hectares in 2020. The area of heavily ventilated lands has increased 9282 hectares during the same time.

Analyzing the situation by administrative districts, we consider it necessary to single out the Kursk district, in which about 34% of agricultural lands are already deflated, including 16.6% to an average degree and 7.5% to a strong one. Over the entire period of research, the number of lands subject to deflation increased by 9601 hectares. Also, a difficult situation has developed within the boundaries of the Petrovsky district, where more than 26% of the lands suffer from the negative effects of wind. There are no lands degraded by wind erosion in the Stepnovsky district, and in the Soviet District their area is minimal (39 ha).

The area of deflated agricultural land has grown by almost 24 thousand hectares over the period of research, while the area of land with a weak degree of degradation has decreased, but the areas of land with medium, strong and very strong degree of degradation have significantly increased.

Monitoring of lands subject to wind erosion has shown that the development of these processes tends to decrease the area on arable land, and on other types of agricultural land to increase. Pasture lands are less susceptible to deflation, but favorable conditions for the development of negative processes are created on sloping lands and in areas where there is no dense grass. In addition, an increase in the number of livestock in the private sector is a serious problem that negatively affects the state of natural forage lands. Because of this, the load on pastures increases and pasture turnover is not observed, which leads to desertification of individual territories (Volkov, 2017). In most administrative districts of the arid zone of the Stavro-Polish region, such a situation is noted.

The development of deflation depends on many factors and urgent measures are needed to preserve land and protect agricultural landscapes to reduce the intensity of its development. The reduction in the area of deflated arable land is associated with increased attention to arable land and the use of anti-erosion measures, but the qualitative condition of hayfields and pastures, as well as perennial plantings is ignored (Fig. 2).

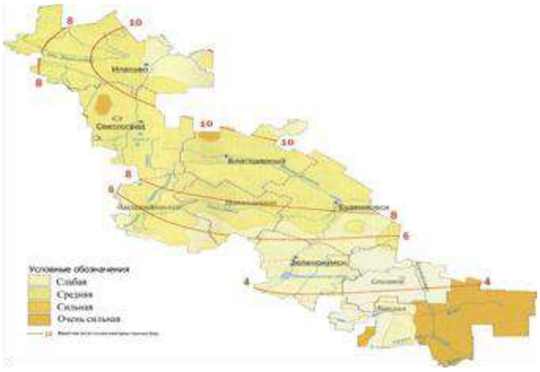


Figure 2: Deflated agricultural landscapes of the arid agroclimatic zone of the Stavropol territory.

Every year more and more agricultural lands are exposed to the combined effects of water and wind erosion, which leads to a rapid deterioration in the quality of these lands. The development of joint negative processes is typical for many regions of Russia, which of course includes the Stavropol Territory. The result of the impact of water and wind erosion is an in-tensive decrease in the upper fertile soil layer and a decrease in humus and nutrient reserves. That is, it is no longer possible to obtain high yields and high-quality products in eroded areas. Also, as a result of the development of erosion, the physical, biological and chemical proper-ties of soils deteriorate sharply.

The natural causes of both water and wind erosion include, first of all, relief, geology, climate, soils and the density and character of vegetation cover. There are also anthropogenic or as they are also called socio-economic causes of the occurrence and development of erosion. These include large plowing of the territory, an increase in the sowing of row crops, a decrease in the sowing of perennial grasses, non-compliance with pasture turnover, that is, not rational use of agricultural land.

As a result of monitoring the lands degraded by joint water erosion and deflation, we have established a stable increase in the area of degraded lands of all types (Magomedov, 2018). As a result of land monitoring, we have established a stable increase in the area of land degraded by water and wind. Over a twenty-year period of research, the area of eroded agricultural land in the arid zone has grown by 100%. This is a very high intensity of the degradation of highly productive lands. Of great concern is the significant increase in the land area of the arid (II) agroclimatic zone, which is subject to various degradation processes. As of 2020, this area is 59098 hectares and this is the maximum value for the entire period of monitoring studies that show the activation of these processes. It is also possible to state an increase in the number of lands with an average and severe degree of erosion. There is no such problem on the territory of two districts - Sovetsky and Stepnovsky. Significant eroded areas were identified in the Blagodarnensky (22707 ha) and Ipatovsky (12603 ha) districts. Also, only in the Ipatov district were found areas heavily eroded by water and wind.

Analysis of the data obtained shows a significant increase in the area of agricultural land subject to water erosion and deflation. In addition, there is an increase in medium-degraded lands and the appearance of highly degraded agricultural landscapes. This fact indicates the absence of comprehensive concrete measures to combat joint negative processes and measures aimed at protecting and improving agricultural land. Monitoring of degraded lands by the combined manifestation of water erosion and deflation is necessary, since the area of eroded lands is constantly increasing. The development of water erosion and deflation occurs in the direction of increasing the degree of degradation across all lands, which can lead to the loss of large areas of arable and pasture lands in a short period of time.

Figure 3: Combined water and wind erosion on agricultural landscapes of the arid agroclimatic zone of the Stavropol territory.

Agrolandscapes subject to joint degradation processes are distributed in noncharacteristic territories. These include the Kursk, Stepnovsky, Sovetsky and Budyonnovsky municipal districts, where the occurrence of this problem occurred during the period of our research. This indicates that the intensity of agricultural production is constantly increasing, and in addition, according to these districts, there is a significant increase in the area of agricultural land and especially arable land.

A systematic approach to monitoring agricultural landscapes in our work is based on the coverage of the entire study area by combining modern means and technologies (space photography, aerial photography and ground surveys) and a set of indicators of the qualitative state of land based on the emergence and development of degradation processes. Systematic monitoring of agrolandscapes makes it possible to carry out work on zoning and zoning of the territory of an agricultural region with the appearance of the territories of the spread of the main processes of land degradation. We implement a systematic approach based on the analysis of the use of agricultural landscapes (by type of land) and monitoring studies of all degradation processes with subsequent cartographic support for land monitoring.

4 DISCUSSION

This The obtained research results show that the problem of the development of degradation processes remains very serious. Studies conducted by other scientists confirm the severity of the problem for other territories of the region. Previously published works show that the areas of agricultural landscapes subject to negative processes are constantly changing depending on the implementation of various targeted programs aimed at the protection and protection of ugodii. Our research over a twenty-year period indicates the actualization of the problem of degrdation of agricultural landscapes, since the areas of degraded land tend to increase constantly.

The results of monitoring studies obtained in the past were not used to predict the development of degradation processes in the study area. It is also necessary to develop and implement comprehensive programs for the protection, restoration and protection of agricultural landscapes, as there is a real threat of deterioration of their quality and withdrawal from agricultural production.

5 CONCLUSION

Based on the results of monitoring of agricultural landscapes, it is possible to state an increase in the intensity of the development of degradation processes, which leads to the loss of once fertile soils and a significant shortage of crop yields. On the basis of studies of degradation processes, cartographic support of monitoring of agrolandscapes in the context of agroclimatic zones of Stavropol on the basis of modern geoinformation technologies was carried out. Cartographic schemes of erosion zoning, zoning for salinization and flooding, as well as a scheme for the use and protection of the lands of the Stavropol Territory have been developed.

Reclamation and reclamation measures on degraded agricultural landscapes will prevent the reduction of agricultural land areas and obtain stable crop yields. In addition, environmental problems of the use of agricultural land subject to various types of degradation will be solved. The development and implementation of adaptive land management projects in all districts of the dry agroclimatic zone of Stavropol should be aimed at protecting agricultural landscapes and improving their quality condition, taking into account regional and zonal features of agricultural land use. In addition, the developed schemes of forest reclamation, agrotechnical, hydrotechnical and soil protection measures are aimed at correcting the existing ecological situation and protecting agricultural landscapes from degradation processes.

The results of land monitoring over a twenty-year period indicate a difficult environmental situation and the aggravation of the problem of degradation of agricultural landshafts. The developed matrices of the main problems of agricultural land use are necessary for the development of comprehensive measures aimed at correcting the current situation.

REFERENCES

Klyushin, P., Musaev, M., Savinova, S., Shalov, T., 2016. *Monograph.* Rational use of agricultural land in the North Caucasus Federal District. Moscow-Makhachkala.

Klyushin, P., Savinova, S., Loshakov, A., Kipa, L., 2017. *Scientific article.* Land management, cadastre and monitoring of land. Rational use of agricultural land on the territory of the Stavropol territory. Moscow.

Dubrovsky, A., Ershov, A., Novoselov, Yu., Moskvin, V., 2017. Elements of geoinformation support of inventory works. Vestnik SGUGIT (Siberian State University of Ge-osystems and Technologies).

Shapovalov, D., Klyushin, P., Shirokova, V., Khutorova, A., and Savinova, S., 2018. *18th Int. Multidisciplinary Scientific GeoConf. SGEM.* Problems and efficiency of land use in the North Caucasian federal district.

Yesaulko, A., Trubacheva, L., Vlasova, O., Volters, I., & Perederieva, V., 2016. *Biosciences Biotechnology Research Asia.* The degree of influence of the forest strip on the formation of crop yields in the Central Ciscaucasia.

Trukhachev, V., Sklyarov, I., Sklyarova, Y., Gorlov, S., Volkogonova, A., 2018. *Montenegrin Journal of Economics.* Monitoring of efficiency of Russian agricultural enterprises functioning and reserves for their sustainable development.

Pavlova, A., 2016. *In the world of scientific discoveries.* Application of digital relief modeling methods for mapping erosive lands.

Trukhachev, V., Esaulko, A., Antonov, S., Loshakov, A. and Sigida, M., 2018. *Research journal of pharmaceutical biological and chemical sciences.* Water Erosion Monitoring on the Territory of Agrolandscapes Stavropol Territory by Remote Methods.

Volkov, S., Shapovalov, D., Klyushin, P., Shirokova, V., and Khutorova A., 2017. *17th Int. Multidiscipl. Sci. GeoConf. SGEM.* Solutions of problems in defining indicators of agricultural land within the framework of activities for the implementation of the concept of development monitoring in the Russian Federation.

Magomedov, A., Abdulaev, K., 2018. Ecological approaches of agrorecreational land use South of Russ.: Ecol., development.

Computational Experiments to Analyze the Effectiveness of the Algorithm for Decomposing a Formal Context into Fragments

Mongush Choduraa Mikhailovna[a], Ondar Sevil Kechil-oolovna[b], Bayyr Dolaan Borisovich[c] and Oorzhak Choygana Kamaevna[d]
Tuvan State University, 36 Lenina Street, Kyzyl, Russia
mongushchod91@yandex.ru, sevil.badyma@mail.ru, dolaan.bayyr@mail.ru, oorzhak-choygana@mail.ru

Keywords: analysis of formal concepts, fragmentation algorithm, formal context, combinatorial problem, the problem of finding the set of all formal concepts, computational experiments.

Abstract: The article presents the results of computational experiments. The following is evaluated: the effectiveness of the algorithm for fragmentation and defragmentation of the formal context with a single decomposition of the context; the number of fragments formed depending on the density of the original formal context; the number of possible iterations of the fragmentation process; the number of fragments and the running time of the algorithm for the context depending on the threshold value σ for the fragments being formed.

1 INTRODUCTION

This work continues the research started in the works (Mongush, 2019; Bykova, 2019), which are devoted to improving the performance of existing algorithms for solving the problem of finding all formal concepts by decomposing the formal context into fragments. In these works, to solve this problem, a method of fragmentation and defragmentation of the formal context without losing the sought-for formal concepts was proposed and proven. An algorithm implementing the proposed method has been developed. A detailed description of the algorithm is given in (Mongush, 2023). This paper presents the results of computational experiments to evaluate the effectiveness of the algorithm for fragmentation and defragmentation of the formal context.

2 BASIC CONCEPTS

We briefly present the basic concepts of formal concept analysis.

Formal Concept Analysis (FCA) is an applied direction of G. Birkhoff's lattice theory (Birkhoff, 1984). The main ideas of FCA were formulated in the works of R. Wille and B. Ganter in the early 80s of the 20th century (Ganter, 2011; Ganter, 2016). Based on the FCA method, the description of the term "concept" is formalized in the form of a pair (volume, content), object-attribute dependencies are visualized by constructing a lattice of formal concepts.

The formal context is an object-attribute table, represented as a triple $K = (G, M, I)$, where G is a set of objects, M is a set of features, and I is a binary incidence relation between G and M sets. The G, M sets are linearly ordered. Then the formal context K is uniquely defined by the (0, 1)-matrix T, where 0 means that $(g, m) \notin I$ object g does not have the attribute m, and in the matrix 1 denotes $(g, m) \in I$ – object g has the property m. An example of the formal context $K = (G, G, \neq)$ is presented in Table 1. This context corresponds to a (0, 1)-matrix, all elements of which are equal to 1, except for the diagonal elements.

Table 1: Formal context $K = (G, G, \neq)$.

0	1	1	1	1
1	0	1	1	1
1	1	0	1	1

[a] https://orcid.org/0000-0002-0006-4835
[b] https://orcid.org/0009-0003-8808-2505
[c] https://orcid.org/0009-0000-6904-7286
[d] https://orcid.org/0009-0009-0073-8770

1	1	1	0	1
1	1	1	1	0

In formal concept analysis, the problem of finding all formal concepts of a formal context is formulated as follows. The formal context $K = (G, M, I)$ is given, represented as a (0, 1)-matrix T. Find the set of all formal concepts of the formal context K.

In FCA, the formal concept is defined by a Galois map. Let $A \subseteq G$ and $B \subseteq M$. Then the Galois map for them is calculated using the formula:

$$A' = \cap_{g \in A} g' = \{m \in B \mid \forall g \in A \ (g, m) \in I\},$$

$$B' = \cap_{m \in B} m' = \{g \in A \mid \forall m \in B \ (g, m) \in I\}.$$

If for $A \subseteq G$ and $B \subseteq M$ the following is true

$$A' = B \text{ and } B' = A,$$

then the pair (A, B) is called the formal concept of the formal context $K = (G, M, I)$. In other words, the formal concept (A, B) of the context K with a (0,1)-matrix is a maximally complete submatrix of the matrix T, where the rows of this submatrix correspond to elements from A, and the columns correspond to elements from B. Here, a maximally complete submatrix is a submatrix, all elements of which are equal to 1 and which is not contained in other complete submatrices.

The set of all formal concepts of a formal context is denoted by FC. For the context $K = (G, G, \neq)$ from Table 1, the set FC contains exactly $2^{|G|}$ formal concepts. The number of formal concepts depends exponentially on the size of the original formal context. This problem belongs to combinatorial enumeration problems and has high computational complexity (Kuznetsov, 2004; Kuznetsov 2001).

Let $A_1, A_2 \subseteq G$ и $B_1, B_2 \subseteq M$. On the set of all formal concepts, we define the operations of union $\sqcup$ and $\sqcap$ intersection through the set-theoretic operations $\cap$ and $\cup$ as follows:

$$(A_1, B_1) \sqcup (A_2, B_2) = ((B_1 \cap B_2)', B_1 \cap B_2),$$

$$(A_1, B_1) \sqcap (A_2, B_2) = (A_1 \cap A_2, (A_1 \cap A_2)').$$

Then the ordered set of all formal concepts forms a lattice of formal concepts L. The lattice of formal concepts can be considered as a conceptual model of the domain. It defines classes of homogeneous objects and connections between them, which is the basis for solving applied problems of data analysis. Using FCA methods, it is possible to solve problems of classification, clustering, identification of dependencies between data, etc. ().

3 DECOMPOSITION ALGORITHM

Many algorithms have been developed to calculate the set FC and construct the lattice L (Qian, 2017; Simon, 2015; Poelmans, 2013). The running time of the algorithms in the worst case is $O(|FC| \cdot |G|^2 \cdot |M|)$. Since the value $|FC|$ exponentially depends on $|G|$ and $|M|$, the running time of these algorithms can also be exponential.

To date, research to reduce the computational complexity of the problem of finding all formal concepts is relevant. In the works (Mongush, 2019; Bykova, 2018), a method of fragmentation and defragmentation of the formal context is proposed. The idea of the method is that the original formal context is divided into various fragments. The fragments have different sizes and a nonempty intersection. Each fragment is further considered as a formal context and is decomposed again. As a result, a finite set of fragments is formed. Then formal concepts are found in each fragment using the well-known Close-by-One algorithm. The resulting formal concepts are combined and the sought-for set of all formal concepts of the formal context is formed. In the work (Mongush, 2019) it is proved that the method of fragmentation and defragmentation of the formal context is "non-distorting", i.e. each fragment contains at least one formal concept, when the context decomposes, the sought-for formal concepts do not disappear and new concepts do not appear. The process of context decomposition is performed iteratively. To stop this process, one must specify the number of iterations, and one can additionally enter a threshold for the density of fragments. Based on this method, an algorithm was developed, which is described in detail in the work (Mongush, 2023).

Theoretically, the computational complexity of the formal context fragmentation and defragmentation algorithm is high and amounts to

$$O(\sigma(K) \cdot |G|^2 \cdot |M|^2),$$

where $\sigma(K)$ is the density of the formal context, i.e. $\sigma(K) = ||T||/(|G| \cdot |M|)$ the ratio of the number of ones in the (0,1)-matrix T to the size of the formal context K.

The algorithm can be performed iteratively. If the number of iterations is equal to k, then the process of decomposing the original context into fragments by the algorithm takes $O(|G|^{2k} \cdot |M|^{2k})$ time. The iteration process can be stopped in two ways: fix the number of iterations k, and impose a limit on the density of the fragments formed σ. In this case, the running time of the algorithm will be polynomial relative to the size of the original formal context.

3 COMPUTATIONAL EXPERIMENTS

A number of computational experiments were conducted to analyze the effectiveness of the fragmentation and defragmentation algorithm of the formal context.

The first experiment is aimed at evaluating the effectiveness of the algorithm with a single decomposition of the context and without limiting the density of fragments. The results are presented in Table 2.

Table 2: Results of the first experiment.

	The size of the formal context	Time *t*, ms
Finding the *FC* set using the fragmentation algorithm	100×20	2,450
Finding the *FC* set in the simplest way		150,533
Finding the *FC* set using the fragmentation algorithm	200×30	91,200
Finding the *FC* set in the simplest way		810,530

The obtained result shows that finding the set of all formal concepts using the fragmentation and defragmentation algorithm of the formal context takes significantly less time compared to the algorithm without fragmentation.

The second experiment is aimed at estimating the number of fragments formed depending on the density of the original formal context at $|G|=100$, $|M|=20$, $k=1$. The results are shown in Table 3.

Table 3: Results of the second experiment.

The density of the original context σK	Number of fragments N	Time t, ms
0.1	137	11
0.2	261	108
0.3	466	506
0.4	677	1,760
0.5	826	3,234
0.6	828	6,262
0.7	883	10,974
0.8	402	14,438
0.9	478	15,004

From Table 3 it follows that the higher the density of the original context, the more time it takes to decompose the context once.

The third experiment is aimed at estimating the number of possible iterations of the fragmentation process and the time required to implement this process. The worst case is considered: $K = (G, G, \neq)$ at $|G|= 7$, $k=6$. The results are shown in Figures 1, 2.

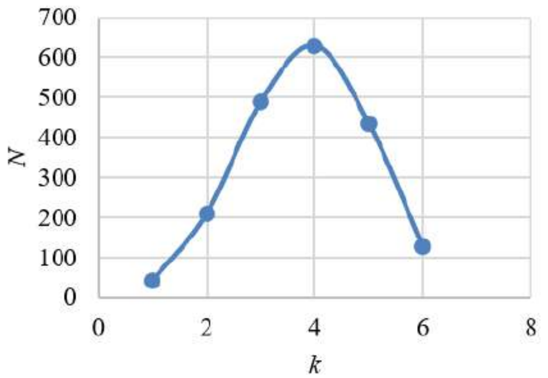


Figure 1: Dependence of the number of fragments N on the number of iterations k.

From these graphs it follows that an increase in the number of iterations leads to an increase in the number of fragments to be further decomposed, and for large values of k, the number of fragments and the time of decomposition of the formal context grow rapidly. Therefore, the value of k should be small and significantly less than $k << n/2$.

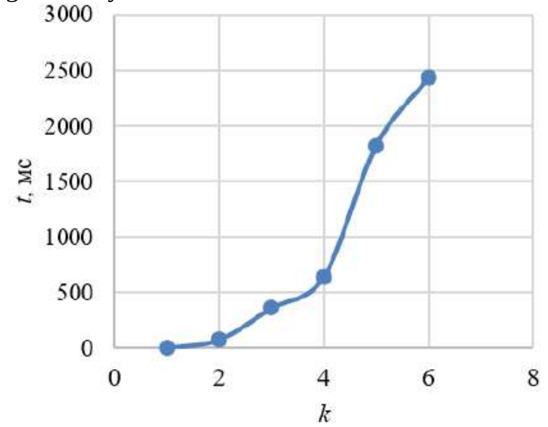


Figure 2: Dependence of the running time t on the number of iterations k.

The fourth experiment is aimed at estimating the number of fragments and the running time of the algorithm for the context, depending on the threshold value σ for the fragments being formed. Let's consider the context $K = (G, G, \neq)$. The evaluation was carried out at $|G|= 7$, $k=6$, $\sigma = 1$; $\sigma = 0.9$; $\sigma = 0.87$; $\sigma = 0.865$; $\sigma = 0.86$. The results are presented in Table 4.

From Table 4 it follows that the threshold value for the density of fragments to be further decomposed must be selected from the interval $\sigma_K < \sigma < 1$. If σ is close to or equal to one, for example, $\sigma = 1$ and $\sigma = 0.9$, then the number of fragments formed increases and, accordingly, the decomposition time of the formal context increases. If σ is close to σ_K, for example, $\sigma = 0.86$, then the formal context is decomposed into fragments once.

Table 4: Results of the fourth experiment.

$\sigma = 1$						
k	1	2	3	4	5	6
N	42	210	490	630	434	126
t, ms	1	75	360	640	1,820	2,430
$\sigma = 0.9$						
k	1	2	3	4	5	6
N	42	210	490	630	714	
t, ms	1	75	350	940	1,620	
$\sigma = 0.87$						
k	1	2	3	4	5	6
N	42	210	490			
t, ms	1	60	380			
$\sigma = 0.865$						
k	1	2	3	4	5	6
N	42	210				
t, ms	1	60				
$\sigma = 0.86$						
k	1	2	3	4	5	6
N	42					
t, ms	3					

4 CONCLUSIONS

Thus, the results of computational experiments showed the effectiveness of the developed algorithm if certain recommendations are followed.

REFERENCES

Mongush, Ch.M., Bykova, V.V., 2019. On decomposition of a binary context without losing formal concepts. Journal of Siberian Federal University. *Mathematics and Physics.* Vol. 12. № 3. P. 323–330.

Bykova, V.V., Mongush, CH.M., 2019. Dekompozicionnyj podhod k issledovaniyu formal'nyh kontekstov. *Prikladnaya diskretnaya matematika.* № 44. S. 113–126.

Mongush, CH.M., 2023. Algoritm fragmentacii i defragmentacii formal'nyh kontekstov. *Inzhenernyj vestnik Dona.* № 11.

Birkgof, G., 1984. Teoriya reshetok. M.: Nauka, 568 s.

Ganter, B., Wille, R., 2012. Formal Concept Analyses: Mathematical Foundations. Springer Science and Business Media.

Ganter, B., Obiedkov S.A., 2016. Conceptual Exploration. Berlin Heidelberg: Springer, 2016. 315 p.

Kuznetsov, S. O., Ganter, B., Eklund, B., 2004. Sertkaya Machine Learning and Formal Concept Analysis. 2th International Conference on Formal Concept Analysis. Berlin: Heidelberg. Vol. 2961. P. 287–312.

Kuznecov, S.O., 2001. Avtomaticheskoe obuchenie na osnove analiza formal'nyh ponyatij. *Avtomatika i telemekhanika.* № 10. S. 3–27.

Qian, T., Wei, L., Qi, J., 2017. Decomposition methods of formal contexts to construct concept lattices. *International Journal of Machine Learning and Cybernetics.* Vol. 8. No. 1. P. 95–108.

Simon, A. A., 2015. Best-of-Breed approach for designing a fast algorithm for computing fixpoints of Galois Connections. *Information Sciences.* Vol. 295. No. 2. P. 633–649.

Poelmans, J., Ignatov, D. I., Kuznetsov, S. O., Dedene, G., 2013. Formal concept analysis in knowledge processing: a survey on applications. *Journal of Mathematical Sciences.* Vol. 40. No16. P. 6538-6560.

Foresight of the Energy Transition Within the Framework of the Climate Agenda and Conditions of Geopolitical Turbulence

Igumnov M.A[1][1], Kim A.A[2][2], Pavlova E.A[1][3], Kim R.V[2][4], Nikonorova P.P[1][5]
[1]*IITMO University, Kronverksky ave., 49, lit. A, St. Petersburg, Russian Federation, 197101*
[2]*OOO Rusgazburenie, Nametkina Street, 12., St. Petersburg, Russian Federation, 197430*
Sim4ikgood@mail.ru, ea_pavlova@mail.ru, kim@rusgazburenie.ru

Keywords: energy transition, decarbonization, geopolitical turbulence, energy security, climate agenda.

Abstract: Currently, the world community is facing the acute problem of climate change, the consequences of which have a significant impact on the environment, food security, life and health of people around the world. Both environmental and social spheres are under threat. Greenhouse gas emissions emitted as a result of anthropogenic activities are peculiar catalysts of this process. The study of climate change problems and the development of measures aimed at the formation of energy security is on the agenda of many leading companies in the world. This paper analyzes the forecasts of energy sector development scenarios from IRENA World energy transitions-2022 and E.ON Forecast Digest Zeroing in on the Energy Transition-2022 in the prism of the climate agenda, as well as non-financial disclosure reports of a number of major energy companies, such as ExxonMobil, BP, Shell. In addition, the authors provide their own alternative development forecast, based on the current geopolitical situation and life-cycle analysis of renewable energy production, related to opacity, carbon footprint and environmental impact produced.

1 INTRODUCTION

The serious political crisis we have been witnessing for several years has led to significant changes in geopolitical interactions in the energy sector, creating a real threat to energy security by disrupting previously established supplies of traditional energy resources. This situation has emphasized the heavy dependence of many countries on these resources, especially in the context of the global drive to reduce carbon emissions and combat climate change. In response to these challenges, the global community is actively seeking alternative energy sources and strategies to ensure a sustainable and secure energy future.

Russian oil and gas supplies to the European Union have been suspended indefinitely, which has become a catalyst for rethinking energy policy and accelerating the transition to low-carbon energy. This decision has triggered the need for new comprehensive and sustainable infrastructure investment plans to meet climate targets by 2030. In this context, renewable energy sources such as solar, wind, hydro and green hydrogen are of particular importance, offering an alternative to conventional energy sources and helping to reduce dependence on fossil fuels.
Thus, the current geopolitical situation and related energy challenges actualize the issues of sustainable energy development, search for new energy sources and rethinking traditional approaches to energy security and environmental sustainability.

2 MATERIALS AND METHODS

Purpose of the study – analyze the forecast scenarios of the energy sector development in the context of the

[1] https://orcid.org/0009-0000-3733-8062
[2] https://orcid.org/0009-0007-7493-1755
[3] https://orcid.org/0000-0001-6492-7102
[4] https://orcid.org/0009-0005-6832-7290
[5] https://orcid.org/0009-0002-5058-3091

climate agenda and annual non-financial reports of major oil and gas companies in order to form an alternative forecast taking into account the current geopolitical and energy turbulence.

The research uses data from many information sources that are listed in the list of references, general scientific empirical and theoretical methods, methods of comparative analysis.

3 RESULTS

Russian oil and gas supplies to the European Union have been suspended indefinitely. European leaders interpret the current circumstances as a new impetus for the development of low-carbon energy, as well as for the development of new comprehensive and sustainable infrastructure investment plans that will help the world meet climate goals by 2030. Among the renewable energy sources that can serve as substitutes for conventional energy sources are solar, wind and hydropower. Also, one such source is green hydrogen, the production of which is planned to be increased by EU countries. The lower cost of oil and gas makes hydrogen more competitive.

Thus, the German company Energiewende sets ambitious goals, assigning to wind farms and photovoltaics the decarbonization of 85% of the electricity supply sector by 2050. It is expected that their share will reach 60% of the total energy volume. At the same time, the company plans to completely exclude nuclear energy. The above-mentioned examples illustrate the formation of a sustainable orientation of energy giants towards the goals of achieving climate goals, including achieving carbon neutrality.

However, according to Reuters, as of March 29, 2023, 27 countries of the NATO bloc continue to import Russian energy resources, putting energy stability and security above political differences. The authors of the article consider this fact as an additional factor in the possible divergence of analysts' forecasts for the development of the energy sector in the near future.

According to experts' opinions, the decarbonization policy in Russia, including the development with the prospect of introducing carbon credits, is likely to be revised, since the driver of these measures was not only the climate agenda, but also trade and export relations with the European Union, which initiated and actively supports measures on transboundary carbon regulation.

4 AN ANALYSIS OF CHANGES IN THE COST AND AVAILABILITY OF DIFFERENT TYPES OF RENEWABLE ENERGY REVEALED THE FOLLOWING RESULTS

According to Reuters, in 2022, the cost of “gray” hydrogen produced from natural gas by steam reforming in Europe increased to $ 12 per kilogram. While green hydrogen from Spain, produced using solar panels, costs only $ 4. Also, the increase in the availability of energy obtained with the help of renewable energy sources (RES) is indicated by statistics on price reduction. The cost of solar energy decreased by 85%, concentrated solar energy by 68%, onshore wind energy by 56% and offshore wind energy by 48%. Today, renewable energy is the main target area for investments by large energy and chemical companies.

In addition, it is known that various types of biofuels have already been created and are being used for land, rail, sea and air transport. Thus, the oil and gas giant BP, together with BUNGE, launched 11 biofuel plants with a capacity of 32 million tons per year.

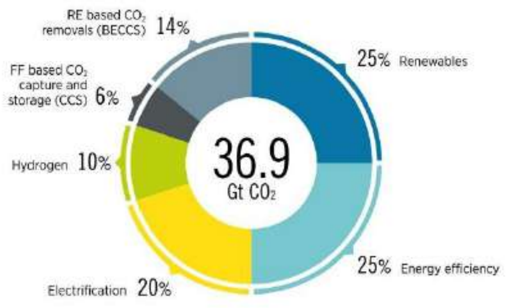


Figure 1: Reducing emissions by 2050 through six technological approaches (source IRENA Agency).

As part of the presented research review, the International Renewable Energy Agency (IRENA) formulates an optimistic forecast for achieving global carbon neutrality by 2050, assuming the integration of six advanced technological approaches detailed in Figure 1. The deployment of renewable energy sources (RES) and the improvement of energy efficiency, which account for approximately 25% of the potential for reducing carbon emissions, are highlighted as fundamental elements of this transformation. In addition, electrification of transport and other sectors of the economy plays an important role, emphasizing the need to switch to low-carbon energy sources.

Additional coverage of this topic is provided in Figure 2, which illustrates the expected reduction in greenhouse gas emissions from the energy sector between 2018 and 2030. The data provided by the IRENA agency reflects the projected trajectory of reducing emissions as intermediate steps towards achieving carbon neutrality. These data highlight the importance of the previously mentioned technological strategies and provide a quantitative measurement of progress towards a sustainable energy future.

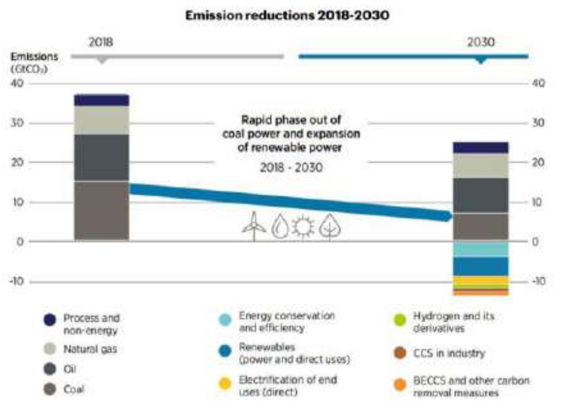


Figure 2: Expected reduction of greenhouse gas emissions from the energy sector in the period from 2018 to 2030.

The key principles of the future energy sector will be carb-free, decentralized and digitalized processes.

As the Energy transition gathers momentum, major European oil and gas companies (BP, Shell, Total, Equinor, Repsol and ENI) are adapting their businesses to meet both growing energy demand and reduce their carbon footprint over the next decade and beyond. All of them have set zero emissions targets for their businesses. Although oil and gas are expected to continue to dominate their business in 2030, there is a growing desire to increase the share of renewable energy sources (primarily wind and solar), as well as to increase natural gas production. In addition, these companies are participating in projects for the production of blue and green hydrogen, as well as increasing capacities for the use of CCUS carbon dioxide capture and utilization technologies.

The companies have formulated their strategic goals and plans for the development and use of renewable energy sources (RES) for a long period of time, focused on 2030 and 2035. Currently, these companies account for about 13 GW of installed renewable capacity (according to the February 2021 disclosure), led by Total at 7 GW (about 55%). Solar energy and onshore wind account for about 85% of the total capacity of all devices and equipment capable of producing electricity from renewable energy sources that have been installed and connected to the grid at the moment.

Major European oil and gas companies have said they will evaluate renewable energy projects with an assessment of the level of financial barriers. This means that they plan to analyze the economic viability of such projects and identify possible obstacles to their implementation that are associated with costs or financial risks. Companies also believe that they can increase the profitability of renewable energy projects by combining their operational experience, financing structures, integrated operations and portfolio rationalization.

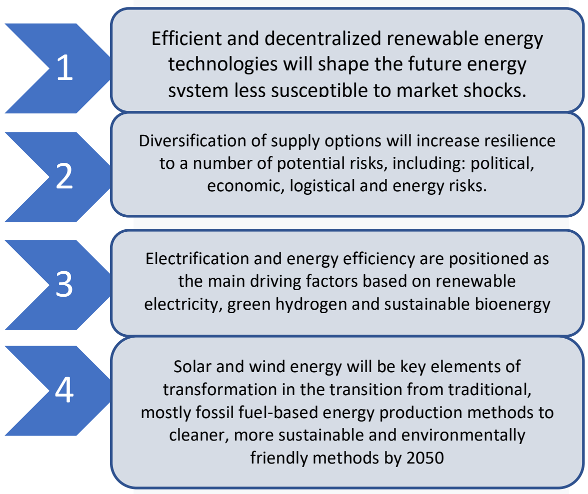


Figure 3: Key directions of global energy development in the 2050 horizon. Positive outlook (compiled by the authors).

An analysis of the annual non-financial statements of companies focused on European Union standards revealed widespread adherence to the principles of environmental, social and corporate responsibility (ESG). Companies operating within the EU or strongly associated with it integrate aspects of sustainable development into their strategic and operational activities, taking into account not only economic results, but also environmental and social impacts, as well as the quality of corporate governance. This approach highlights the companies' commitment to comply with pan-European efforts to promote a green economy and transition to sustainable business models, which is reflected in their investment strategies and participation in projects.

So SHELL, which decided to support the Paris Agreement and its climate goals, has developed measures for its decarbonization policy, having achieved some success in this, reducing carbon emissions by 30% compared to 2016.

The company intends to become a zero-carbon energy company through significant investments in solar, wind energy, biofuels and hydrogen. SHELL has invested $2 billion in the Denmark's Nature Energy project, which produces renewable gas from household, agricultural and industrial waste. In addition, in 2022, the company invested $8.2 billion in low-carbon energy and products not related to the energy sector, of which $ 4.7 billion in biofuels, hydrogen, charging stations for electric vehicles and renewable energy sources. Commitment to a positive outlook is also confirmed by the company's construction of the Holland Hydrogen 1HYDROGEN RACE plant, which will be built in 2024 on 2,000 hectares of alluvial areas, using new environmentally friendly construction technologies. The plant will produce up to 60,000 tons of green hydrogen per year.

Table 1: Investments by leading energy companies.

Company	**Projects and Initiatives**	**The Volume of Investments**	**The Main Directions**
Rosneft	Various environmental projects	57 billion rubles (2022)	Improving environmental safety, preserving biodiversity
Lukoil	Modernization of processing facilities	More than $14 billion	Increasing the depth of processing, production of ecological class "Euro-5"
Valero Energy	Production of "green" diesel	Not specified	Development of biofuel production
Saudi Aramco	Production of green hydrogen and ammonia	Not specified	Achieving zero greenhouse gas emissions by 2050
Sinopec	Construction of a plant for the production of green hydrogen	5.7 billion yuan ($830 million)	Production of green hydrogen and oxygen

A much less positive foresight is presented by the E.ON forecasting agency, which sees the implementation of the above-mentioned principles as difficult to implement. In addition, the analysis casts doubt on the speed of energy transfer, assuming that it will last longer than planned, which will require the introduction of renewable, clean and intelligent technologies. The forecast also identifies risks related to carbon dioxide capture and burial technologies. Concerns have been expressed that the buried CO2 will come to the surface sooner or later. The storage of radioactive waste from nuclear power also raises doubts about the safety of environmental and human health impacts. The analysis of the report indicates that there is also an underestimated barrier that can significantly slow down the energy transition and the development of alternative energy in general. Alternative energy is faced with a shortage of qualified personnel. The situation is expected to worsen, as significant time and resources are needed to create and test new educational programs.

As of 2020, about 12 million people are employed in the renewable energy sector in the world, in 2030 it is expected to increase to 38 million, and in 2050 to 43 million workers. In the coming years, there will be a massive retraining of workers in the oil and gas sector, the number of jobs in which will be reduced to 6.9 million people by 2030. On the contrary, the number of employees in the hydrogen sector will increase to 2 million by 2030.

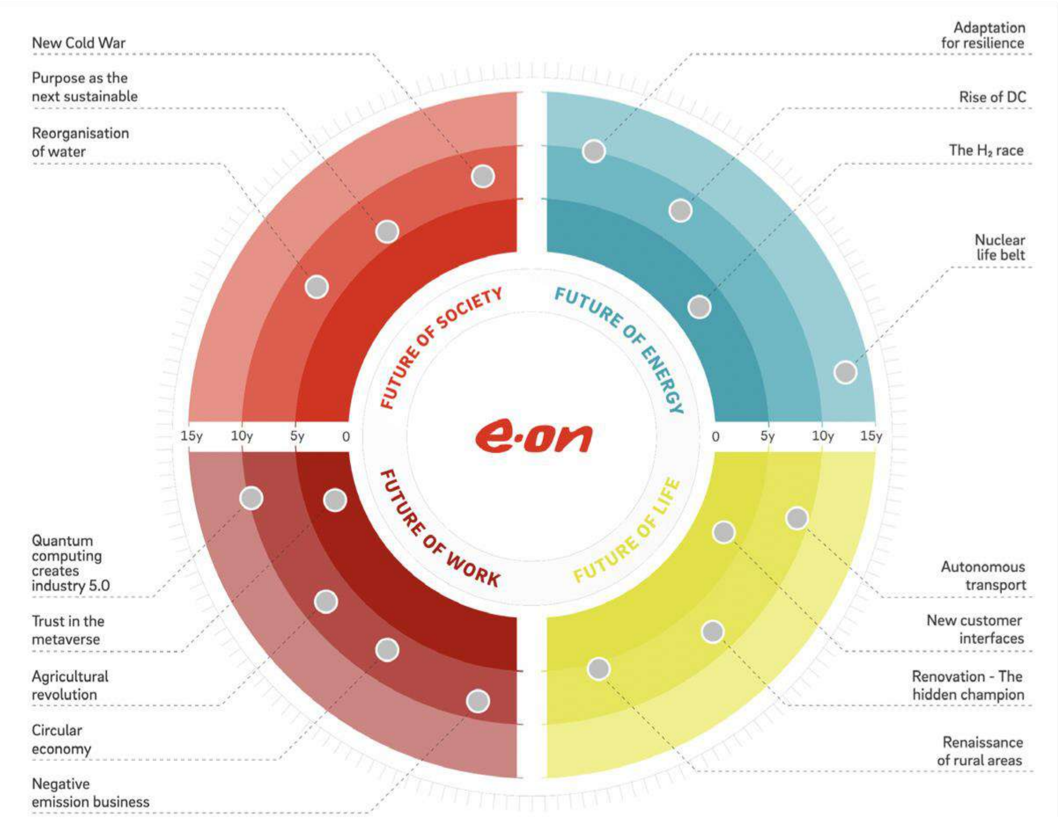


Figure 4: E.ON's energy sector development forecast for the next 15 years.

According to E.ON's forecast, a kind of hydrogen race will take place in the energy sector in the next 5 years, which will be stimulated by the introduction of carbon credits. Investments in projects for the production of green hydrogen and other sustainable energy resources, such as biogas, will help companies with a difficult-to-reduce carbon footprint achieve the desired performance. Turning to the topic of the hydrogen race, it can be argued that the introduction of carbon credits makes investments in clean technologies such as hydrogen energy more attractive. Hydrogen is considered a key element in the transition to a low-carbon economy because its use as a fuel does not lead to CO2 emissions. As a result, companies investing in the development and distribution of hydrogen technologies can potentially benefit economically from carbon credits by reducing their own greenhouse gas emissions and selling credits to those looking for ways to offset their emissions.

In the next 10 years, it is expected to strengthen the position of electrification of transport, but in 15 years, due to the insufficient effectiveness of decarbonization measures and instability of renewable energy sources, the gradual depletion of fossil resources, there will be a forced change of vector to nuclear energy.

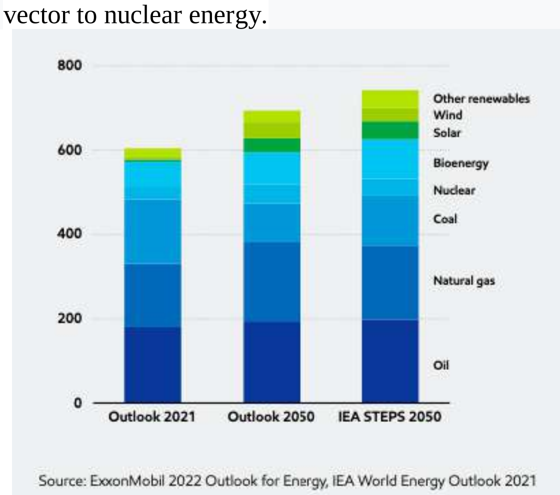


Figure 5: Comparative chart on the estimated ratio of types of energy resources by 2050 (source ExxonMobil 2022 Outlook for Energy, IEA World Energy Outlook 2021).

A comparison of 3 Outlook 2001 forecasts, Outlook 2050 IEA STEPS 2050, shows a slight discrepancy in the percentage of oil, gas, coal, nuclear energy, biofuels, solar, wind and other renewable energy sources. The main volume is occupied by traditional energy sources. There is an obvious discrepancy with the forecast of the IRENA agency.

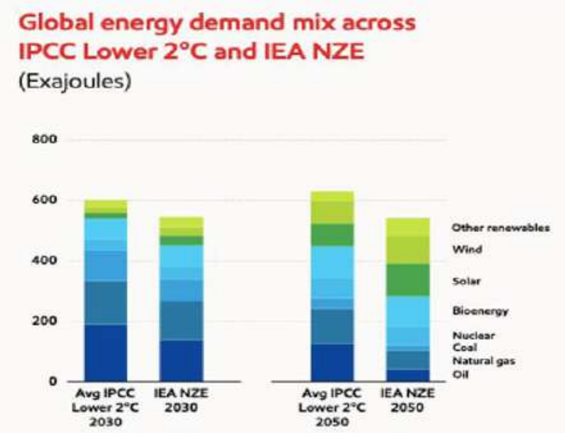


Figure 6: Comparative diagram on the estimated ratio of types of energy resources by 2030 and 2050 in the Net Zero Emission concept (source ExxonMobil analysis, IEA World Energy Outlook 2021, IPPC Sixth Assessment Report).

The diagram above (Fig. 6) presents a more extreme forecast based on the goal of limiting the temperature rise to 1.5 C. When making the forecast, we started from the final critical point for curbing global warming within 2 degrees C.

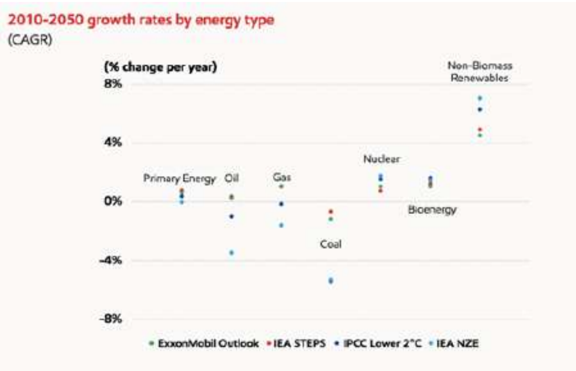


Figure 7: Comparative diagram of the estimated change in the ratio of energy resources in 2050.

Figure 7 shows the most noticeable discrepancies in the forecast from the agencies regarding the use of oil, gas and coal. The greatest coincidence, according to the agencies, concerns biofuels. Obviously, this is the absolute advantage of the NSE IEA (net zero emission).

Figure 8: Long-term goals of oil and gas corporations for the total increase in renewable energy capacity (source Westwood Global Energy Group).

Figure 8 shows how different the goals for capacity building in renewable energy projects are. Thus, Shell has not yet confirmed its measurable goals, while TOTAL has set a goal to increase its renewable energy capacity to a significant level by 2030. This reflects the different approaches to the strategy of sustainable development in the energy sector. While Shell has not yet decided on specific goals, TOTAL is actively investing in solar and wind energy projects, aiming to become one of the leaders in the field of green energy. This difference in strategies may be due to various factors, including corporate policies, market conditions, and regulatory requirements in different countries.

The conducted study of forecast scenarios for the development of the global energy system presented by international rating agencies allows us to conclude that in the next 5 years, hydrogen energy will develop rapidly. The key challenges are related not only to the high cost of producing green hydrogen, the high cost of carbon dioxide capture and burial technologies in the production of blue hydrogen (Dawood, 2020), the search for new ways to commercialize large amounts of solid carbon as a by-product in the production of turquoise hydrogen, the lack of infrastructure, but also with recent research presented by Bloomberg in 2022, indicating that the influence of inevitable hydrogen leaks in 20 years will lead to an even greater rate of temperature increase and deterioration of climatic indicators, than emissions from the combustion of oil, gas and coal.

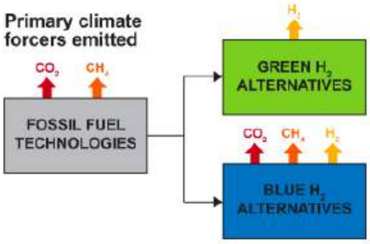


Figure 9: Comparison of emissions from traditional fuels and hydrogen (Dawood, 2020).

Figure 9 clearly shows that the production and use of blue and green hydrogen, which are regarded as the main methods for achieving decarbonization of the energy and transport sectors, along with traditional energy sources, are accompanied by the emission of gases that negatively affect the rate of global warming.

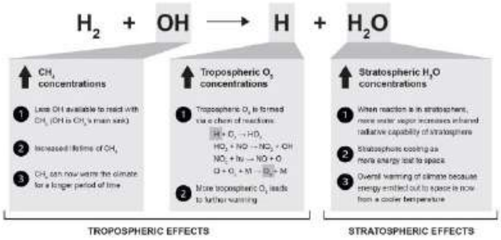


Figure 10: The effect of hydrogen leaks on the heating of the troposphere and stratosphere (Dawood, 2020).

Figure 10 shows the chains of chemical reactions triggered by hydrogen leaks. As can be seen, the effect is associated with the interaction of hydrogen with other components of air and gases. At the same time, the warming effect occurs both in the troposphere and in the stratosphere, so hydrogen can significantly accelerate the process of global warming, which contradicts the goals of the climate agenda.

The research results (Labidine, Messaoudani, Rigas, Hamid, Hazards, 2016; Konishchev, Semenov, CHaban, Lobanova, Kashkovskij, 2019; Abdalla, Hossain, Nisfindy, Azad, Dawood, Azad, 2018) also indicate a number of unresolved difficulties and challenges associated with the use of hydrogen, including its ability to reduce the ductility and strength of metals, which entails regular and significant costs for replacing pipelines, increasing the economic inexpediency of using hydrogen.

Comparative analysis of various forecasts for the development of the energy sector from different agencies and companies

4 DISCUSSION

Based on the analysis, the authors have developed their own vision for the forecast of energy development in the world. Recent studies indicate that hydrogen is likely to be removed from its role as the main tool for decarbonizing the energy and transport sectors. It may take from 5 to 10 years until the moment of complete abandonment, since long-term projects for the development of hydrogen technologies and production have already been launched, entire hydrogen clusters are developing, including in Russia, and the hydrogen infrastructure is being built up. At the same time, hydrogen production using methane pyrolysis (turquoise hydrogen) will be the most appropriate, since despite the development of technologies for carbon dioxide capture and storage, the economic feasibility and long-term effectiveness are questionable. While many large enterprises and government institutions have already taken steps and investments to slow global warming, there is a risk that the progress made may require reassessment and adjustment due to new circumstances and research results.

The authors of the article see significant potential in the development of biofuel production, since the population is growing, and economic growth entails an increase not only in energy consumption, but also in household overconsumption in general, which affects the growth of waste volumes that can be recycled into energy.

At the same time, the authors suggest that traditional fuel sources will prevail over alternative ones in the coming decades, since the production of equipment for solar panels and wind farms requires fossil resources that are at risk of depletion. It is also important to take into account the fact that most of such equipment is currently manufactured in China, while coal is often used as an energy resource, the dirtiest type of fuel in terms of greenhouse gas emissions. The need to transport equipment and the lack of technologies for full-fledged recycling of used equipment complements the already significant carbon footprint.

5 CONCLUSION

Despite the discrepancies in the forecasts of different agencies on the distribution of the energy mix in the short and long term, all analyzed sources show unanimous support for the climate agenda and emphasize the need to continue developing and implementing measures to curb the growth of global warming despite emerging geopolitical factors. This means that the course towards the development of low-carbon energy will be continued. Geopolitical tensions have had a significant impact on the revision of scenarios and the postponement of the implementation of projects to reduce the carbon footprint. Based on the studies reviewed in the article concerning the effect of hydrogen leaks on the rate of climate change, the place of hydrogen as a leading decarbonization tool will be taken by biofuels, including those produced from waste. The introduction of measures aimed at developing a closed-cycle economy, breaking the link between economic growth and the volume of household and electricity consumption, will also have a great impact on decarbonizing economies.

REFERENCES

https://www.eon.com/en/innovation/future-of-energy/intelligent-networks/energiemonitor-the-german-technology-spearheading-energy-transparency.html

https://www.dp.ru/a/2022/04/22/Suverennaja_dekarbonizaci

ZHurnal Neftegazovaya vertikal' «Metan, vodorod, uglerod: novye rynki, novye vozmozhnosti» https://ngv.ru/articles/metan-vodorod-uglerod-novye-rynki-novye-vozmozhnosti/?sphrase_id=4200390

https://www.eni.com/en-IT/operations/energy-evolution/biorefineries.html

https://www.bp.com/en/global/corporate/news-and-insights/reimagining-energy/bp-expands-biofuels-business-in-brazil.html

World Energy Transitions Outlook 2022 https://www.irena.org/Digital-Report/World-Energy-Transitions-Outlook-2022

https://www.weforum.org/events/world-economic-forum-annual-meeting-2023/about/meeting-overview

https://www.ru.shell/about-us/powering-progress/achieving-net-zero-emissions.html

https://teknoblog.ru/2022/07/07/118094#

https://www.eon.com/en/innovation/future-of-energy/eon-trend-radar.html

https://corporate.exxonmobil.com/?utm_source=google&utm_medium=cpc&utm_campaign=1ECX_GAD_TRAF_OT_Brand_ExxonMobil+BM&utm_content=OT_Brand_Exxon_BM&utm_term=exxon&gad_source=1&gclid=EAIaIQobChMIqsy30KvkgwMVtkBBAh1QNgLeEAAYASAAEgJqT_D_BwE&gclsrc=aw.ds

Dawood, F., 2020. Hydrogen production for energy: An overview. *International Journal of Hydrogen Energy.*

Climate consequences of hydrogen emissions Ilissa B. Ocko and Steven P. Hamburg Environmental Defense Fund, New York, NY, USA

https://www.edf.org/blog/2022/03/07/hydrogen-climate-solution-leaks-must-be-tackled

Labidine, Z., Messaoudani, F., Rigas, M.D.B., Hamid, C.R.C., Hazards, H., 2016. safety and knowledge gaps on hydrogen transmission via natural gas grid: A critical review. *International Journal of Hydrogen Energy.* Vol. 41. № 39. P. 17511-17525.

Konishchev, K.B., Semenov, A.M., CHaban, A.S., Lobanova, N.A., Kashkovskij, R.V., 2019. Osobennosti mekhanizma korrozionnogo rastreskivaniya pod napryazheniem metalla trub v sredah, soderzhashchih serovodorod i dioksid ugleroda. *Vesti gazovoj nauki.* № 3 (40). S. 60-66.

Abdalla, A.M., Hossain, S., Nisfindy, O.B., Azad, A.T., Dawood, M., Azad, A.K., 2018. Hydrogen production, storage, transportation and key challenges with applications: a review. *Energy conversion and management.* Vol. 165. P. 602-627.

Alternative Forms of Employment for Population in Rural Areas as Part of Sustainable Develop Problem: Cognitive Model

Kozlova O.A.[1][a], Kopylova Y. V.[1][b], Luchko O.N.[2][c], Marenko V.A.[3][d]
[1]*Omsk State Agrarian University named after P.A. Stolypin, Omsk City, Russia*
[2]*Omsk Humanitarian Academy, Omsk City, Russia*
[3] *Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences, the city of Novosibirsk, Russia*
oa.kozlova@omgau.org, yulia.kopylova.1983@yandex.ru, marenko@ofim.oscsbras.ru, o_luchko@rambler.ru

Key words: alternative employment, sustainable development, rural areas, modelling, cognitive model, expert methods, simplicial analysis.

Abstract: The urgency of the problem of rural dwellers' employment in the context of the task of sustainable development of rural areas is a crucial issue affecting numerous aspects of public life and the economy. Lack of permanent employment with decent pay makes rural residents look for new sources of income outside villages. This article aims at considering alternative employment for the population as the foundation for sustainable development of rural areas, which involves application of various means for data analysis. To achieve the goal, we have conducted a sociological poll among public and government officials at different levels. The results of the polls have been used to make graphic models of certain aspects of the problem. Within the theme of the research, we have performed cognitive modelling, which, among other things, includes the process of finding facts influencing the subject of the study, as well as building and analyzing the cognitive model. The results of the cognitive modelling have shown that factors like "instability" of life conditions, "insufficient qualification of workers", "loan benefits", "attracting employers", and "entrepreneurial activity" are the most functionally important factors for the development of alternative forms of employment in rural areas. We recommend administrative authorities using those factors for strategic planning and supporting managerial decision-making for sustainable development of rural areas.

1 INTRODUCTION

Today, in administering rural areas, officials face numerous problems that include negative trends of the urbanization process. Rural dwellers' migration to cities and towns often stems from their aspiration for better quality of life, which includes access to better education and health services, as well as effective employment opportunities. International experts find that, as cities and towns offer broad opportunities for employment, education, and access to highly qualified health services, such conditions of life attract people from rural areas. On the other hand, rural dwellers' migration to cities and towns might promote urbanization and modernization of rural areas, as dwellers who stay might use resources available to develop small and medium non-agricultural businesses. Such solution of the issue might help reduce the level of poverty in the remaining population, improve the quality of life in rural areas and, consequently, enhance sustainable development of rural areas (Islam, Rashid, Howlader, Ahmed, 2011; Bjerke, Mellander, 2022). Applying data received from public polls and using MATLAB software, we have built a model for sustainable development of rural areas using "rural tourism" as an example form of employment. The results have shown that the "financial support" component of the model is the cornerstone of sustainable rural tourism (Asadi, Jabbari, 2022).

[a] https://orcid.org/0000-0002-5422-219X
[b] https://orcid.org/0000-0003-3221-185X
[c] https://orcid.org/0000-0001-8476-8954
[d] https://orcid.org/0000-0001-7288-9353

Russian specialists also write that rural territories, remote from centers of economic activity, and unequal conditions of life between rural dwellers and urban residents result in mass out migrations from rural areas (Lebedeva, Sabinov, Shatalova, 2021). Russian researchers also see low quality or total lack of social infrastructure, jobs, insufficient transport accessibility, limited access to end markets, technological, financial, and informational resources as causes for rural dwellers' out migration (Chudinova, Mitrofanova, 2021). Low social protection and level of life of the rural population, as well of lack of alternative employment opportunities are the reality of village life (Petrikov, 2021). Declining rural population is fraught with the risk of social desolation of Russian territories. That is why sustainable development of rural settlements is one of the currently urgent areas of the socioeconomic policy of the Russian administration (Kopylova, Kozlova, 2024).

One of prioritized areas of sustainable development of rural territories is creating conditions for growth of non-agricultural businesses, or alternative employment. The form of employment can be implemented through different types of small and medium entrepreneurship. In practice, that can be collecting, storage, and processing of wild fruit and berries; retail; agricultural product storage, processing, and selling; transportation services and many other businesses. Moreover, today, amid the active growth of Internet resources, that might include any kind of online, remote job. Creating additional jobs with decent pay will help constrain urbanization processes that have been witnessed so far.

The purpose of writing this article is to analyze the results of the problem under study, which is actualization of the rural dwellers' need in alternative employment and, consequently, sustainable development of rural territories. To achieve the purpose, we have conducted a poll to get primary data, have built graphic models as diagrams, and have performed cognitive modelling of the problem being studied.

2 BUILDING GRAPHIC MODELS

We have conducted a poll in the Ural Federal District (UrFD). Our respondents were government officials at different levels (421 people), who had outlined the main causes for rural population migration as follows (See fig. 1):

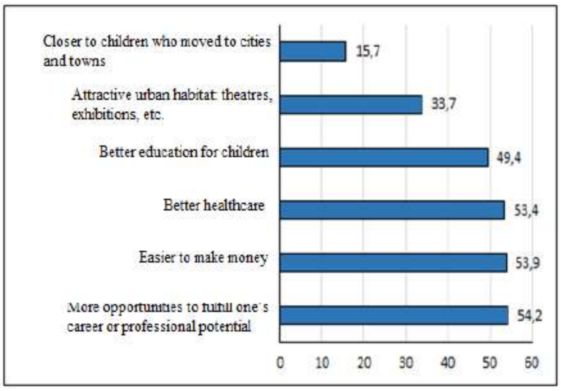


Figure 1: Causes for rural population migration in UrFD.

On Figure 1 and onwards, the sum of votes exceeds 100% as every respondent might have choses several answers at a time. Figure 1 shows that most votes came for the answer showing that people were willing to fulfill their potential in careers not associated with agriculture; however, villages offer insufficient opportunities for that. Municipal officials in the UrFD believe that following causes might help stop the out migration from rural areas:

- high pay;
- social guarantees;
- providing free accommodation/ house/ apartment;
- interesting jobs available;
- opportunities for fulfilling personal potential;
- remote job opportunities (See fig. 2).

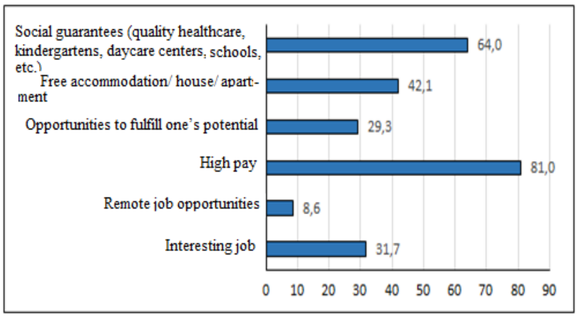


Figure 2: Possible causes for residents' return to rural areas.

Therefore, the main reason that can bring rural dwellers back to villages from cities and towns is high pay, according to UrFD officials. That level of wages cannot be provided for through traditional employment. The problem can be solved through alternative businesses only.

Alternative forms of employment in rural areas play an important part in diversifying the income of rural dwellers and improving their welfare. Figure 3 represents the results of the poll among UrFD municipal officials concerning alternative employment of the population.

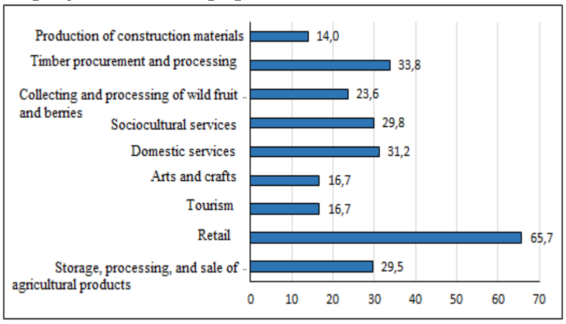


Figure 3: Types of alternative employment in rural territories.

Figure 3 shows that retail, timber procurement, and domestic services are the main types of employment for rural dwellers. Self-employment is a form of labor that has been gaining weight because of the simplified procedure of getting the status, low tax rates, and the lack of strict reporting requirements it offers.

Modern science pays specific attention to dynamic characteristics of phenomena studied. T.A. Nestik suggested interpreting social time as direct adaptation of human perception of information in close connection with the change of environment (Polunin, Alakoz, Cherkashin, 2020). That is why we conducted polls to score the level of unemployment among rural dwellers from 1 to 5 in 2022 and 2023 to compare (See fig. 4).

Figure 4: Scoring the level of unemployment among rural dwellers.

Figure 4 shows the scaled number of answers illustrating the immediacy of the problem of unemployment. Figure 4 demonstrates that in 2023, the criticality of the problem under consideration declined substantially, as the solid line is below the dashed one.

3 BUILDING THE COGNITIVE MODEL

Scientific literature surveying has proved that the development of alternative forms of employment for rural populations represents a diverse spectrum of activities, which includes both standard and unconventional forms of labor, whose advantages and disadvantages are mostly studied using statistic researches. We suggest using cognitive modelling that allows structuring and analyzing the problems by singling out the key factors that affect the development of strategies to improve the activity of the subject under research. Cognitive modelling not just allows analyzing the problems, it also suggests options for their management strategies.

The cognitive model of the problem studied is represented as a mathematical structure, a weighted directed graph G=(V, E), where V=$\{v_i, v_j\}$ is a vertex set of the cognitive model, E={eij} is an arc set; i, j=1, 2, …, n (Nestik, 2011). The rule where each $v_i \in$ V element of the cognitive model is linked with other $v_j \in$ V elements is represented by the n-ratio $r(v_i, v_j)$. The research by cognitive modelling is performed using the scheme as follows. A survey of scientific literature is performed to find out reference factors that are concepts of the topical area, positively or negatively affecting the subject of research. In our research, such factors are “population employment”, “loan benefits”, “income diversification”, “creating new opportunities”, etc. Then, cause and effect relationships are found between the factors using expert reasoning under the “if A, then B” scheme, where A is cause and B is effect. For example, “if touristic attraction of a rural territory is high, then employment of the population is high”, “if attracting employers is high, then employment of the population is high”, etc. Direct and reverse causalities between the factors are supported by expert-approved scoring within the [-1; 1] interval and are found using expert methods (Fig. 5).

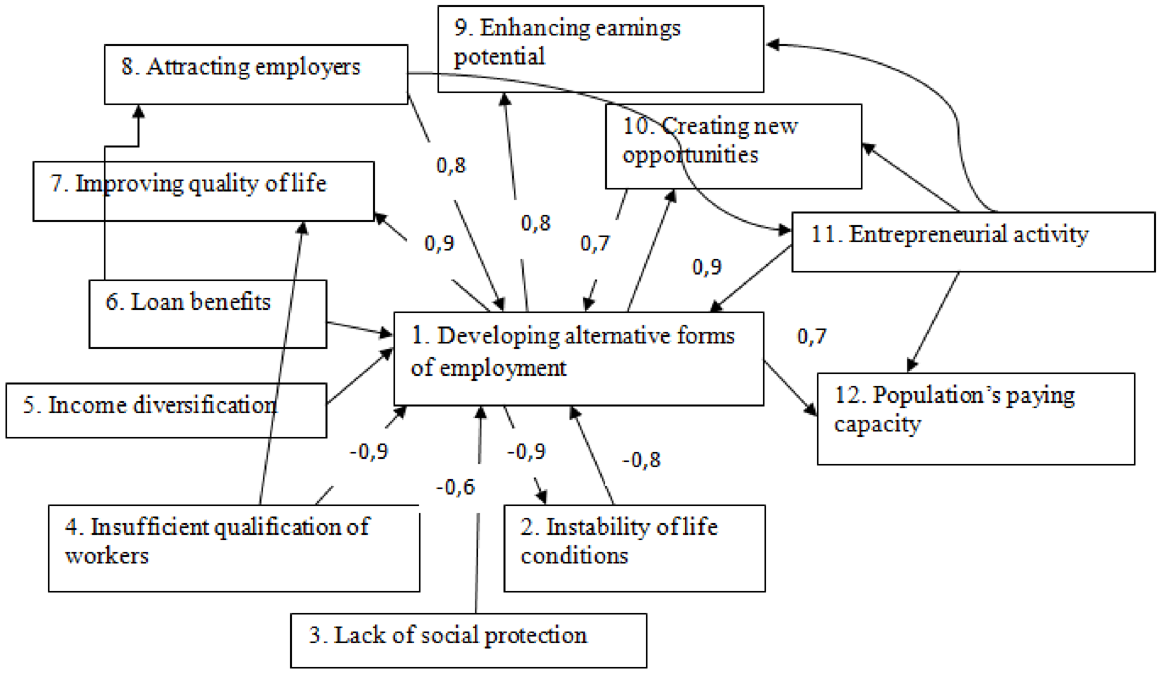


Figure 5: "Developing Alternative Forms of Employment" cognitive model.

The cognitive model is then subject to simplicial analysis to find out implicit connections between the factors (Luchko, Marenko, 2014). The simplicial analysis applies concepts like incidence matrix, simplex, complex, and other terms. In our research, simplicial complexes have been studied using the incidence matrix consisting of twelve simplexes. The analysis started with the greatest connectivity and ended with zero connectivity. The line with the greatest number of elements is line one, corresponding to the x1 factor "developing alternative forms of employment", which consists of eight units. The greatest connectivity of the complex is q=7.

Results of the calculation procedure for the KY(X, R) complex:

q=7 Q7=1 {x1}
q=6 Q6=1 {x1}
q=5 Q5=1 {x1}
q=4 Q 10=2 {x1}{x10}
q=3 Q3=3 {x1 x11}{x10}{x7}
q=2 Q2=3 {x1 x11}{x10}{x7}
q=1 Q1=3 {x1 x11}{x10 x9 x12}{x7}
q=0 Q0=1 {all}

The KY(X, R) complex on its third connectivity level has the first connected component {x1 x11}, which shows that upon including a control action in the vertex of directed graph V11 "entrepreneurial activity", the vertex of directed graph V1 "developing alternative forms of employment" will respond to that action.

Results of the calculation procedure for the KX(Y, R) complex.

Column one of the incidence matrix of the directed graph contains the biggest number of elements, five. The connectivity level of the complex equals four.

q=4 Q4=1 {x1}
q=3 Q3=2 {x1}{x11}
q=2 Q2=5 {x1}{x11}{x2}{x4}{x6}
q=1 Q1=3 {x1}{x11}{x8 x2 x4 x6}
q=0 Q0=1 {all}

The KX(Y, R) complex on its first connectivity level has a connected component that shows that upon including a control action in the vertex of directed graph V2 "instability" of life conditions, V4 "insufficient qualification of workers", or V6 "loan benefits", the vertex of directed graph V8 "attracting employers" will respond to the action.

The studies conducted using cognitive modelling allow choosing applicable and acceptable strategies for practice implementation.

4 CONCLUSION

The problem of employment for rural dwellers and their respective migration to cities and towns is an unavoidable process that requires large focus and thorough analysis from public authorities' part. It is crucial to secure the balance between the development of cities and towns and maintaining rural areas to support sustainable development of territories. Solving the problems faced by rural population requires comprehensive measures, including active cooperation between the state and businesses, as well as creating new jobs outside the agricultural sector. Developing alternative forms of employment will contribute to maintaining the population number in rural territories, along with improving the level and quality of life in villages.

Overall, the development of alternative employment in rural areas is an important course to reduce unemployment, diversify sources of income, and maintain rural settlements. The results of cognitive modelling have shown that "instability" of life conditions, "insufficient qualification of workers", "loan benefits", "attracting employers", and "entrepreneurial activity" are the key factors of the problem of developing alternative forms of employment in rural areas. It is recommended that public authorities use the factors for strategic planning and supporting managerial decision-making.

ACKNOWLEDGEMENTS

The research was funded in accordance with the state task of the IM SB RAS, project FWNF-2022-0016

REFERENCES

Islam, M.S., Rashid, H.A., Howlader, A., Ahmed, M. F., 2011. Rural Urban Migration: A Quest for Economic Development and Poverty Reduction. Journal of Economic Policy and Research. Vol. 6, No 2, Pp. 119-136.

Bjerke, L., Mellander, C., 2022. Mover stayer winner loser a study of income effects from rural migration. Cities. 130. 103850.

Asadi, M.M., Jabbari, G., 2022. Factors Affecting the Resilience of Rural Tourism Community in Terms of Sustainable Development (Case Study: Tourism Target Villages of Hamadan County). J. Rural Research. Vol. 12. Iss. 4. Pp. 684-699.

Lebedeva, T.V., Sabinov, A.P., Shatalova, A. V., 2021. Rural Territory Development: Demographics. *Filosofiya Khozyaystva* [Philosophy of Economy]. No.2 (134). Pp. 253-271.

Chudinova, O. A., Mitrofanova, O.N., 2021. Problems of Development of Rural Territories in the Russian Federation. *Innovatsionnaya Ekonomika: Perspektivy Razvitiya i Sovershenstvovaniya* [Innovative Economy: Prospects for Development and Elaboration]. No. 1 (51). Pp. 136-141.

Petrikov, A.V., 2021. Streamlining Rural Policy in Russia: Courses and Priorities. *Problemy Natsionalnoy Strategii* [Problems of National Strategy]. No. 5 (68). Pp. 57-70.

Kopylova, Y.V., Kozlova, O.A., 2024. Role of Governmental Programs in Regulating Employment in Rural Areas. *Ekonomika Selskogo Khozyaistva v Rossii* [Economics of Agriculture in Russia]. No. 1. Pp. 117-121.

Polunin, G.A., Alakoz, V.V., Cherkashin, K. I., 2020. Land and Labor Potential for Expanding Agricultural Production. *Ekonomika, Trud, Upravleniye v Selskom Khozyaystve* [Economics, Labor, Management in Agriculture]. No. 1 (58). Pp. 17-22.

Nestik, T.A., 2011. Attitude to Time in Small Groups and Organizations. M.: Institute of Psychology of the Russian Academy of Science, 296 p.

Luchko, O.N., Marenko, V.A., 2014. Cognitive Modelling as Support Tool of Decision-Making: Monograph. Novosibirsk: Published by SB of RAN, 118 p.

Marenko, V.A., 2020. Research Method for Socioeconomic Objects for Information Support of Decision-Making.*Trudy Instituta Sistemnogo Analiza RAN* [Works of the Institute of Systems Analysis of RAN]. No. 4. Vol. 70. Pp. 3-12.

Machine Results Interpreting and Data Understanding

Burnásov Alexánder S.[1], Zheriborov Denis S.[2], Zheriborova Ekaterina V.[3]
Ural Federal University. Lenina, 51, Ekaterimburgo, 620007, Russian Federation
asburnasov@urfu.ru, dszheriborov@urfu.ru, evzheriborova@urfu.ru

Keywords: The paper must have at least one keyword. Data in Machine Learning, data science, data mining, machine learning(ML), anomaly detection, cyber physical systems.

Abstract: Machine learning solves a large number of tasks that a human could not cope with. It has huge potential and is applicable in many areas of human activity. However, often scientists in the field of machine learning, getting the results of the models, can not get an accurate forecast, explain, or interpret the data obtained. The stage of analysis and preparation of data is one of the main tasks. In machine learning, data play a critical role, machine learning model developers often ignore them or treat them incorrectly. As a result, hundreds of hours are spent on adjusting the model based on incorrect data, which may cause low accuracy of the model, and this will not be related with model optimization and adjusting. When analyzing datasets, knowing what needs to be discovered in the data is often just as important as learning its overall structure. The area of data analysis concerned with detecting rare occurrences is called anomaly detection. Anomaly detection has many applications in security, healthcare, finance, and many others. Because of the complexity of obtaining marked-up data, machine learning algorithms with supervised learning are less attractive for the task of anomaly detection. And the lack of reliable and marked-up data makes it difficult to evaluate anomaly detection methods. The article provides a specific example of identifying errors that affect the quality of machine learning models. This study shows the identified errors in the SWaT 2015.

1 INTRODUCTION

To understand and correctly interpret the results of machine learning models it is necessary to have a good understanding of the data structure and the area to which the data belong.

Processed and structured information presented in tabular form is called a Dataset. Rows in a dataset are called objects, and columns are called attributes. The block of this kind of information with the data aggregated in it forms the basis for machine learning.

Labeling is an integral stage of data preprocessing. The distinctive feature of data labeling analysis is that when using models, the accuracy of the results depends on the dataset quality.

Depending on the goals various ways of data labeling can be used.

The authors (Kenyon and et. al, 2020) analyzed various data sets, identified the shortcomings of anomaly detection methods, and identified patterns, features, relationships, and limitations of the methods.

In this respect, in machine learning it is important to have a high-quality dataset. Representative and accurate labels are two key aspects of dataset quality measuring (Sharafaldin and et. al. 2018; Maciá-Fernández et. al. 2018).

Incorrectly labeled or distorted dataset will have a negative impact on the operational outcome of the applied machine learning models.

First of all, let’s consider the main pros and cons of various types of labeling that are currently used. A generalized analysis of “-“ and “+” is presented in Fig. 1.

[1] https://orcid.org/0000-0002-9568-4542
[2] https://orcid.org/0000-0003-2662-1107
[3] https://orcid.org/0009-0005-3560-9814

PROS AND CONS OF LABELING APPROACHES

Approach	Description	Pros	Cons
Internal labeling	Assignment of tasks to an in-house data science team	✓ Predictable results ✓ High accuracy of labeled data ✓ The ability to track progress	It takes much time
Outsourcing	Recruitment of temporary employees on freelance platforms, posting vacancies on social media and job search sites	✓ The ability to evaluate applicants' skills	The need to organize workflow
Crowdsourcing	Cooperation with freelancers from crowdsourcing platforms	✓ Cost savings ✓ Fast results	Quality of work can suffer
Specialized outsourcing companies	Hiring an external team for a specific project	✓ Assured quality	Higher price compared to crowdsourcing
Synthetic labeling	Generating data with the same attributes of real data	✓ Fewer constraints for using sensitive and regulated data ✓ Training data without mismatches and gaps ✓ Cost- and time-effectiveness	High computational power required
Data programming	Using scripts that programmatically label data to avoid manual work	✓ Automation ✓ Fast results	Lower quality dataset

Figure 1: Pros and cons of different labeling approaches.

2 DATA ANALYSIS

It is important to note that it is almost impossible to obtain data on the operation of a technological system collected with the use of automated control systems. Such data are not always available to researchers.

In this article we will consider a quite well-known and interesting dataset in the field of anomaly detection iTrust SWaT 2015. The data is collected on a test bench Secure Water Treatment which has a six-stage water purification system. This test bench is a smaller copy of a modern water treatment plant.

The data in this set could be described as Time Series, each register in which is an outcome of measurements monitoring performed with a frequency of 1 second.

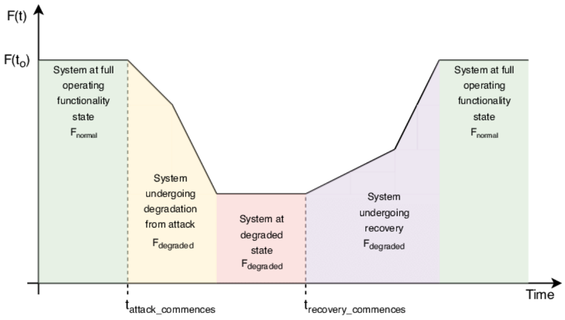
If we thoroughly study the data and compare it them with the information from the description to the dataset placed in the file “List_of_attacks_Final”, we can notice that there is a time deviation of the moment of the beginning and end of the attack, indicated in the data label, and the moment of the beginning / end of the attack, corresponding to changes in the sensors or actuators readings that were attacked.

Also, during the analysis of the dataset two time intervals were identified (from 6:30:00 2015-12-29 to 6:42:00 2015-12-29, from 13:40:57 2016-02-01 to 13:41:11 01.02.2016). They were labeled as moments of attacks, while in the data description file “List_of_attacks_Final” no information about attacks was found and only 36 attacks of 38 identified were marked in the dataset labeling.

It is also important to distinguish the task of finding the moment of an attack on an industrial equipment from the task of searching for anomalies in the data. For example, some attacks failed to affect the operation of the equipment, the results of the attack did not affect the readings of the sensors and actuators, the process was not disrupted.

Therefore, these attacks, despite the fact that they are labeled as attacks, are difficult for models to identify basing on the information from the dataset.

On the other hand, attacks often do not immediately affect the operation of the equipment, but only after a period of time. It takes some time to restore the normal state of the system. Fig. 2 shows how the state of a system that has been subjected to a disruptive effect changes over time.



1 – the system is in a state of full operation
2 – system undergoing degradation as a result of an attack
3 – the system is in a degraded state
4 – a system that is in the process of being rebuilt
5 – the system is in a state of full operation

Figure 2: Operational Level F(t), Transition Over Time[Zhongyua and et. al. 2019].

If we evaluate the performance of machine learning models focusing only on the labeling of attacks in the dataset, without taking into account all the features of the data, then we can get results that will show rather low accuracy and most likely a high frequency of false positives.

3 OVERVIEW OF RESEARCH

The main problem is that the models used by researchers are trained basing on data that are available. Let's analyze several research works aimed at finding attacks/anomalies in the dataset SWaT 2015.

Kravchik M. and Shabtai A. (Kravchik and Shabtai, 2018) suggested to use the assembly method 1 D CNN to find attacks in the dataset. The authors claim that this assembly method was able to detect 31 attacks out of 36, and if we take into account that there are 38 labeled attacks in the dataset, then we can speak about 31 attacks out of 38.

Nedeljkovic D., Jakovljevic Z. (Nedeljkovic and Jakovljevic, 2021) used a method belonging to a class of semi-controlled approaches based on IDS-CNN convolutional neural networks. The authors state that the IDS-CNN method was able to detect 30 attacks out of 36 (30 out of 38).

Elnour M., Meskin N., Khan K., Jain R. (Elnour and et. al., 2020) in their study used two Isolated Forest (IF) models, which were trained independently using normalized raw data. The authors stated they had detected 30 out of 36 attacks.

Lin Q., Adepu S., Verwer S., Mathur A. used a graphical model (Time Automata and Bayesian netwORk–TABOR) (Lin and et. al., 2018). The results of this model are slightly worse than those considered earlier. The authors found 24 attacks out of 36 (24 out of 38).

Also, Gauthama R., Mathur A. and Ahmed C. in their work (Raman and et., al., 2021) (Raman and et., al., 2021) mention that when using unsupervised learning methods, the frequency of false alarms of anomaly detection sensors is high. The cause might be the fact that the attacks do not immediately affect the operation of equipment, but only after some time. Moreover, a series (cascade) of attacks can create a disturbance in the system, which will be absorbed by the system only after a period of time. The system will resist, adapt and recover after the impact, it will take some time. The impact of the attack itself may already be over by that moment.

4 THE OUTCOME OF THE DATASET ANALYSIS

The authors of the above mentioned works agree that the method they used did not manage to detect 4 out of 36 attacks. If we take into account two more attacks identified in labeling, then we can speak about 6 attacks out of 38 detected in labeling.

Within the framework of this study the dataset labeling was examined. Analysis of the dataset indicates that:

In the description of the data 36 attacks were announced; in the dataset there are two attacks, which are labeled but not mentioned in the description; there are no obvious impacts (changes in the operation of the system) at the moments of attacks.

- There are discrepancies in the time of the beginning and end of attacks. An example of such a discrepancy is shown in Fig. 3.

Timestamp	FIT401	Normal/Attack	Timestamp	FIT401	Normal/Attack
2/1/2016 11:43:45 AM	1,706212	Normal	2/1/2016 11:50:24 AM	0,5	Attack
2/1/2016 11:43:46 AM	1,704674	Normal	2/1/2016 11:50:25 AM	0,5	Attack
2/1/2016 11:43:47 AM	1,703777	Normal	2/1/2016 11:50:26 AM	0,5	Attack
2/1/2016 11:43:48 AM	1,703777	Attack	2/1/2016 11:50:27 AM	0,5	Attack
2/1/2016 11:43:49 AM	1,703777	Attack	2/1/2016 11:50:28 AM	0,5	Attack
2/1/2016 11:43:50 AM	1,703777	Attack	2/1/2016 11:50:29 AM	0,5	Normal
2/1/2016 11:43:51 AM	1,703777	Attack	2/1/2016 11:50:30 AM	0,5	Normal
2/1/2016 11:43:52 AM	1,70429	Attack	2/1/2016 11:50:31 AM	0,5	Normal
2/1/2016 11:43:53 AM	1,706981	Attack	2/1/2016 11:50:32 AM	0,5	Normal
2/1/2016 11:43:54 AM	1,707878	Attack	2/1/2016 11:50:33 AM	0,5	Normal
2/1/2016 11:43:55 AM	1,708519	Attack	2/1/2016 11:50:34 AM	0,5	Normal
2/1/2016 11:43:56 AM	1,708519	Attack	2/1/2016 11:50:35 AM	0,5	Normal
2/1/2016 11:43:57 AM	1,708519	Attack	2/1/2016 11:50:36 AM	0,5	Normal
2/1/2016 11:43:58 AM	1,70634	Attack	2/1/2016 11:50:37 AM	0,5	Normal
2/1/2016 11:43:59 AM	1,704931	Attack	2/1/2016 11:50:38 AM	0,5	Normal
2/1/2016 11:44:00 AM	1,704931	Attack	2/1/2016 11:50:39 AM	0,5	Normal
2/1/2016 11:44:01 AM	1,705315	Attack	2/1/2016 11:50:40 AM	0,5	Normal
2/1/2016 11:44:02 AM	1,706212	Attack	2/1/2016 11:50:41 AM	0,5	Normal
2/1/2016 11:44:03 AM	1,706597	Attack	2/1/2016 11:50:42 AM	0,5	Normal
2/1/2016 11:44:04 AM	1,706597	Attack	2/1/2016 11:50:43 AM	0,5	Normal
2/1/2016 11:44:05 AM	1,706853	Attack	2/1/2016 11:50:44 AM	0,5	Normal
2/1/2016 11:44:06 AM	1,707878	Attack	2/1/2016 11:50:45 AM	0,5	Normal
2/1/2016 11:44:07 AM	1,708903	Attack	2/1/2016 11:50:46 AM	0,5	Normal
2/1/2016 11:44:08 AM	1,709544	Attack	2/1/2016 11:50:47 AM	0,5	Normal
2/1/2016 11:44:09 AM	1,710313	Attack	2/1/2016 11:50:48 AM	0,5	Normal
2/1/2016 11:44:10 AM	1,710313	Attack	2/1/2016 11:50:49 AM	0,5	Normal
2/1/2016 11:44:11 AM	1,710313	Attack	2/1/2016 11:50:50 AM	0,5	Normal
2/1/2016 11:44:12 AM	1,710313	Attack	2/1/2016 11:50:51 AM	0,5	Normal
2/1/2016 11:44:13 AM	1,710313	Attack	2/1/2016 11:50:52 AM	0,5	Normal
2/1/2016 11:44:14 AM	1,710313	Attack	2/1/2016 11:50:53 AM	0,5	Normal
2/1/2016 11:44:15 AM	1,707237	Attack	2/1/2016 11:50:54 AM	0,5	Normal
2/1/2016 11:44:16 AM	1,707237	Attack	2/1/2016 11:50:55 AM	0,5	Normal
2/1/2016 11:44:17 AM	1,706981	Attack	2/1/2016 11:50:56 AM	0,5	Normal
2/1/2016 11:44:18 AM	1,706981	Attack	2/1/2016 11:50:57 AM	0,5	Normal
2/1/2016 11:44:19 AM	1,706981	Attack	2/1/2016 11:50:58 AM	0,5	Normal
2/1/2016 11:44:20 AM	1,706981	Attack	2/1/2016 11:50:59 AM	0,5	Normal
2/1/2016 11:44:21 AM	1,709544	Attack	2/1/2016 11:51:00 AM	0,5	Normal
2/1/2016 11:44:22 AM	1,710057	Attack	2/1/2016 11:51:01 AM	0,5	Normal
2/1/2016 11:44:23 AM	1,710057	Attack	2/1/2016 11:51:02 AM	0,5	Normal
2/1/2016 11:44:24 AM	1,711466	Attack	2/1/2016 11:51:03 AM	0,5	Normal
2/1/2016 11:44:25 AM	0,5	Attack	2/1/2016 11:51:04 AM	0,5	Normal
2/1/2016 11:44:26 AM	0,5	Attack	2/1/2016 11:51:05 AM	1,713261	Normal
2/1/2016 11:44:27 AM	0,5	Attack	2/1/2016 11:51:06 AM	1,712748	Normal
2/1/2016 11:44:28 AM	0,5	Attack	2/1/2016 11:51:07 AM	1,712363	Normal
2/1/2016 11:44:29 AM	0,5	Attack			

Figure 3: Attack 35 on FIT-401(sensor; controls the UV dechlorination). Discrepancy in the time of the beginning and end of the attack.

- If we do not take into account the longest attack, which lasted about 34209 seconds (9.5 hours), labeling of which coincided in time with the impact of the attack, and two attacks that were labeled, but no impact and description of these attacks were found, then the total percentage of deviation in time between actual changes in the operation of the equipment triggered by the attacks (in accordance with the description of the data) and labeling is about 14 %.

- Some of the attacks were unsuccessful and had no impact on the equipment. It corresponds to the description given in the column "Unexpected Outcome" in the file "List_of_attacks_Final". An example of such a description is shown in Fig. 4.

Attack Point	Unexpected Outcome
MV-504	No impact
Mv-303	Attack Failed because Startup sequence did not start because Tank 301 was already full
P-201, P-203, P-205	The three dosing pump did not start because of some mechanical interlock

Figure 4: Example 1 from the description of the dataset.

- In the description we can also see the that the impact of the attack had an influence on the work after a long period of time. An example of the description is shown in Fig. 5.

Attack Point	Unexpected Outcome
AIT-202	Impact seen on AIT-504 after two hours at around 14:15. It increased above HH but Drainage did not start

Figure 5: Example 2 from the description of the dataset.

- We must not forget that a large number of false positives when searching for anomalies in data can be triggered by malfunction of the system, which takes time to restore its normal operation after an attack, especially in the case of simultaneous attacks at various levels of the system, as well as when a series of attacks occur at short intervals. An example is shown in Fig. 6. and Fig. 7.

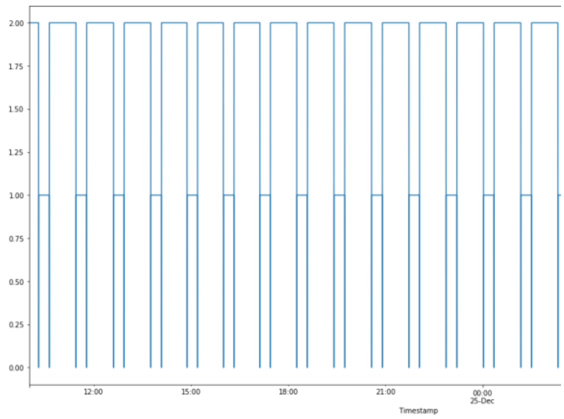
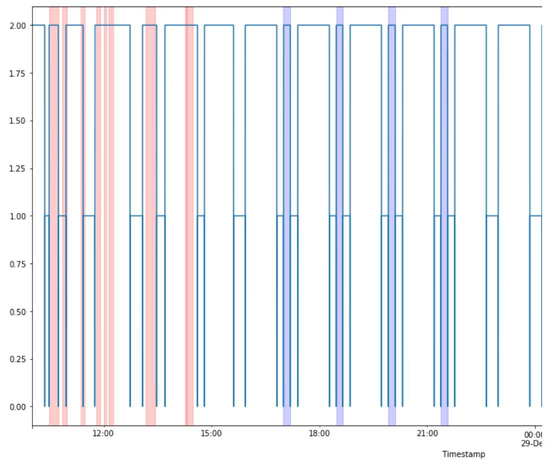


Figure 6: Behavior of MV101(electrically operated valve; controls the water supply to the raw water tank) during the time period when no attacks were performed.



pink lines – moments of attacks,
blue lines – moments of time, when there were no attacks, but the behavior of MV101 is different from normal

Figure 7: Non-standard behavior of MV101 after a series of attacks at the moment, when attack is not carried out.

4 CONCLUSIONS

The analysis shows that labeled data are an important component of any research.

Often the problems emerging when using machine learning models are that most models learn from data not only unclearly labeled, but also distortledy set.

In our case, such a distortion can be considered, for example, a deviation in the time of the beginning and end of the attack, the presence of two attacks in the dataset that are labeled, but there is no description for them and no obvious deviations in the operation of the equipment are observed in the marked period of time.

When working with any dataset, it is necessary to carefully study the data beforehand, analyze and pre-process them, determine what the data contain, what features they may have. It is also necessary to understand what outcome we get from training the model and predicting the results, and according to which criteria the model should evaluate and receive the result.

Researchers should always remember that the quality of a model depends on the quantity and quality of the data on which it is trained no less than on algorithms used. Data labeling deserves special attention and resources.

REFERENCES

Sharafaldin, I., Habibi Lashkari, A., Ghorbani, A., 2018. “Toward Generating a New Intrusion Detection Dataset and Intrusion Traffic Characteriza- tion,” International Conference on Information Systems Security and Privacy, pp. 108–116.

Maciá-Fernández, G., Camacho, J.A., Magán-Carrión, R., García-Teodoro, P., Therón, R., 2018. “UGR'16: A new dataset for the evaluation of cyclostationarity-based network IDSs,” Computers and Security, vol. 73, pp. 411–424.

Zhongyuan, H., Castellanos, J., Zhou, J., 2019. “Evaluating Cascading Effects of Attacks on Resilience of Industrial Control Systems: A Design-Centric Modeling Approach,” May pp. 42–53.

Kravchik, M., Shabtai, A., 2018. “Detecting Cyber Attacks in Industrial Control Systems Using Convolutional Neural Networks,” in Workshop on Cyber-Physical Systems Security and Privacy (CPS-SPC ’18), Toronto, Canada, October pp. 72–83.

Nedeljkovic, D., Jakovljevic, Z., 2021. “CNN based Method for the Development of Cyber-Attacks Detection Algorithms in Industrial Control Systems,” Computers and Security, December pp. 102585.

Elnour, M., Meskin, N., Khan, K., Jain, R., 2020. “A Dual-Isolation-Forests-Based Attack Detection Framework for Industrial Control Systems," February pp. 36639–36651.

Lin, Q., Adepu, S., Verwer, S., Mathur, A., 2018. "TABOR: A Graphical Model-based Approach for Anomaly Detection in Industrial Control Systems," Incheon, Republic of Korea, June pp. 525–5.

Raman, M.R., Dong, W., Mathur, A., 2021. "Deep autoencoders as anomaly detectors: Method and case study in a distributed water treatment plant," Computers and Security, vol. 99, December pp. 102055.

Raman, M.R., Ahmed, C., Mathur, A., 2021. "Machine learning for intrusion detection in industrial control systems: challenges and lessons from experimental evaluation," Cybersecurity, vol. 4, December.

Kenyon, A., Deka, L., Elizondo, D., 2020. Are public intrusion datasets fit for purpose characterising the state of the art in intrusion event datasets, Computers & Security 99 102022.

Performance Research of Object-Relational Mapping Technologies in Interaction to MySQL

Vladislav V. Ivanov[1][a], Natalia I. Pikuleva[1][b], Amina Sh. Khafizova[1][c], Elmira Sh. Kremleva[1][d] and Oksana V. Panchenko[2][e]

[1]*Institute of Computer Technologies and Information Security, Kazan National Research Technical University named after A. N. Tupolev – KAI, Kazan, Russia*

[2]*Institute of Management, Automation and Information Technologies, Kazan National Research Technological University, Kazan, Russia*

coolloggin@yandex.ru, pikulevan@inbox.ru, aminahafizova@yandex.ru, e-smile29.04@mail.ru, ov_panchenko@mail.ru

Keywords: Object-Relational Mapping, Hibernate, Entity Framework, Django ORM, Sequelize, Performance Analysis.

Abstract: This paper examines the performance of popular object-relational mapping (ORM) technologies such as Hibernate for Java, Entity Framework for .NET, Django ORM for Python, and Sequelize for Node.js, focusing on their interaction with the MySQL database management system. The analysis covers key aspects including data management, query complexity and scalability, providing valuable insights into the advantages and disadvantages of each technology in different usage scenarios. The article details the process of configuring and using each ORM, offering practical tips for optimizing performance and improving data management. Special attention is given to migration automation capabilities, performance tuning, and integration with other technologies. Through a discussion of testing ORMs using standard benchmarks and customizable test databases, the article offers guidance on testing methods to help developers evaluate the right ORM technology for their projects. The final section emphasizes the importance of proper selection and a thorough understanding of ORM to improve the development process and application performance.

1 INTRODUCTION

In today's world of software development, where efficiency and speed of development are critical factors, Object-Relational Mapping (ORM) techniques play an important role. ORM is a programming technique used to transform data between incompatible types of systems, typically between object-oriented programming languages and relational databases. It allows developers to work with data at a higher level of abstraction, focusing on business logic rather than database-level details.

Существует множество технологий ORM, Each of them has its own features and is designed to work with specific programming languages. The best known are Hibernate for Java, Entity Framework for .NET, Django ORM for Python, and Sequelize for Node.js. These tools provide powerful data manipulation and database schema management capabilities, including automatic table creation, CRUD (create, read, update and delete) operations, and complex queries and transactions.

For the purposes of this research, of particular interest is the interaction of these ORM technologies with the relational database management system MySQL, which is one of the most popular and widely used database management systems in the world. MySQL offers high performance, reliability and flexibility, making it the preferred choice for many web applications and enterprise systems.

This paper will analyze the performance of popular ORM technologies in the context of their interaction with MySQL. The purpose of the study is to identify how different aspects of ORMs affect

[a] https://orcid.org/0009-0006-5254-9988
[b] https://orcid.org/0009-0002-4561-6303
[c] https://orcid.org/0009-0008-3803-3613
[d] https://orcid.org/0000-0003-0858-0575
[e] https://orcid.org/0009-0006-9440-6563

performance when performing typical database operations, as well as to identify best practices and recommendations for developers seeking to optimize the interaction between object models and relational databases.

2 MYSQL

MySQL is an open source relational database management software (RDBMS) that uses structured query language (SQL) to manage data. Created in 1995 by Swedish developers Mikael Widenius and David Axmark, MySQL has become one of the most popular database management systems in the world, widely used in Internet applications, especially when combined with the PHP and Perl programming languages.

Main features of MySQL:

1) Performance and scalability: MySQL is known for its high performance. The system is capable of handling large amounts of data and supporting a significant number of concurrent queries, making it suitable for large websites and applications. MySQL's scalability allows you to manage both small and large workloads efficiently.

2) Reliability and resilience: MySQL offers various mechanisms to ensure data integrity, including support for transactions with ACID properties (atomicity, consistency, isolation, and durability) through the use of InnoDB and other similar storage engines.

3) Flexibility and accessibility: MySQL supports a variety of operating systems, including Linux, Windows and MacOS, making it accessible to a wide range of users and applications. In addition, the system offers flexible customization and configuration options, allowing you to customize the server to meet specific application requirements.

4) Security: MySQL includes powerful security features such as data encryption, user authentication, host-level access restriction, and SSL support to protect data in transit.

5) Open Source: As an open source program, MySQL provides developers with the ability to explore and modify the code to create customized solutions or improve functionality.

6) Ecosystem and Community: MySQL has a large and active developer and user community that provides significant resources, support, and documentation. This facilitates continuous improvement of the product and makes it easier to find solutions to issues that arise.

7) Integration with other technologies: MySQL easily integrates with many web technologies and programming languages, making it the preferred choice for web application development.

Because of these features, MySQL is used in a wide variety of applications, from websites and e-commerce to enterprise applications and data management systems.

3 HIBERNATE USAGE

Hibernate is a popular object-relational mapping (ORM) library designed for the Java programming language. It is a powerful tool that allows developers to interact with a database in terms of object-oriented models, minimizing the need to write SQL code. In the context of using MySQL, Hibernate provides a convenient and efficient way to manage data.

To get started with Hibernate and MySQL, there are a few configuration steps to follow:

1) Adding dependencies: Hibernate and MySQL driver dependencies should be added to a Java project. This can be done via Maven or Gradle by adding the corresponding libraries to the `pom.xml` or `build.gradle` file.

Example of a Computer Program in Pascal:

```xml
<!-- Для Maven -->
<dependency>
   <groupId>org.hibernate</groupId>
   <artifactId>hibernate-core</artifactId>
   <version>5.4.12.Final</version>
</dependency>
<dependency>
   <groupId>mysql</groupId>
   <artifactId>mysql-connector-java</artifactId>
   <version>8.0.19</version>
</dependency>
```

2) Hibernate session configuration: configuring the `hibernate.cfg.xml` file to connect to MySQL, specifying the database dialect, connection parameters, and other properties such as transaction management and caching.

```xml
<hibernate-configuration>
   <session-factory>
      <property name="hibernate.connection.driver_class">com.mysql.cj.jdbc.Driver</property>
```

```
        <property name="hibernate.connection.url">jdbc:mysql://localhost:3306/yourdatabase</property>
        <property name="hibernate.connection.username">username</property>
        <property name="hibernate.connection.password">password</property>
        <property name="dialect">org.hibernate.dialect.MySQL5Dialect</property>
        <property name="hibernate.hbm2ddl.auto">update</property>
        <property name="show_sql">true</property>
      </session-factory>
   </hibernate-configuration>
```

3) Creating entities: defining Java classes that will represent database tables. These classes are annotated with `@Entity` and their fields are annotated with `@Column`, `@Id` to indicate the relationships between the class and the table.

```java
   @Entity
   public class User {
      @Id
      @GeneratedValue(strategy = GenerationType.IDENTITY)
      private Long id;
      @Column(name = "username")
      private String username;
      @Column(name = "email")
      private String email;
      // getters and setters
   }
```

4) Database interaction: using `SessionFactory` and `Session` to create, read, update and delete data in the database.

```java
   SessionFactory sessionFactory = new Configuration().configure().buildSessionFactory();
   Session session = sessionFactory.openSession();
   session.beginTransaction();
   User user = new User();
   user.setUsername("example");
   user.setEmail("example@example.com");
   session.save(user);
   session.getTransaction().commit();
   session.close();
```

Using Hibernate with MySQL provides several key benefits:

- Database abstraction: Hibernate reduces dependency on a particular database implementation, allowing you to more easily switch to another database if needed.
- Managing complex relationships: Hibernate simplifies the management of complex relationships between data and provides automatic linking between tables.
- Performance: caching, lazy loading, and batch operations help optimize application performance.
- Transactions and Data Integrity: Hibernate supports transaction management and ensures data consistency.

Using Hibernate with MySQL makes the development process simpler and less error-prone, allowing developers to focus on the business logic of the application rather than the details of database interaction.

4 ENTITY FRAMEWORK

Entity Framework (EF) is an object-relational mapping tool from Microsoft designed for .NET developers. It allows you to work with data in the form of objects and properties, minimizing the need to write SQL code. EF supports multiple databases, including MySQL, making it a powerful tool for developers working in the Microsoft ecosystem.

To get started with Entity Framework and MySQL, you need to perform the following steps:

1) Installing the required NuGet packages: To connect to MySQL via the Entity Framework, you will need to install the `MySql.Data.EntityFrameworkCore` or `Pomelo.EntityFrameworkCore.MySql` packages, depending on your preference. Pomelo is a popular third-party provider that supports the latest Entity Framework Core features.

```bash
   Install-Package Pomelo.EntityFrameworkCore.MySql
```

2) Data Context Configuration: create a data context class that inherits from `DbContext`. In this class, you define properties that represent tables in the database.

```csharp
public class ApplicationDbContext : DbContext
{
   public DbSet<User> Users { get; set; }
   protected override void OnConfiguring(DbContextOptionsBuilder optionsBuilder)
   {
      optionsBuilder.UseMySql("server=localhost;database=mydatabase;user=myuser;password=mypassword",
         new MySqlServerVersion(new Version(8, 0, 21)));
   }
}
```

3) Define models: define model classes that map to tables in your database. These classes are annotated to specify relationships and keys.

```csharp
public class User
{
   public int UserId { get; set; }
   public string Username { get; set; }
   public string Email { get; set; }
}
```

4) Migrations: Entity Framework supports migrations to automatically manage database schema changes. You can create and apply migrations to synchronize your data model with the database.

```bash
Add-Migration InitialCreate
Update-Database
```

5) Database interaction: use data context to perform CRUD operations on your data. Entity Framework supports lazy loading, explicit loading, and greedy loading of linked data.

```csharp
using (var context = new ApplicationDbContext())
{
   var user = new User { Username = "newuser", Email = "user@example.com" };
   context.Users.Add(user);
   context.SaveChanges();
   var users = context.Users.ToList();
}
```

Advantages of using Entity Framework with MySQL:

- Code Reduction: Entity Framework automates much of the data access code, which reduces errors and speeds up the development process.
- .NET integration: full integration with the .NET Framework and .NET Core makes EF an ideal choice for developers working in this ecosystem.
- Powerful query capabilities: EF provides rich query capabilities using LINQ, making code more readable and simplifying complex queries.
- Migration support: Automatic database schema management through migrations simplifies application maintenance and upgrades. Migrations allow you to incrementally modify the database schema while maintaining synchronization with the data models in your code. This is especially useful in team development and when deploying applications in different environments (development, testing, production).

Using Entity Framework to interact with MySQL in .NET projects provides not only convenience and speed of development, but also high reliability and scalability of applications.

5 DJANGO USAGE

Django ORM is an integral part of the Django framework for developing Python web applications. This system allows developers to use Python code to define data structures, which are then automatically translated into SQL queries. This allows you to work with a database such as MySQL without directly writing SQL code.

Configuring Django ORM to work with MySQL:

1) Installing the necessary packages: to connect Django to MySQL, the `mysqlclient` library must be installed. This can be done using pip:

```bash
pip install mysqlclient
```

2) Database configuration: in the settings file of your Django project (`settings.py`) you need to configure database access using MySQL connection data.

```python
DATABASES = {
```

```
    'default': {
        'ENGINE': 'django.db.backends.mysql',
        'NAME': 'mydatabase',
        'USER': 'myuser',
        'PASSWORD': 'mypassword',
        'HOST': 'localhost',   # Or IP address of MySQL server
        'PORT': '3306',
    }
}
```

3) Creating models: in Django, data models are created by defining classes in the `models.py` file. These classes represent database tables. Each attribute of a model class represents a field in the table.

```python
from django.db import models
class User(models.Model):
    username = models.CharField(max_length=100)
    email = models.EmailField()
    def __str__(self):
        return self.username
```

4) Migrations: after creating or modifying models, you need to create migrations that apply the changes to the database. Django manages this with a migration system similar to the one used in the Entity Framework.

```bash
python manage.py makemigrations
python manage.py migrate
```

5) Database interaction: Django ORM allows you to interact with the database using Python code. You can create, retrieve, update and delete records without writing SQL queries.

```python
# Adding a new user
User.objects.create(username='newuser', email='user@example.com')
# Getting all users
users = User.objects.all()
# Getting one user by condition
user = User.objects.get(username='newuser')
# Updating user data
user.email = 'newemail@example.com'
user.save()
# Deleting a user
user.delete()
```

Advantages of using Django ORM with MySQL:
- High level of abstraction: Django ORM provides a high level of abstraction, allowing developers to focus on the logic of the application rather than the details of database interaction.

- Automatic migration management: Django manages migrations automatically, which simplifies database maintenance and development.
- Security: Django ORM helps prevent SQL injection and other security vulnerabilities by automatically escaping database queries.
- Integration with Django framework: ORM is deeply integrated with other Django components such as forms and admin panel to ensure efficient and consistent development.

Using Django ORM to interact with MySQL facilitates many aspects of web application development, reducing code complexity and increasing development productivity.

6 USE SEQUELIZE

Sequelize is an ORM for Node.js that supports multiple databases, including MySQL. It provides a powerful and flexible tool for managing data in Node.js applications through simple and expressive object-relational mapping APIs.

Configuring Sequelize to work with MySQL:
1) nstalling the necessary packages: to start working with Sequelize and MySQL you need to install the Sequelize library itself, as well as the corresponding package for connecting to MySQL - `mysql2`.

```bash
npm install sequelize mysql2
```

2) Configure the database connection: create an instance of Sequelize and configure it to connect to your MySQL database. This is usually done in a separate configuration file.

```javascript
const { Sequelize } = require('sequelize');
const sequelize = new Sequelize('mydatabase', 'username', 'password', {
    host: 'localhost',
    dialect: 'mysql'
});
```

3) Defining models: in Sequelize, models are defined by calling the `define` method on a Sequelize instance. Models in Sequelize correspond to tables in your database.

```
```javascript
const User = sequelize.define('User',
{
    username: {
        type: Sequelize.STRING,
        allowNull: false
    },
    email: {
        type: Sequelize.STRING,
        unique: true,
        allowNull: false
    }
});
```
```

4) Synchronize models with your database: Sequelize can automatically create tables in your database corresponding to specific models, if they do not already exist.

```
```javascript
sequelize.sync({ force: false
}).then(() => {
    console.log("The database and
tables have been created!");
});
```
```

5) Database Interaction: Sequelize provides methods for creating, reading, updating, and deleting records.

```
```javascript
// Creating a new user
User.create({
    username: 'newuser',
    email: 'user@example.com'
});
// User Search
User.findOne({ where: { username:
'newuser' } }).then(user => {
    console.log(user);
});
// User update
User.update({ email:
'updated@example.com' }, {
    where: { username: 'newuser' }
});
// Deleting a user
User.destroy({
    where: { username: 'newuser' }
});
```
```

Benefits of using Sequelize with MySQL:

- User-friendly and expressive: Sequelize provides an expressive, almost natural data API that makes code easy to understand and maintain.
- Promice support (a promis is a construct in JavaScript designed to control asynchronous operations): all asynchronous operations in Sequelize return promises, making them usable with modern JavaScript features like async/await.
- Automatic schema synchronization: Sequelize can automatically create and update table schemas in the database, making it easy to manage migrations.
- Security: Sequelize provides protection against SQL injection by automatically escaping input data.

Using Sequelize to interact with MySQL in Node.js applications makes data management easier, increases development speed, and helps reduce database errors.

7 ORM PERFORMANCE

Comparing the performance of different object-relational mappings such as Hibernate for Java, Entity Framework for .NET, Django ORM for Python, and Sequelize for Node.js can be challenging due to the many factors that affect performance in different usage scenarios. All these technologies have been developed for different purposes and for different platforms, which also brings diversity in their performance and optimization. Here is a detailed performance comparison of these ORMs taking into account a few key aspects:

1) Data Operations: Hibernate (Java): One of the most mature and powerful ORM tools, Hibernate boasts a wide range of functionality for query optimization such as lazy loading, second-level caching, and batch processing operations. These features can significantly improve performance when properly tuned. Entity Framework for .NET: EF also supports lazy loading, caching, and batch updates. However, it is known that EF can suffer from performance issues when dealing with large amounts of data or complex queries if specialized query optimizations are not applied. Django ORM (Python): Django ORM offers fewer performance fine-tuning options compared to Hibernate and EF, although it supports features such as selective and prefetching of linked data. Django ORM is best suited for applications where simplicity of development and code cleanliness are more important than the highest performance. Sequelize

(Node.js): Sequelize provides support for asynchronous Node.js operations and can perform well in high-load applications if its connection pooling and transaction capabilities are properly utilized. However, performance can suffer if large amounts of data are not properly handled or if complex queries are used.

2) Query complexity: Hibernate and Entity Framework both offer advanced capabilities to generate complex queries via criteria or LINQ (Language Integrated Query), respectively, which can lead to less optimized SQL queries. That said, the role of the developer in optimizing these queries is important. Django ORM provides less flexibility in complex queries compared to Hibernate or EF, but its approach provides more predictability and ease of understanding the SQL it generates. Sequelize supports flexible queries using raw SQL and provides fairly good performance, but can be prone to issues related to query optimization in Node.js, especially in relational-intensive operations.

3) Scalability: Hibernate and Entity Framework both scale well in large applications, especially when their advanced caching and session management features are utilized. Django ORM can suffer in very large or highly loaded systems without additional caching and database optimization tweaks. Sequelize performs well in scalable Node.js applications, especially due to the non-blocking nature of Node.js, but may require additional optimization to maintain high performance.

The choice of ORM should be based on the requirements of a particular project, development preferences, and the specifics of the target platform and programming language. No one tool is perfect for all scenarios, and each has advantages and disadvantages in different aspects of performance.

ORM testing requires a comprehensive approach that includes the use of standardized tests, customization of scenarios, and active community participation to achieve the best results.

For Hibernate and Java Persistence APIs, official benchmarks such as Hibernate's Benchmark Suite or Jakarta Persistence Performance Benchmark can be used to evaluate the performance of various JPA providers, including Hibernate. Entity Framework for .NET can be tested using TechEmpower Framework Benchmarks, as well as using specialized tools such as ORM Profiler, which helps analyze performance.

Django ORM for Python, although it does not have widely known benchmarks, can be evaluated through community benchmarking projects and testing using real applications or publicly available datasets, such as MaxMind's GeoLite data. Sequelize for Node.js can be tested through community projects on GitHub or by creating your own benchmarks, including test databases with large amounts of data.

In addition, sample databases are available, such as Northwind and AdventureWorks from Microsoft, which can be adapted to different database management systems. These databases can be found on GitHub or used as a basis for creating your own test databases.

You can use traffic generation tools such as Apache JMeter or Locust, as well as real-time performance profiling and monitoring tools to create representative test scenarios. This allows you to identify bottlenecks and optimize performance, including testing data creation, reading, updating, and deletion operations, queries of varying complexity, and transactional operations.

8 CONCLUSION

In conclusion, this study on object-relational mapping in various technology stacks, including Hibernate for Java, Entity Framework for .NET, Django ORM for Python, and Sequelize for Node.js, highlights the importance of selecting the appropriate ORM tool depending on specific project requirements and development preferences. Each of the technologies reviewed offers unique features and optimizations aimed at improving application performance, development usability, and scalability.

ORM performance can vary significantly depending on how it is used, customizations, and data scenarios. Hibernate and Entity Framework offer advanced capabilities for managing complex operations and optimizing queries, making them suitable for large enterprise systems. Django ORM, through its integration with the Django framework, provides superior development speed and usability, which is ideal for projects requiring rapid web application development. Sequelize, taking advantage of Node.js, offers an efficient solution for working with databases in an asynchronous manner, which is especially valuable in applications requiring high real-time performance.

Testing the performance of these ORMs through standardized benchmarks and real-world use cases allows developers to better understand their potential impact on projects. In addition, using open data and resources for testing can help optimize and customize these technologies for specific application requirements.

In general, the right choice and deep understanding of the capabilities of the ORM technology used can significantly improve the efficiency of application development and performance. Sharing knowledge and experience in the development community also plays a key role in improving data handling practices and software quality.

REFERENCES

Pikuleva, N. I., Khafizova, A. S., Khakov, R. A., 2020. Query processing for heterogeneous data sources in SQL generator. In *2020 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)*, pp. 1-7.

Burris, J. W., 2017. Test-Driven Development for Parallel Applications. In *2017 Second International Conference on Information Systems Engineering (ICISE)*, pp. 27-31.

Pikuleva, N. I., Khafizova, A. S., Gashigullin, D. A., 2021. Event correlation with undefined data. In *2021 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)*, pp. 479-483.

Yogesh, T., Vimala, P., 2020. Test-Driven Development of Automotive Software Functionality. In *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)*, pp. 1162-1165.

Fontela, C., Garrido, A., 2013. Connection between Safe Refactorings and Acceptance Test Driven Development. *IEEE Latin America Transactions* 11(5): 1238-1244.

Gibadullin, R. F., Vershinin, I. S., Minyazev, R. S., 2018. Development of load balancer and parallel database management module. In *2018 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)*, pp. 1-6.

Guerra, E., 2014. Designing a Framework with Test-Driven Development: A Journey. *IEEE Software* 31(1): 9-14.

Amrit, C., Meijberg, Y., 2018. Effectiveness of Test-Driven Development and Continuous Integration: A Case Study. *IT Professional* 20(1): 27-35.

Moe, M. M., Oo, K. K., 2020. Evaluation of Quality, Productivity, and Defect by applying Test-Driven Development to perform Unit Tests. In *2020 IEEE 9th Global Conference on Consumer Electronics (GCCE)*, pp. 435-436.

Dookhun, A. S., Nagowah, L., 2019. Assessing The Effectiveness Of Test-Driven Development and Behavior-Driven Development in an Industry Setting. In *2019 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)*, pp. 365-370.

Viktorov, I., Gibadullin, R., 2023. The principles of building a machine-learning-based service for converting sequential code into parallel code. *E3S Web of Conferences* 431: 05012.

Kozlov, E, Gibadullin, R, 2023. Prerequisites for developing the computer vision system for drowning detection. *E3S Web of Conferences* 474: 02031.

Gorodova, J., Pachina, N., Tkachenko, S., Pachin, G., 2021. Digital Literacy in the Aspect of Continuing Teacher's Education. In *2021 1st International Conference on Technology Enhanced Learning in Higher Education (TELE)*, pp. 220-223.

Yoqubjonov, J., Gibadullin, R., Nuriev, M., 2023. Advanced robotic process automation for enterprise efficiency. *E3S Web of Conferences* 431: 07011.

Kondratiev, V., 2020. Fundamental Changes in Mathematics Education in the Context of Digital Transformation. In *2020 Ivannikov Ispras Open Conference (ISPRAS)*, pp. 75-77.

Shakirzyanov, M., Gibadullin, R., Nuriyev, M., 2023. Prerequisites for the development of the system of automatic comparison of video and audio tracks by the speaker’s articulation. *E3S Web of Conferences* 419: 02029.

Chituc, C. -M., 2022. An Analysis of Technical Challenges for Education 4.0 and Digital Education Ecosystems. In *2022 IEEE German Education Conference (GeCon)*, pp. 1-5.

Gibadullin, R. F., Perukhin, M. Y., Mullayanov, B. I., 2020. Optimization of water supply by the method with model predictive. In *2020 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)*, pp. 1-6.

Comprehensive Neutralization of Fuel Energy Waste in the Production of Calcining Efficient Building Materials

Yatsenko Natalya Dmitrievna[a], Kartashov Evgeniy Maksimovich[b]
[1]PLATOV SOUTH-RUSSIAN STATE POLYTECHNIC UNIVERSITY (NPI), Prosveshcheniya St., 132, Novocherkassk, Russia
rektorat@npi-tu.ru, natyacen@yandex.ru

Keywords: Fuel energy production waste, efficient ceramic bricks, mathematical planning method.

Abstract: The development of technologies for producing ceramic building materials based on energy waste fuels is associated with the study and identification of their valuable properties, which ensure the possibility of producing wares with high performance characteristics. The physicochemical and technological properties of ash and slag and high-calcium waste from the Novocherkassk Regional Power Station have been studied and their influence during high-temperature treatment on the basic properties of ceramic bricks - porosity, density, strength, depending on the chemical and mineralogical composition of the clay raw material has been established. The use of the mathematical planning method using a Scheffe lattice plan of incomplete 3rd order made it possible to determine the areas of structures formation with different properties depending on the content of waste and clay raw materials and to establish the area of tailored compositions, which can significantly reduce the number of experiments performed. Studies of the phase composition have shown that the strength properties of ceramics are ensured by the formation of new crystalline phases

1 INTRODUCTION

The fuel and energy complex generates a huge amount of waste, the disposal of which is the most important task of environmental safety. Depending on the production methods, the resulting waste is characterized by different chemical, granulometric composition and permanence of properties.

However, a thorough study of fuel energy waste using a set of modern physical and chemical methods makes it possible to identify valuable properties and obtain various materials based on them, most often for construction purposes (Abdrakhimova, 2019; Fedorova, Shaforost, 2015).

For the production of building materials, solid energy waste is of interest, the most significant of which is ash and slag waste (ASW), accounting for about 99%, currently used in an amount of no more than 4%, and the rest occupies large areas of enterprise territories. As a result of burning coal in the furnaces of steam boilers, sintered and even fused pieces of ash are formed, ranging in size from 0.2 to 20...30 mm.

The teams of Russian and foreign scientific schools have been engaged in the disposal of ash and slag for a long time. Most often, technologies for neutralizing ash and slag are associated with the production of foam glass-crystalline materials based on them (Grushko, 2020; Yatsenko, 2014).

2 SOLID WASTE FROM FUEL ENERGY AND ITS CHARACTERISTICS

One of the promising directions is the use of ash and slag waste as an alkali-containing mineralizer (Table 1) for the production of burnt clay masonry materials (Yatsenko, Palamarchuk, 2002; Yatsenko, 2005).

Another fuel energy waste is high-calcium waste (HCW), which is formed as a result of chemical water treatment during cooling of boiler furnaces at power

[a] https://orcid.org/0000-0001-7674-7491
[b] https://orcid.org/0009-0006-4307-3447

plants. They are a serious problem in the operating cycle of these industries, due to the large tonnage, the need to equip large-area settling tanks, and environmental pollution (Yatsenko, Ratkova, 2005).

The studies of HCW have shown a slight fluctuation in their chemical and mineralogical composition, associated with the constant regional composition of the water used for cooling. Thus, the phase composition of the HCW of the Novocherkassk State Regional Power Station is represented by calcite and a metastable reactive phase of aragonite.

The integrated use of electrical energy waste in the production of effective solid ceramic bricks, characterized by a porosity of more than 30%, while implementing previously established patterns of their use, is of scientific interest. Thus, the HCW, containing about 90% of calcium carbonate (Table 1), at roasting temperatures above 950 °C decomposes with the formation of CaO and CO_2, facilitating the porosity of the ceramic material, and interacts with other components of the mass with the formation of new crystalline phases (Yatsenko, Yatsenko, Zakarlyuka, 2017). The porosity of the ceramic will depend on the content of waste introduced into it, and the strength will depend on the phase composition. In the formation of the phase composition, alkali-containing additives play an important role, which help reduce the decarbonization temperature of calcium-containing materials.

3 STUDY OF THE ROLE OF VKO AND ZSHO IN THE PRODUCTION OF FIRED BUILDING MATERIALS

In this work, to produce ceramic durable and porous bricks based on solid fuel energy waste, ash and slag waste from the Novocherkassk Regional Power Station was used as such an additive.

To regulate the technological and physical-technical properties of the material, local clays of the Rostov region of the Vladimirovskoye and Kamennobrodskoye deposits have been introduced, the chemical composition of which is given in Table 1.

Table 1: Chemical composition of natural raw and industry-related materials.

Material	Content, % in mass.									Sum
	SiO_2	Al_2O_3 + TiO_2	FeO+ Fe_2O_3	CaO	MgO	K_20	Na_2O	SO_3	nnn	
Novocherkassk Regional Power Station HCW	5.10	2.60	1.70	45.10	4.60	0.30		-	40.30	99.70
Novocherkassk Regional Power Station ASW	54.56	20.19	11.92	3.72	1.64	3.35	0.98	0.08	3.44	99.88
Kamennobrodskoye Clay	61.25	12.01	5.19	6.48	1.25	2.89		-	10.38	99.45
Vladimirovskoye Clay	57.48	22.86	2.29	0.83	1.39	3.48		-	9.30	97.63

To establish the maximum possible content of HCW to ensure high porosity, the main components of the mass were varied as follows, % in mass: clay - 20, HCW - 40...50, ASW - 30...40. Roasting was carried out at a temperature of 950°C. The research results are presented in Table 2.

Table 2: Properties of ceramics depending on the content of energy waste.

Compo-	Materials content, % in mass.	Property indicators			
					Strength,

sition No.	Kamen-nobrodskoye Clay	Vladimirovskoye Clay	HCW	ASW	Water absorption, %	Pore content, %	Density g/cm3	MPa
1	20.0	-	50.0	30.0	58.0	63.0	1.00	7.4
2	20.0	-	45.0	35.0	52.0	57.0	1.05	7.5
3	20.0	-	40.0	40.0	27.0	36.0	1.18	9.6
4	-	20.0	50.0	30.0	33.1	41.0	1.20	9.3
5	-	20.0	45.0	35.0	32.0	40.0	1.20	9.4
6	-	20.0	40.0	40.0	30.0	39.0	1.20	9.4

4 RESULTS OF STUDIES OF THE PHASE COMPOSITION AND PROPERTIES OF CERAMICS DEPENDING ON THE METHOD OF POROSITY USING THE MATHEMATICAL PLANNING METHOD AND THEIR DISCUSSION

The research results show the greatest porosity when introducing HCW in an amount of 50%. At the same time, the presence of its own carbonate in Kamennobrodskoye clay increases porosity to 63%. Having the same HCW content, the samples based on Vladimirovskoye clay have a porosity of only 41%. As the ASW content increases, the strength properties increase. The optimal composition based on Vladimirovskoye clay contains 45% high-calcium and 35% ash and slag waste and is characterized by the following properties: porosity - 39%, density - 1200 kg/m3, compressive strength - 9.4 MPa.

To increase porosity, the additional porosity was used at the preparation stage for the mass based on Vladimirovskoye clay (composition 61) through the use of reactions associated with the release of gaseous products between carbonates and acids:

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2\uparrow + 2H_2O$$

Sulfuric acid (2%) was introduced into the plastic mass in an amount of 10%. The molding of samples from a porous mass with a moisture content of 30% was carried out in metal molds. The dried samples were roasted at the temperatures of 950 and 1000°C at exposure at maximum temperature for 2 hours. The research results presented in Figure 1 show that when containing 6_1 (40% HCW, 40% ASW and 20% Vladimirovskoye clay) when using chemical porosization at the stage of mass preparation and decarbonization, the HCW at roasting temperatures of 950 and 1000 °C more porous structure of the material (porosity 45 and 55%) compared to composition No. 6, with a density of 1.2 and 1.0 is formed

g/cm3, strength 4.0 and 5.5 MPa.

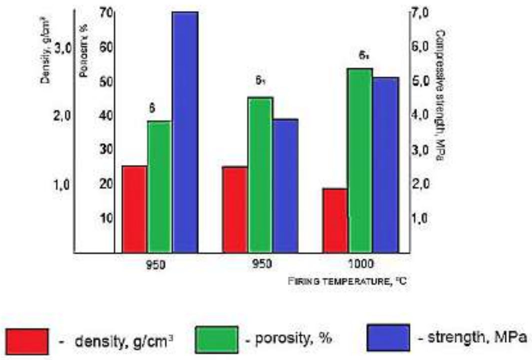


Figure 1: Properties of samples of composition 6 and 6_1 depending on the roasting temperature and porosization methods

The obtained properties are ensured by the formation of a porous structure and phase composition due to physicochemical processes occurring in clay-carbonate systems at a roasting temperature of 1000 °C.

To establish the influence of the content of industry-related energy waste using the thermal porosity method, we used a mathematical method of experiment planning using an incomplete 3rd order Scheffe lattice design, the matrix of which is given in Table. 3.

Table 3: Experiment design matrix.

Composition no.	Component content, wt. %			∑, %
	HCW	SRPS slag	Vladimirovskoye Clay	

X1	80.0	-	20.0	100.0
X2	-	-	100.0	100.0
X3	-	80.0	20.0	100.0

The experimental data obtained with the help of mathematical planning are given in table. 4.

Table 4:The studies results according to the Scheffe plan.

Experience no.	Furnace-charge composition, unit fractions			Response functions			
	X1	X2	X3	Water absorption,% (U1)	Porosity, % (U2)	Density, g/cm3 (U3)	Strength, MPa (U4)
1	1	0	0	61.0	69.0	0.76	0
2	0	1	0	8.9	17.49	1.89	12.76
3	0	0	1	9.1	18.35	1.87	28.27
4	0.5	0.5	0	31.3	41.51	1.26	11.72
5	0	0.5	0.5	8.4	16.99	1.90	15.62
6	0.5	0	0.5	39.3	50.15	1.23	2.25
7	0.333	0.333	0.333	28.4	40.73	1.37	11.85
8*	0.6	0.2	0.2	48.2	54.58	1.08	2.04

* Experience 8 corresponds to the control point.

According to the formulae corresponding to the Scheffe plan, the incomplete third order polynomials of general form are calculated:

$$y = \sum b_i x_i + \sum b_{ik} x_{ik} + \sum b_{ikl} x_i x_k x_l$$

Where: ; ; $b_i = y$ $b_{ik} = 4y_{ik} - 2y_i - 2y_k$

$$b_{ikl} = 27y_{ikl} - 12(y_{ik} + y_{kl} + y_{il}) + 3(y_i + y_k + y_l).$$

The incomplete third order polynomial for strength (a), porosity (b), density (c) has the form:

У1 = 41.55· X1 + 0 · X2 – 34.48· X3 – 42.98 · X1 · X2 – 65.12 · X2 · X3 + 4.78· X1 · X3 – 205.82 · X1 · X2 · X3. (A)

У2 = 16.01 · X1 + 50.06 · X2 + 21.56 · X3 – 10.46 · X1 · X2 + 29.24 · X2 · X3+ + 1.82 · X1 · X3 + 151.5 · X1 · X2 · X3 (b)

У3 = 1.875 · X1 + 1.268 · X2 + 1.849 · X3 – 0.622 · X1 · X2 - 0.566 · X2 · · X3+ 0.232· X1 · X3 – 2.856 · X1 · X2 · X3 (c)

The results obtained on the basis of equations (a, b, c), presented in the diagrams (Fig. 2), make it possible to establish the range of post-roasting properties depending on the content of industry-related energy waste.

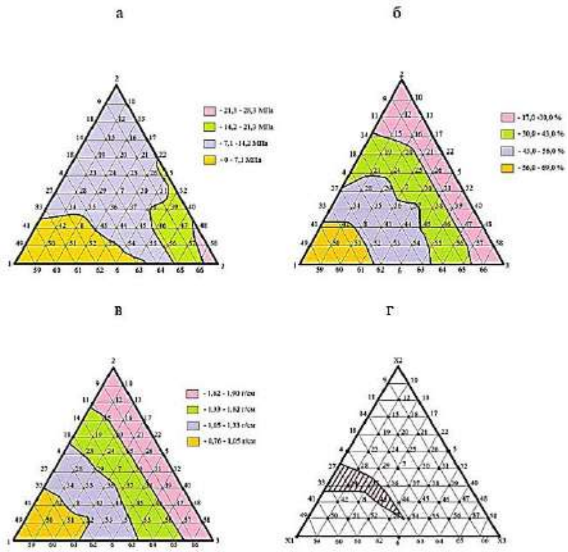


Figure 2: Diagram of strength (a), porosity (b), density (c) depending on the content of technogenic waste, area of optimal properties (d).

The results of the studies made it possible to establish the area of the compositions with optimal properties (Fig. 2, d), which is highlighted by shading. This area includes compositions (27, 33, 34, 35, 43) with a porosity of more than 40%, which classifies such ceramics as low-density, with a density of less than 1.2 g/cm3 (effective ceramic brick) and a strength of more than 7.5 MPa. The calculated properties of the compositions of the optimal region are given in Table 5.

Table 5: Properties of optimal area compositions.

Composition no.	Furnace-charge composition, unit fractions			Response functions			
	X1	X2	X3	Water absorption,% (U1)	Porosity, % (U2)	Density, g/cm3 (U3)	Strength, MPa (U4)
27	0.6	0.4	0	36,656	46,730	1.149	10,230
33	0.7	0.3	0	42,304	52,089	1,044	8,313
34	0.6	0.3	0.1	39,504	52,942	1.106	8,643
35	0.5	0.3	0.2	36,030	51,895	1,188	9,396
43	0.5	0.2	0.3	37,630	53,623	1.182	7,502

To study the phase composition of a ceramic material with optimal properties, we chose the composition 43, containing clay - 36.0%, HCW - 40.0%, ASW - 24.0%. Based on this composition, the experimental studies were carried out (Table 6), the results of which indicate their reproducibility and comparability with the calculated ones.

Table 6: Calculated and experimental data on the properties of ceramic samples.

Composition no.	Water absorption,%	Porosity, %	Density, g/cm3	Strength, MPa
43(calculated)	37.6	53.6	1.183	7.5
43(experiment)	37.5	49.5	1.217	9.5

It should be noted that the resulting diagrams make it possible to establish the composition of ceramic masses based on technogenic waste from the Novocherkassk Regional Power Station, with a different set of properties, including high-strength properties and meeting the requirements for producing ordinary ceramic bricks.

X-ray phase studies (Figure 3) showed that in a ceramic sample of composition 43 the following crystalline phases are incredible: β-quartz (0.426, 0.337, 0.245, 0.181, 0.145nm), a solid solution of the melilito-helenite row (0.371, 0.324, 0.285 nm), hedenbergitis $CaO \cdot FeO \cdot 2SIO_2$ (0.300; ; 0.238 nm), which ensures the strength properties of the ceramic material.

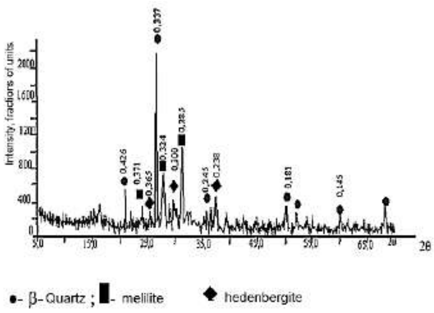


Figure 3: Phase composition of a sample of composition 43.

5 CONCLUSIONS

Thus, when forming the structure of ceramics based on technogenic raw materials from the Novocherkassk Regional Power Station, the phase composition of the shard depends on the physicochemical processes occurring during low-temperature sintering. In such masses, the melilite phase is formed predominantly due to the interaction of metakaolinite directly with $CaCO_3$ and hedenbergite, provided that it contains a sufficient amount of CaO, SiO_2 and alkaline components.

The use of the method of mathematical experimental planning makes it possible to obtain reproducible results when conducting a minimum number of studies and, in industrial production conditions, to respond quickly to changes in the physicochemical and technological properties of raw materials and production factors.

The integrated use of fuel energy waste in the production of ceramic roasting materials helps to improve their performance properties, ensures the recycling of technogenic raw materials and improves the environmental situation.

REFERENCES

Abdrakhimova, E.S., 2019. Use of waste from the fuel and energy complex - burnt rocks and chromite ore enrichment waste in the production of porous aggregates based on a liquid glass composition. Coal. No. 7. pp. 67–69.

Fedorova, N.V., Shaforost, D.A., 2015. Prospects for the use of fly ash from thermal power plants in the Rostov region. *Thermal power engineering*. No. 1. pp. 53–58.

Grushko, I.S., 2020. Ways of formation and features of development of the crystal phase in amorphous material (a review).*Glass Physics and Chemistry.* No. 6. P. 549-561.

Yatsenko, E.A., 2014. Investigation of the factors influencing the properties and structure of foamed slag glass. *Glass and ceramics.* Vol. 71 (3-4). P. 111-114.

Yatsenko, N.D., Palamarchuk, A.V., 2002. Ensuring waste-free water use regimes for chemical water treatment at thermal power plants and nuclear power plants. *Ecology of industrial production*. 2. pp. 27-29.

Yatsenko, N.D., 2005. Thermal insulation materials based on waste from thermal power plants. *Bulletin of higher educational institutions. North Caucasus region. Technical sciences.* Special. issue : Problems of thermal power engineering. pp. 66-67.

Yatsenko, N.D., Ratkova, V.P., 2005. Carbonate waste from power plants as raw materials for the production of construction products. *Bulletin of higher educational institutions. North Caucasus region. Technical science.* Special. issue: Problems of thermal power engineering. pp. 63-65.

Yatsenko, N.D., Yatsenko, E.0.A, Zakarlyuka, S.G.P., 2017. hase Composition and Properties of Building Ceramic as a Function of the Contents of Calcium Carbonates and Iron Oxides. *Glass and Ceramics*. Vol. 73, Is. 9. P. 319–322.

Digital Technologies for the Sustainable Development of the Economic Ecosystem of the Territory

Evgeny Popov[1][a], Igor Chelak[1][b] and Sergey Kavetskiy[1][c]
[1]Centre of socio-economical investigation, Ural Institute of Management of the Russian Presidential Academy of National Economy and Public Administration, Yekaterinburg, Russian Federation
epopov@mail.ru, chelak@mail.ru, skavetskiy@inbox.ru

Keywords: Digital ecosystem, change management, sustainable development, ecosystem of the territory, digital technologies.

Abstract: The article deals with topical issues affecting the key areas of development of digital technologies and their implementation in the management of the economic ecosystem of the territory. End-to-end technologies, including predictive analytics, create unique opportunities in many public sectors, and the speed with which they develop provides an opportunity to achieve sustainable development goals. The paper considers economic relations for the development of methods for managing changes in the sustainable development of economic ecosystems of territories. The purpose of the article is to systematize the planned digital technologies for managing the sustainable development of the economic ecosystem of the territory.

1 INTRODUCTION

Sustainable development and digitalization are two frequently encountered terms defining modern social, political and scientific spheres. Sustainable development is associated with serious social and economic problems, such as uneven development of the territory, social inequality, which are becoming more and more obvious and are reflected in initiatives such as the UN Sustainable Development Goals (SDGs). In this vein, research has begun to cover the concept of sustainable development of the economic ecosystem of the Territory as a vital source of promoting efforts to create a favorable, competitive environment with a high standard of living for the population by ensuring a sustainable socio-economic system.

Digitalization lies in the transformative power of digital technologies and their widespread introduction into everyday life. Digital technologies such as platforms, blockchain, artificial intelligence, virtual reality or the Internet of things have transformed many industries (e.g. housing, agriculture, transportation), providing companies with unprecedented advantages and new business opportunities. Recently, scientists and government policy makers have begun to consider digital technologies as key tools for mitigating and countering the most pressing economic and social problems of our time. This article is aimed at conducting additional research in the field of sustainable development of the economic ecosystem of the territory and digitalization, presented through a scientific review of the literature. The article conditionally consists of two parts: the first reveals the concept of the economic ecosystem of the territory, considers an approach to ensuring the sustainable development of the economic ecosystem, examines the methods of digitalization in the management of the economic ecosystem, extracts and presents the main topics from the literature, developing the role of digital technologies for the sustainable development of the ecosystem. These topics include ensuring socio-economic sustainability in the interaction of stakeholders in the ecosystem. In the second part, the application of planned digital technologies in managing changes in the sustainable development of the economic ecosystem of the territory is additionally discussed and systematized, as well as promising areas for future research are

[a] https://orcid.org/0000-0002-5513-5020
[b] https://orcid.org/0000-0001-8770-0533
[c] https://orcid.org/0009-0002-1990-9428

developed. In particular, the focus is on the prospect of achieving the UN SDG targets by 2030 by stakeholders of the Territory's ecosystem through the use of end-to-end digital technologies in management. Thus, this work contributes to the formation of a new field of research that can change the theory and practice in managing changes in the ecosystem of the territory (Holzmann et al., 2023)

2 THE CONCEPT OF THE ECONOMIC ECOSYSTEM OF THE TERRITORY

Considering the concept of an economic ecosystem, most researchers draw an analogy with natural ecosystems, which are communities of living organisms interacting with their environment. The "eco" part of the term refers to the environment, while "system" refers to a group of related parts working together as a whole.

Natural ecosystems can be large or small, but they usually exist within a specific geographical area. An economic ecosystem is similar, consisting of a core group of entities, the environment, and various stakeholders who interact with each other through interconnections. These elements coexist and evolve within the ecosystem. The ecosystem plays a crucial role in the dynamism, sustainability, and viability of a territory. It creates competitive advantages and adds value, which in turn contributes to the economic success of the area. This success contributes to the reputation of the ecosystem, attracting financial, human, and other resources. An ecosystem must perform two main functions: creating value for itself and distributing that value among its members (Audretsch et al., 2019).

2.1 Digital ecosystems

The digital ecosystem enables each participant in the system to generate, share, and consume a vast amount of data and knowledge, which can be utilized in various fields such as artificial intelligence, data mining, and information retrieval. These technologies help organize and process digital assets and determine the interactions between them.

A digital ecosystem is a self-organizing, scalable, and sustainable system composed of diverse digital objects and their connections. It focuses on facilitating interactions between objects to increase the system's effectiveness, reap benefits, and facilitate information sharing, internal and personal cooperation, and system innovation.

The sustainability of a digital ecosystem depends on the alignment of digital resources, knowledge, and people. This indicates the ability to sustain good performance, resist changes in the internal and external environments, and recover from mistakes and system failures. The development of technologies that support ICT for digital ecosystems is another important task. This includes the research and development of intelligent and autonomous infrastructure, advanced software development platforms, and protocols and formal languages for implementing digital ecosystems (Behera et al., 2019).

2.2 The concept of sustainable development of the economic ecosystem of the territory

The sustainable development of regions is a complex process that includes changes in both quantitative and qualitative aspects taking place in the field of social, economic and environmental activities. The process of regional development takes place in changing conditions, which include endogenous factors associated with the effective use of the internal economic and social potential of the region, as well as exogenous conditions.

The level of vulnerability of the economic ecosystem of the Territory depends on the resilience to failures. Therefore, the crisis, which exposed the imperfection of the territory's ecosystem, should be considered as an impetus for changes aimed at increasing resistance to various external influences that may occur in the future. Sustainable development in the context of a socio-economic ecosystem is influenced by various factors that affect the acceleration or deceleration of the processes of change (Barska et al., 2022)

Currently, one of the most important tasks for the ecosystem of the territory is to stimulate sustainable development, which includes spatial, economic and social planning, which allows for better coordination of activities and increase the efficiency of the system. The decline in the pace of sustainable development of the territory's ecosystem ultimately affects its competitiveness and the standard of living of the population. The stability of the Territory's economic ecosystem is tested not only by its ability to "recover from the crisis", but also by its sensitivity to crisis phenomena, which is manifested in various reactions of the socio-economic system of the territory to negative external stimuli and changes in the economic situation.

The concept of "territorial vulnerability" can be defined as the susceptibility of an economic ecosystem to external influences, including negative crises or structural changes of a global nature. It is about their reaction to developmental disorders and the ability to follow the right trajectory of development (Wyrwa et al., 2022).

Currently, the priorities of sustainable development are focused on socio-economic issues, since the greatest effort, in accordance with the 2030 agenda, should be the eradication of poverty in all its manifestations while ensuring social and economic goals. The success of the sustainable development of the economic ecosystem of the Territory depends on various factors, including the active interaction of all elements of the core system and all stakeholders. Thanks to this structure, the economy of the territory contributes to socio-economic prosperity and promotes social stability (Kajiita et al., 2024).

2.3 Digitalization of management methods

Digitalization can be defined as the adoption and use of digital technologies by individuals and organizations within the economic ecosystem of a particular territory. The sustainability of a digital ecosystem refers to organizational activities that aim to achieve sustainable development goals through the use of technologies that generate, process, transmit, and receive electronic data. In short, research into the digital ecosystem focuses on applying digital technologies as tools that support and facilitate the socio-economic growth of the territory's ecosystem (Holzmann et al., 2023).New digital technologies are affecting the fundamental mechanisms of interaction within the economic ecosystem of a territory. This requires the application of new management methods and strategies in order to cope with the challenges posed by digital transformation.

The impact of digital technology is particularly significant due to the potential for introducing technologies that can improve business processes. These technologies are flowing into the ecosystem of the territory in order to achieve results such as increased efficiency and reduced costs through automation and process optimization (Klos et al., 2021).Digital tools expand the capabilities of the territory's economic ecosystem by collecting and analyzing data in real time to monitor productivity and activity across all elements of the system. The core of this ecosystem generates a vast amount of data in the digital age. However, new data analysis software and artificial intelligence can help monitor and analyze this data more efficiently. Stakeholders in the territory's ecosystem can better control and coordinate their activities by obtaining better insights into the needs and preferences of other participants in the system through data analysis. This allows them to introduce new digital technologies more effectively (Lindquist, 2022).Advances in digital technologies have led to their widespread use in various sectors of the territory's economy. The development of digital ecosystems, platforms, and solutions not only enables real-time monitoring of environmental conditions but also supports well-informed management decisions that contribute to improved quality of life for citizens, increased social and economic development, and more sustainable use of domestic resources. Additionally, these technologies help to enhance general literacy and knowledge among the population (Martins et al., 2022).

3 FORMULATION OF A RESEARCH PROBLEM

The active development of digital technologies leaves an appropriate imprint on the organization of the territory change management system and requires coordinated steps to improve it.

The result of the research of scientific papers showed that at this stage of the development of the digital ecosystem of the territory there is no systematization of digital technologies for managing changes in the sustainable development of the economic ecosystem of the territory. Based on this, it is necessary to identify the main end-to-end technologies for managing stakeholders of the ecosystem of the territory, as well as to rank them by importance.

4 METHODOLOGY

This study is a review of scientific articles based on the results of studying issues related to economic relations for the development of methods for managing changes in the sustainable socio-economic development of the economic ecosystems of the territory. Methods of change management are considered, as well as the use of end-to-end digital technologies. Three dominant digital technologies in each quadrant of the matrix were identified based on a survey of experts. The focus group of experts included representatives of municipalities, the media, universities, business, and society.

5 SYSTEMATIZATION OF PLANNED DIGITAL TECHNOLOGIES

Digital technologies can be defined as a wide range of electronic equipment, systems, resources and tools that generate, store or process data. Thanks to innovations such as the Internet, mobile technologies, digital networks and applications, the field of digital technology is constantly evolving and changing. New technologies such as artificial intelligence, robots, data analysis and machine learning are becoming more widespread in the digital sphere (Shikongo et al., 2019)

Based on the expert assessment, a matrix was developed that reflects the change management system for the sustainable development of the economic ecosystem of the territory. This matrix represents the use of end-to-end digital technologies by stakeholders of the Territory to achieve the targets of the sustainable development program until 2030.

Table 1: Digital technologies used to achieve the Sustainable Development Goals (SDGs) of municipalities.

SDGs	Technologies
Ensuring a healthy lifestyle and promoting well-being for everyone at any age	1. Big data
	2. Wireless communication technologies
	3. Neurotechnology and artificial intelligence
Ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all	1. Wireless communication technologies
	2. Virtual and augmented reality
	3. Big data
Promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	1. Neurotechnology and artificial intelligence
	2. Big data
	3. Blockchain
Building resilient infrastructure, promoting inclusive and sustainable industrialization and innovation	1. Neurotechnology and artificial intelligence
	2. Virtual and augmented reality
	3. Big data
Ensuring the transition to rational consumption and production models	1. Neurotechnology and artificial intelligence
	2. Big data
	3. Blockchain

The key "end-to-end" technologies for the public administration system include big data, artificial intelligence, and blockchain. These are the most promising areas for integration. Big data technologies aim to solve this problem by analyzing large amounts of data to formulate goals, determine public policy directions, and monitor and evaluate results. Artificial intelligence can produce highly effective results when combined with big data, generating decisions and making short- and long-term forecasts. Human participation is minimal, as AI can identify and diagnose problems. Information is the basis of decision-making in public authorities, allowing for forecasting the consequences of different types of activities and identifying deep interdependencies between elements of controlled systems. The continuous flow of diverse and unstructured information about citizens demands streamlining and innovative processing methods that adhere to the principles of privacy and security. Blockchain is a database where information is stored and updated independently by participants in a large network. Each node processes transactions and makes decisions, forming a block. After creation, the block is verified by other network members. If everyone agrees, it is added to the chain. The distributed ledger is then updated, but each node retains an identical copy, making it impossible to alter the record.In addition, the information stored and processed on the blockchain is encrypted, completely eliminating the possibility of data deletion or alteration as a result of a hacking attack on the blockchain links. Thanks to distributed ledger technologies, it is possible to enhance the level of government database protection against intruders, facilitate rapid and efficient interdepartmental communication, and organize effective information management regarding individuals and legal entities as well as their activities.

Wireless communication technology is utilized to transfer data between two or more locations at a distance without the need for a wired connection. The 5G network standard offers high bandwidth, reliable connectivity, and security, as well as low data transmission delays, making it possible to effectively utilize large volumes of data. Radio waves, infrared radiation, optical signals, or laser beams serve as carriers of information in these networks. In the municipal economy, 5G networks will enable real-time monitoring of urban spaces, housing and communal services, energy management systems, and utilities. Thanks to the high data transfer rates, fifth-generation networks offer great opportunities for telemedicine applications. Wireless communication will improve the efficiency of transport infrastructure, including systems for monitoring traffic congestion, public transportation based on video analytics, detecting traffic violations, and monitoring road conditions.

In industry, agriculture, logistics, and retail, 5G will enable the use of robots and drones. The practical application of virtual and augmented reality technologies is based on the projection of virtual elements into the real world, enhancing physical objects with digital additions or markers that can be seen, heard, or even felt using mobile devices. The main reason for introducing augmented reality technologies into public administration is to visualize complex and diverse information from large amounts of data that are collected and analyzed. This information is used to make better management decisions.

To achieve this goal, several tasks need to be completed, including collecting primary data, classifying it, storing it, sharing it between different departments and employees, preparing it for processing, transforming it, visualizing it, and providing direct and feedback links with those who implement government decisions and those who receive government services.

Table 2: Digital technologies used to address the Sustainable Development Goals (SDGs) of the media.

SDGs	**Technologies**
Ensuring a healthy lifestyle and promoting well-being for everyone at any age	1. Wireless communication technologies
	2. Big data
	3. Neurotechnology and artificial intelligence
Ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all	1. Wireless communication technologies
	2. Blockchain
	3. Big data
Promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	1. Big data
	2. Wireless communication technologies
	3. Blockchain
Building resilient infrastructure, promoting inclusive and sustainable industrialization and innovation	1. Wireless communication technologies
	2. Big data
	3. Neurotechnology and artificial intelligence
Ensuring the transition to rational consumption and production models	1. Big data
	2. Wireless communication technologies
	3. Neurotechnology and artificial intelligence

End-to-end digital technologies are able to perform important functions in the activities of mass media, such as generating original content based on big data and verifying additional news to exclude fake messages. They also analyze the qualitative composition of the audience and take into account its requests. These technologies help find potential advertisers and, as a result, develop the processes of monetizing content broadcast by specific mass media.

The field of application for end-to-end technologies also includes the work of journalists and creators of materials using big data, such as graphs, databases, and statistical information. Accessing this kind of data becomes one of the main sources for conducting extensive investigations, analytical programs, and creating stories covering historical events. It also helps create news programs on TV. The neural network allows for the moderation of both verbal and visual texts, and in this context, the media, through end-to-end technologies, can not only resist dangerous trends but also form genuine dialogical relationships with their audience. Big data, according to recent research, allows for decisions based on user feedback to be made five times faster (Oleshko et al., 2022). Blockchain technology provides both authentication and a high level of security. In a highly distributed world where journalism is increasingly dependent on third-party technology, there are two challenges that need to be addressed.

Table 3: Digital technologies used to support the Sustainable Development Goals of universities.

SDGs	Technologies
Ensuring a healthy lifestyle and promoting well-being for everyone at any age	1. Virtual and augmented reality
	2. Big data
	3. Quantum technologies
Ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all	1. Virtual and augmented reality
	2. Wireless communication technologies
	3. Blockchain
Promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	1. Big data
	2. New production technologies
	3. Wireless communication technologies
Building resilient infrastructure, promoting inclusive and sustainable industrialization and innovation	1. Neurotechnology and artificial intelligence
	2. Quantum technologies
	3. Virtual and augmented reality
Ensuring the transition to rational consumption and production models	1. Big data
	2. New production technologies
	3. Components of robotics and sensors

The use of big data in education. Over time, educational institutions have collected a significant amount of information about different aspects of their activities: academic and educational content, information about students and teachers, electronic library archives, and more. Big data technologies allow us to create a unified structure by extracting useful information and using it for various activities in educational organizations.

In the field of education, big data sources include information from learning management systems, certification results, sociological research data, and other sources that are used to analyze resource management effectiveness, student performance, and develop individual educational paths for students. This information is processed using artificial intelligence techniques. Artificial intelligence technologies are a set of tools and techniques for creating intelligent systems that mimic human cognitive functions using mathematical models and computational algorithms. Neurotechnologies address a similar goal. Blockchain is a data storage technology based on a decentralized ledger that ensures data security, integrity, and confidentiality.

The value of blockchain for education lies in its ability to provide reliable and long-term preservation of documents related to academic achievements. It protects against unauthorized access and alteration, making it easy to retrieve and verify information.

Blockchain allows the storage of various types of educational data, such as personal files, diplomas, exam results, essays, video recordings, awards, and more. These principles form the basis for a cooperative approach to education. This model assumes that students achieve a specific, planned, and measurable educational goal. Blockchain serves as the concept of "learning is earning," where students earn tokens by studying topics funded through a marketplace. Artificial intelligence (AI) methods are used to create smart and robotic devices that are integrated into the educational process. AI technologies are also used to ensure adaptability in learning, based on evaluating student performance and predicting academic outcomes.

One of the most commonly used educational tools is the chatbot, which supports the learning process by performing informational, consulting, supportive, and entertaining functions. Chatbots act as virtual teaching assistants, providing assistance with various tasks and answering questions. AI tools are also utilized in the development of educational simulators and games, as well as virtual learning environments. Virtual simulators and training simulators are used at various levels of education. They are particularly important in the development of practical skills and abilities for future specialists, especially in cases where real-life practice is difficult or impossible due to technical, ethical, safety, or other reasons. These simulators play a crucial role in the training of various professionals, including machinists, pilots, medical professionals, law enforcement officials, and technical specialists (Grechushkina et al., 2022).

Table 4: Digital technologies used to support the Sustainable Development Goals of businesses.

SDGs	Technologies
Ensuring healthy lifestyles and promoting wellbeing for all at all ages	1. Neurotechnology and artificial intelligence
	2. Virtual and augmented reality
	3. Robotics and sensor technology
Ensuring quality education for all and providing lifelong learning opportunities	1. Blockchain
	2. Big data
	3. Neurotechnology and artificial intelligence
Promoting economic growth, employment, and decent work	1. Components of robotics and sensors
	2. Big Data
	3. New production technologies
Building resilient infrastructure, promoting inclusive and sustainable industrialization and innovation	1. Components of robotics and sensors
	2. Big Data
	3. New production technologies
Transition to Sustainable Consumption and Production Models	1. Components of robotics and sensors
	2. Neurotechnology and artificial intelligence
	3. Virtual and augmented reality

Businesses actively use end-to-end digital technologies in their operations. Virtual reality (VR) technology is a complex system that allows users to immerse themselves in a virtual world using specialized devices. Augmented reality (AR) technology, on the other hand, integrates information with real-world objects, such as text, computer graphics, audio, and other representations, in real time.

Currently, data technologies have seen the most significant development in the entertainment and marketing sectors, but this is only the beginning of their potential. The most promising applications from an economic perspective are in industrial production, education, healthcare, and consumer services. VR is entirely computer-generated, and the most common method of using the technology involves the use of specialized glasses or helmets, which connect wirelessly or via cables to a computer, game console, or smartphone. In augmented reality, a virtual image is combined with a real-world image to create a single view that the user sees on their device's screen. This is achieved through the use of neural networks, which learn to recognize objects, markers, and locations in the real world.

The benefits of augmented reality include increased productivity and efficiency in industrial settings, creating new ways of communicating and providing services to consumers, and improving the skills of workers. It also leads to the creation of new media for the younger generation, such as augmented reality apps and games.

New production technologies, also known as advanced manufacturing techniques, are a set of approaches, materials, and processes that have the potential to revolutionize industries. These technologies are rapidly developing but have not yet been widely adopted. They can reduce the need for manual labor, increase productivity, and create new opportunities for businesses.

There are several types of new production technologies, including 3D printing, robotics, and artificial intelligence. 3D printing allows for the creation of complex objects with precision, while robotics automates repetitive tasks and improves efficiency. Artificial intelligence, on the other hand, uses machine learning to analyze data and make decisions.

Besides,

- Digital design, mathematical modeling, and product lifecycle management,
- Technologies of "smart" production,
- Manipulators and manipulation technologies.

The blockchain distributed ledger system is a database that is shared among several network nodes or computing devices. The technology of distributed ledger systems represents a new approach to database creation, the key feature of which is the absence of a central control center. Each node independently compiles and records updates to the ledger.

This system is a way to transform payment and settlement processes, increase trust in various services, allow direct transfer of database management capabilities, and keep records. Robotics is a technical field that studies the automation of production and other systems through the use of robots. This involves designing, creating, and using robots to interact with their environment and perform various tasks without human assistance. Sensorics, on the other hand, is the study of how robots perceive sensations and interact with their surroundings.

Robotics and sensorics draw on the principles of mechanics, electronics, and other scientific fields. The applications of modern robotics are vast, with robots already being used in everyday life, human services, medicine, agriculture, and more.

Through the use of robotics and sensing technologies, the quality of products and services can be improved, operating costs can be reduced, and the competitive advantage of businesses can be enhanced. Neurotechnologies and artificial intelligence refer to any technologies that have a significant impact on how we understand the brain, consciousness, mental activity, and higher cognitive functions. Artificial intelligence is the ability of artificial intelligent systems to perform tasks that were previously thought to be the exclusive domain of humans. It is the science and engineering of creating intelligent machines, particularly intelligent computer programs, that can perform tasks such as protecting and monitoring equipment, improving products and services by understanding psychophysiological processes, and creating robots with artificial intelligence to assist in the production of goods. Big data is a term used to describe large and complex sets of data that are structured or unstructured. These data sets can be analyzed using special programs and tools to extract valuable information. Big data technologies help businesses understand their current state, make forecasts, automate routine processes, and quickly process large amounts of information.

End-to-end digital technologies are essential for reducing costs, improving production, providing better services, and collecting and processing information more efficiently. These technologies are the future of the economy and the country as a whole.

Table 5: Digital technologies used to achieve the Sustainable Development Goals (SDGs) of society.

SDGs	Technologies
Ensuring a healthy lifestyle and promoting well-being for everyone, regardless of a ge	1. Wireless communication technologies
	2. Blockchain
	3. Virtual and augmented reality
Ensuring inclusive and equitable quality education for all	1. Wireless technologies
	2. Virtual and augmented realities
	3. Blockchain
Promoting sustainable economic growth and full employment	1. Wireless technologies
	2. Big data
	3. New production technolo gies
Building resilient infrastructure and promo ting industrialization	1. Virtual and augmented realities
	2. Neurotech and AI
	3. Big data
Ensuring the transition to more sustainable consumption and production patterns	1. Neurotech and AI
	2. Big Data
	3. New production technologies

The use of end-to-end digital technologies plays a crucial role in the development of society. Artificial intelligence enables intelligent machines to learn, improve and make informed decisions, allowing them to perform tasks that were previously thought to require human experience, creativity and ingenuity alone. These areas include medicine, education, business, science, crime fighting, cybersecurity, recruitment, entertainment and solving everyday issues. For example, in Russia, a robot named Vera conducts initial interviews at some recruitment companies. The public sector currently faces the challenge of processing large amounts of unstructured data and responding to citizen requests, making information and knowledge more accessible. Thanks to automation, "deep analytics", or analysis of data that is not publicly available, can isolate, store, and protect important data from sources such as documents, emails, tickets, videos, and social media.

Image recognition algorithms can read machine-generated documents and handwritten texts, using contextual databases for automatic verification. This allows us to uncover trends, user preferences, population movements, and demographic data. For example, we can analyze the purchasing power of a population to improve customer service and make decisions in areas such as migration more transparent, targeted, and informed. Smart applications and platforms are already being used to make government correspondence and customer services faster, more efficient, and cheaper. These technologies support the digital payment process, manage information flows, and help with reporting. By using analytics, human resources are freed up and costs are reduced by accelerating data collection, transmission, and recognition. This ultimately leads to better customer service.

Technological developments and information exchange between government agencies and the commercial sector can benefit vital areas such as national security, healthcare, social services, financial services, transportation, and public safety. Through digital technologies, governments can easily extract and use data, limiting the number of requests from users. Citizens have the right to change or delete data, and receive information on how and where it is used. (Denisov, 2019)Smart cities are being developed using wireless communication technologies. 5G networks in urban areas will allow real-time monitoring of urban spaces, housing, and communal services, as well as monitoring energy management systems and utility services. Thanks to their high data transfer rates, fifth-generation networks will create great opportunities for telemedicine systems. These networks will also increase the efficiency of transport infrastructure through systems for monitoring traffic congestion and public transport based on video analytics. They will help detect traffic violations and monitor the condition of roadways. Wireless communication technologies are an essential part of smart cities, which consist of several components that work together to create a more efficient and sustainable future. Blockchain technology has several advantages, including enhanced security. The blockchain utilizes advanced cryptographic algorithms to ensure the safety and integrity of data. Each transaction recorded on the blockchain is transparent and can be verified by all parties involved. This eliminates the need for intermediaries, streamlining processes and allowing for direct transactions between individuals or organizations. Virtual and augmented reality technologies have revolutionized education and training, offering a new and immersive learning experience that simulates real-world scenarios. Students can gain practical skills and experience through interactive virtual tours, historical reconstructions, and scientific simulations. This makes learning more engaging and accessible, enhancing the traditional textbook experience by overlaying digital content and animating static objects.

Virtual reality is also making a significant impact on the healthcare industry, helping to treat pain, mental illness, and improve surgical techniques. Surgeons can use virtual reality simulations to practice and refine their skills, leading to better patient outcomes. These technologies are transforming the way we learn and work, opening up new possibilities for innovation and growth. The technology helps medical professionals during surgeries by providing them with real-time access to important patient information, increasing accuracy and reducing the risk of errors. Virtual and augmented reality technologies enable users to meet and interact with each other in virtual spaces, breaking down geographical barriers. This allows remote teams to collaborate and work together on projects, holding virtual meetings and sharing information in shared virtual environments. Architects use virtual reality (VR) to create immersive building design reviews, helping clients visualize projects before construction begins. This technology allows them to see how the building will look in real life, which helps them make informed decisions about the design. Manufacturers also benefit from VR-based assembly instructions. These instructions reduce errors and improve productivity, as they allow workers to see exactly what they need to do and where.

In the tourism sector, VR tours are offered to show potential visitors destinations and attractions. This allows them to get a better idea of what they will see when they visit the place, which can help them decide whether they want to go or not. In retail, VR can improve the shopping experience by allowing customers to try on virtual clothes or visualize furniture in their homes before making a purchase.

Virtual and augmented reality (AR) technologies have also had an impact on society and culture. They provide new opportunities for artistic expression, such as immersive storytelling and virtual art exhibitions. AR can also be used to create interactive performances, allowing users to become part of the show.

These technologies can also help foster empathy and understanding. By allowing users to "step into someone else's shoes", they can better understand different perspectives and cultures. This can help break down barriers and promote understanding between people from different backgrounds. In addition, they have created new forms of social interaction, bringing people from all over the world together through shared virtual spaces and multiplayer games. As technology continues to evolve, it further defines the future and the way we perceive reality.

New production technologies are a range of innovative approaches, materials, methods, and processes used to design and produce products that are both competitive and in high demand on the global market (such as machines, structures, devices, and installations). These new technologies have great potential and are rapidly developing, but they are still relatively underrepresented compared to more traditional technologies.

6 CONCLUSIONS

The use of "end-to-end" digital technologies together will lead to the creation of a flexible state management system that will fully meet the requirements of modern society. The digital transformation of the mechanisms for the implementation of managerial functions and tasks has a number of advantages, including increasing the effectiveness of state control and a high level of satisfaction of citizens with the quality of public services. The new technological paradigm calls for the reformation of the hierarchy of authorities, suggesting the creation of a state architecture based on a single platform (Katrashova et al., 2020)

Thus, the digital ecosystem of the region is a digital macro environment for the interaction of citizens, businesses and authorities, contributing to the stable and sustainable socio–economic development of the region by improving the quality of management decisions through the organization of a mechanism for collecting and processing information about the infrastructure of the region in real time using end-to-end digital technologies. The basis of the regional digital ecosystem is a digital platform / multiple platforms / a single digital platform with certain services, focused on specific areas of activity of the regional government and providing convenient interaction between citizens, business and government. Its direct participants are government authorities, society, business, universities, the media and build communication processes; they exercise their rights and obligations in accordance with national and regional legislation, improve the capabilities of the digital ecosystem in accordance with scientific and technological progress, provide (enterprises and authorities) and receive services (enterprises, authorities, citizens), integrate information into the digital ecosystem through individual end-to-end digital technologies (enterprises and authorities). The network nature of interaction in the digital ecosystem of the region has a positive impact on the social and economic life of the territory of regional administration and the means to ensure the transition to the second and third stages of digital transformation, which is strategically important in the conditions of catching up with the development of the country.

The paper considered the concepts of the economic ecosystem of the territory and sustainable socio-economic development of the ecosystem of the territory. The concept of a digital ecosystem and the possibilities for its management are considered. The main end-to-end digital technologies and their application within the framework of the stakeholder representation of the economic ecosystem of the territory are studied. The systematization of digital technologies for managing changes in the sustainable development of the economic ecosystem of the territory was carried out. The data obtained make it possible to implement the resulting systematization of digital technologies by the stakeholders of the territory for the implementation of the Sustainable Development Goals until 2030.

ACKNOWLEDGEMENTS

The research was carried out at the expense of a grant Russian Science Foundation No. 24-18-20036

REFERENCES

Holzmann, P., Gregori, P., 2023. The promise of digital technologies for sustainable entrepreneurship: A systematic literature review and research agenda. *International Journal of Information Management,* 68, 102593.

Audretsch, D., Cunningham, J., Kuratko, D., 2019. Entrepreneurial ecosystems: Economic, technological, and societal impacts. *The Journal of Technology Transfer,* 44: 313–325.

Behera, C., Jayalakshmi, R., Dash, M.C., 2019. Digital ecosystems: challenges and prospects. *International Journal of Research and Analytical Reviews*, 6(1):176-183.

Barska, A., Jedrzejczak-Gas, J., Wyrwa, J., 2022. Poland on the Path towards Sustainable Development—A

Multidimensional Comparative Analysis of the Socio-Economic Development of Polish Regions. *Sustainability*, 14,10319.

Wyrwa, J., Barska, A., Jędrzejczak-Gas, J., Kubiak, P., 2022. Socio-economic Dimension of the Sustainable Development of Polish Provinces. *European Journal of Sustainable Development*, 11(3):376-393

Kajiita, R., Kang'ethe, S., 2024. Socio-economic Dynamics Inhibiting Inclusive Urban Economic Development: Implications for Sustainable Urban Development in South African Cities. *Sustainability*, 16, 2803.

Klos, C., Spieth, P., Clauss, T., Klusmann, C., 2021. Digital Transformation of Incumbent Firms: A Business Model Innovation Perspective. *IEEE Transactions on Engineering Management*, P. 1–17.

Lindquist, E. A., 2022. The digital era and public sector reforms: Transformation or new tools for competing values? *Canadian Public Administration*, 65(3): 547–568.

Martins, J., Goncalves, C. Silva, J., Goncalves, R., Branco, F., 2022. Digital Ecosystem Model for GIAHS: The Barroso Agro-Sylvo-Pastoral System. *Sustainability*, 14(16), 10349.

Shikongo, S., Iyawa, G., Hamunyela, S., 2019. Can Digital Technologies Tackle Gender Inequality? Proceedings of International Conference on Information systems and Emerging Technologies, 2023. *Information Communication and Society*, 22,(1):1-17.

Kartashova, Yu.V., Mityashin, G.Yu., 2020. The use of "end-to-end" digital technologies in the field of public administration. *Science of Krasnoyarsk region*, 9 (4):85-102. (In russ.)

Kosorukov, A.A., 2020. Augmented reality technologies in the field of public administration. *Sociodynamics*, (1). (In russ.)

Oleshko, V.F., Oleshko, E.V., 2022. End-to-end digital technologies: the range of possibilities of modern mass media. *Questions of Theory and Practice of Journalism*, 11(3):564-585. (In russ.)

Grechushkina, N.V., Tikhonova, O.V., Parshin, A. N., Martishina, N.V., 2022. End-to-end technologies in education in the context of its digital transformation. *School of the Future*, (6):110-123. (In russ.)

Denisov, A.S., 2019. End-to-end technologies in the electronic state: a socio-political aspect. *Digitalization of the political space*, (4):21-37. (In russ.)

Potential of the Industrial Enterprise Ecosystem Digitization

Evgeny V. Popov [a], Victoria L. Simonova [b], Aleksandr S. Zyrianov [c]
Ural Institute of Management, RANEPA, 8th of March Street, 66, Yekaterinburg, Russia
epopov@mail.ru, vlsimonova1409@gmail.com, zyrianov.info@gmail.com

Keywords: Digitalization potential, enterprise ecosystem, platform ecosystems, Industry 4.0, digital technologies in industry.

Abstract: The authors of the article analyse the potential of digitalization in the ecosystem of an industrial enterprise, emphasizing the importance of integration into digital platforms. Describing changes in the business environment caused by uncertainty and turbulence, the authors emphasize that collaboration and network effects are key to achieving competitive advantage. The central theme is the development of digital technologies, which not only create new business opportunities, but also contribute to its evolution within the framework of an ecosystem approach. The article discusses how the digital ecosystem promotes cooperation, sustainable development and the creation of new market opportunities. The authors discuss the contributions of technologies such as artificial intelligence, the cloud, and the Internet of Things to improving manufacturing processes, reducing costs, and improving product quality. The conclusion emphasizes that successful digitalization requires a strategic approach and the active involvement of all ecosystem participants to achieve sustainability and global competitiveness.

1 INTRODUCTION

In general, cyberspace is a system consisting of different digital systems. This is more like an evolutionary digital ecosystem than a holistically engineered system: ecosystem members survive and thrive because of their fitness and ability to change themselves in the face of competition and other evolutionary pressures (Lippert and Cloutier, 2021). At the same time, from the point of view of studying the development of digital ecosystems, at the moment scientists do not have a unified approach and, as a rule, distinguish several types of schools; in a general approximation, some consider the development of digital ecosystems based on digital platforms, and others consider digital ecosystems from the point of view of the influence of individual digital innovations (solutions, tools) on the subject of digitalization (for example, business) and on the stakeholders of this object. However, no matter from what point of view we look at the digitalization process, it is obvious that any entity that integrates into such an ecosystem receives greater potential than entities located outside the digital ecosystem.

From a practical point of view, integration into digital ecosystems is in one way or another associated with resource costs (financial, time, labor, etc.); accordingly, a management decision on the need for such costs should be made based on an understanding of the benefits, payback, and positive potential of these investments. Unfortunately, at the moment, the issue of the potential for digitalization of the ecosystem of an economic entity has been little studied and there are no qualitative and, especially, quantitative solutions for assessing such potential unanimously recognized in the scientific community. In this article, we will take a first look at what exactly this potential is for an industrial enterprise.

2 FEATURES OF THE ECOSYSTEM OF AN INDUSTRIAL ENTERPRISE

[a] https://orcid.org/0000-0002-5513-5020
[b] https://orcid.org/0000-0003-2814-464X
[c] https://orcid.org/0009-0002-2015-6742

In the modern world, we are faced with significant changes in social relations, which are especially noticeable in the business environment. These changes are characterized by a high degree of uncertainty and turbulence, which forces companies to seek new ways to achieve competitive advantage. One of these ways is collaboration based on the use of shared resources, knowledge and network effects, as well as the use of institutional conditions. An important role in this process is played by the development of digital technologies, which open up new opportunities for information exchange and business organization.

These changes create a need for a new research approach that goes beyond the individual firm and takes into account the indirect effects of interactions among ecosystem participants. Thus, ecosystems come to the fore as new objects of research. However, the popularity of the concept "ecosystem" leads to its ambiguous and often vague use.

The ecosystem metaphor in business dates back to the work of J. F. Moore, who, inspired by ideas about coevolution, proposed that an economic community be viewed as a system of interacting organizations (Moore, 1993). The approach to ecosystems as objects of research allows us to better understand the agglomeration interaction of organizations in various aspects: from regional to industry and business. This quest to describe interactions and their effects has a long history, beginning with the work of A. Marshall (Marshall, 1993) and continued in the studies of many scientists, including M. Porter (Porter, 1990) and R.R. Nelson with S. Winter (Nelson and Winter, 1982). Organizational ecology, neo-institutional theory and the theory of dynamic capabilities had a significant influence on the formation of the concept of ecosystems. These areas have provided a theoretical framework for understanding ecosystems as environments in which organizations can develop their competitive advantages through interaction and coordination. The concept of ecosystems provides a powerful tool for analyzing and understanding the complex interactions in modern economies. It allows us to assess both the direct and indirect effects of cooperation and competition between organizations, as well as the role of digital technologies and institutional conditions in the formation of new business models.

An examination of the concept of "ecosystem" in academic discourse reveals its diversity and adaptability, while highlighting the challenges associated with its use in scientific work due to the lack of uniformity in definitions. The diversity of approaches to defining an "ecosystem," including "business ecosystem" and "innovation ecosystem," reflects the concept's rich potential for application in a variety of research and practice contexts. Particular attention is paid to platform ecosystems as an important area of research in the context of the modern digital economy and innovation.

L.A. Ramenskaya's work examines four key discourses in the study of ecosystems, each of which represents a unique perspective on the structure, functioning and strategic importance of ecosystems in various areas of business and innovation (Ramenskaya, 2020). A business ecosystem emphasizes how a firm interacts with its environment to maximize revenue and enhance competitive advantage. This concept covers a wide range of participants, including suppliers, distributors, outsourcing companies, manufacturers of related products and services, regulators and even the media, emphasizing their role in the creation and distribution of value and benefits. Research within this discourse examines how the effectiveness of the ecosystem as a whole affects the success of its components and how the participants co-evolve. An innovation ecosystem focuses on analyzing the interactions between participants to stimulate the creation and commercialization of innovations. Here, the ecosystem is seen as an environment that facilitates the implementation of innovative projects through cooperation and coordination of the actions of all stakeholders. The entrepreneurial ecosystem is closely linked to innovation discourse, with an emphasis on the territorial aspect and the role of the entrepreneur as a key participant in the ecosystem. This approach emphasizes the conditions and resources needed to promote entrepreneurship and new venture creation, including access to finance, markets, and institutional support. A platform-based ecosystem explores the dynamics between a central platform (leader) and multiple participants (followers) connected through technology standards and interfaces. This discourse views platforms as the basis for the creation of innovation, entrepreneurial activity and the development of multi-sided markets. Common to all discourses is the recognition of the importance of interconnections and interdependence between participants, unification around a common value proposition and the need to adapt to the characteristics of the ecosystem. These characteristics highlight the complexity and multidimensionality of ecosystems, as well as their strategic importance for innovation and business development in modern economies.

Most scholars use the concept of ecosystem to refer to the synergies and complementarities achieved between the activities, resources, or outputs of multiple organizations. Such synergies and complementarities are portrayed in the literature as specific to resources or services that significantly enhance the value or profit of ecosystem participants (Adner, 2017), (Jacobides, Cennamo, Gawer, 2018), (Teece, 2018). Ecosystems emerge around specific value-adding activities and resource complementarities that typically span multiple organizations, industries, and platforms.

Current research on ecosystems, including those in the form of platforms, examines the connections of ecosystem participants in terms of the operational and economic benefits they provide to them. The formation of an enterprise ecosystem results from specific and value-enhancing complementarities that go beyond bilateral relationships and entail multilateral connections that often cross industry boundaries. The multilateral relationships that industrial enterprises have with material and technology suppliers, buyers, banks, scientific and educational organizations, government, media and other organizations provide a good illustration of how the interdependent nature of such relationships leads to the formation of an ecosystem, as well as resources and services, which acquire higher value to the extent that they are related to each other. However, what is combined in this way consists of data. Most connections between firms, resources, or activities are expressed and instrumentalized as data relations, and it is in this form that they become objects of ecosystem practices and exchange.

At the same time, if we talk about the features of the ecosystems of industrial enterprises, then in a key sense, in contrast to, for example, the banking sector (fintech) and the service sector in general, at the moment there is a more superficial and uneven process of digitalization between the actors of the system. Of course, there are differences here based on regional and industry characteristics, but nevertheless, due to the low base effect, the potential from digitalization of ecosystems of industrial enterprises can be significant. Unfortunately, now in the scientific world there are virtually no recognized specific methodologies for assessing (calculating) potential; there are mainly two types of approaches to this issue: the integral method of calculation and the method based on a system of balanced indicators (KPI), so the issue of analyzing and calculating potential is the next step for scientific research into industrial ecosystems.

3 RESEARCH METHODOLOGY

The object of this study is the ecosystem of an industrial enterprise, the subject of the study is the economic relations of the elements of the ecosystem with the core - the enterprise based on platform digitalization, deepening specialization and digital cooperation. The methodological basis for the study was the concept of the relationship between the potential of digitalization and individual components of the organization's potential: financial, personnel, production and technological, and scientific and technical (Dunenkova, 2022). Thus, we, in turn, note that the potential for digitalization of the enterprise ecosystem should influence these components (Figure 1).

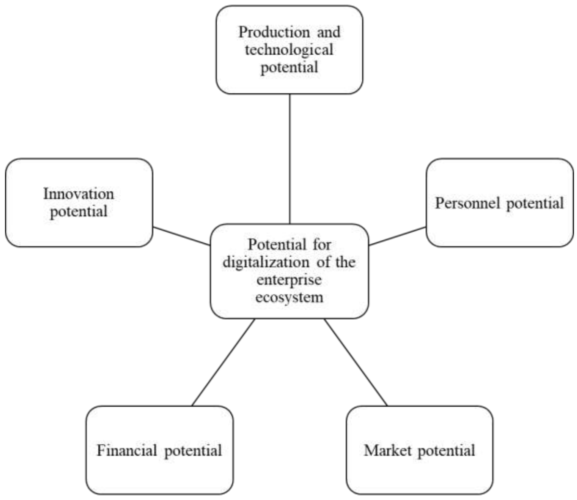


Figure 1: Elements of the digitalization potential of an industrial enterprise ecosystem

The information base of the study consisted of scientific articles indexed in the WoS, Scopus and RSCI databases. The result obtained in the work is based on a review of previous studies with justification of the research problem, identifying ecosystem stakeholders, defining digital technologies or interactions in the ecosystem, as well as taking into account the transformation of key resources as a result of using an integrated approach to the digitalization of the enterprise ecosystem.

4 FORMALIZATION OF THE DIGITALIZATION POTENTIAL OF AN INDUSTRIAL ENTERPRISE

By analogy with the digitalization of individual economic entities, the digitalization of an entire ecosystem and the integration of an industrial enterprise into it gives such an enterprise a range of new opportunities and resources (Chirumalla, 2021). Such a transformation involves both qualitative and quantitative business growth, as well as the formation of new potential for such an ecosystem. At the same time, the fragmented digitalization of the ecosystem creates a loose, disconnected, heterogeneous environment for the company. Here it is possible to compare it by analogy with the so-called “patchwork automation”. In this case, digitalization becomes the automation of individual directions of information flows between system actors, and not the ecosystem formed by a single digital platform. Nevertheless, of course, a certain effect can be obtained by reducing the labor intensity and cost of information transactions, reducing the duration of individual stages of processes, but overall capabilities will not fundamentally improve, and the development of potential will be weak and one-sided. To enhance the digitalization potential of an industrial enterprise, new digital technologies must not only be implemented systematically, but also form a full-fledged digital ecosystem supporting all information flows of the organization.

Due to the fact that at the moment, from the point of view of ecosystem development, companies from the field of fintech , social networks, services are in the foreground, and the vast majority of these ecosystems are developing according to the platform principle, in order to maximize the possible potential of the industrial enterprise ecosystem from the process of digitalization of information flows By analogy, it can be represented in the form of the development of several platforms with key ecosystem actors (Figure 2). The concept of a platform ecosystem, or simply ecosystem, has become increasingly used over the past few years as a means of capturing the benefits provided to ecosystem participants by linkages of resources or activities that cannot be categorized as standard supply chain configurations or other resource and activity interdependencies associated with the concept of industry, cluster, or networks (Gawer and Cusumano, 2014).

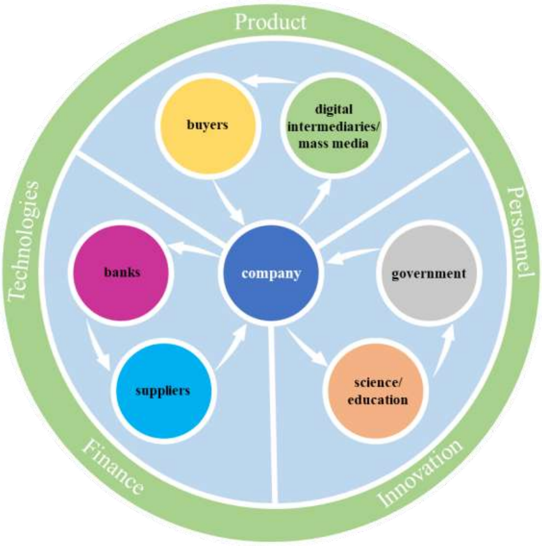


Figure 2: Illustration of platform interaction for the development of an industrial enterprise ecosystem

At the center of the ecosystem is an industrial enterprise, which interacts with certain actors (stakeholders) of the system through key digital platforms. Let us consider in a little more detail the composition and interaction data, which in each case give rise to the development of potential in the directions indicated in Figure 2.

4.1 Platform interaction Company-Suppliers-Banks

The use of digital platforms is becoming key to improving the efficiency of production and technological processes in enterprises in the era of digitalization of ecosystems. These platforms, which include a set of algorithms for the interaction of many participants in a single information environment, can significantly reduce transaction costs by optimizing communication and data exchange, which significantly increases the efficiency of using the production and technological potential of enterprises (Savina and Stepanov, 2020).

At the moment, the banking sector of the economy is actively developing its digital platforms not only for interaction in B2C markets, but also in the B2B direction, being the developer and owner of the platforms. These platforms allow participants (including industrial enterprises, their suppliers and customers) to interact more flexibly in terms of exchanging information digitally, which provides enormous not only technical but also financial potential. It is expressed in minimizing transaction costs when obtaining financing for projects (credit, leasing, insurance and other instruments), operating activities, thereby reducing the financial costs of the ecosystem. In addition, this provides a significant expansion of opportunities, primarily for an industrial enterprise, in increasing its production and technological potential, through direct access through the platform to the technological solutions of supplier actors connected to these platforms.

Thus, the banking digital eco-platform connects banks and entire supply chain systems for the enterprise into a single system, which leads to an increase in both the production and technological potential of the company and the financial one. There are several examples of such collaboration, where banking platforms help companies optimize and establish supply chains, including searching for suppliers. This became possible thanks to the development of digital technologies and the desire of banks to provide comprehensive solutions for business:

a. Alibaba Group - Ant Financial Services. Although Ant Financial (a division of Alibaba Group, now known as Ant Group) is not a traditional bank, its financial and digital solutions are significantly influencing the global B2B services market. Ant Financial offers a range of products that help companies improve their supply chains, including Alipay for financial transactions and 1688.com, a B2B platform that connects Chinese manufacturers with domestic and international buyers. This platform facilitates sourcing, simplifies purchasing processes and provides access to a wide range of products.

b. Sberbank. In Russia, the development of banking digital platforms is also actively keeping pace with global trends. Banks are trying to offer businesses not only electronic financial services, but also solutions for optimizing supply chains and managing production processes. Sberbank, for example, together with leasing or credit products, offers on the basis of its platform to immediately select the most profitable options for equipment suppliers from the pool of its partners and organize interaction with them.

4.2 Platform interaction Company-Digital Intermediaries-Buyers

Digital intermediaries have a significant impact on the product potential of industrial companies by optimizing advertising strategies, improving consumer interaction and expanding market presence. This influence can be viewed through three main categories: online advertising platforms, social networks and marketplaces.

a. Online advertising platforms offer businesses the opportunity to precisely target their audiences using contextual and targeted advertising. An example is Yandex.Direct, which allows companies to place advertisements for their products directly in the search results of potential buyers, significantly increasing visibility and brand awareness.

b. Social networks such as VK or Telegram provide a unique opportunity for brands to interact with consumers, collect feedback and build long-term relationships. With targeted advertising and content promotion capabilities, companies can fine-tune their marketing campaigns to specific audience segments, improving loyalty and increasing product demand.

c. Marketplaces such as Ozon or Alibaba provide industrial companies with access to international markets, providing a platform for large-scale distribution of products. They enable small and medium-sized businesses to compete with large players by offering a seamless experience for end users to search and purchase products.

Overall, integration with digital intermediaries allows industrial companies to not only improve the visibility of their products, but also manage their marketing and sales strategies more effectively, which ultimately leads to increased product potential and a stronger market position (Cozzolino, Leonardo Corbo and Paolo Aversa, 2021).

Thus, interaction with digital intermediaries (social networking platforms, marketplaces, news aggregators, etc.) allows industrial companies to offer comprehensive solutions to customers, again reducing transaction costs for the system. At the moment, there is huge potential in the formation of special platforms that use industrial protocols for the development of the Internet of Things, which is still poorly represented on the market in terms of B2B solutions. Such platforms can multiply the potential of Product solutions (Market potential) of industrial companies, both for consumers and for manufacturers themselves.

4.3 Platform interaction Company-Science/Education-Government

Collaboration between business, government and universities plays a critical role in creating a sustainable ecosystem based on the development of both human resources and innovation potential. Universities, understanding the needs of employers for digital competencies, prepare specialists who can work effectively in digitalization conditions. Governments, in turn, are facilitating the digitization of services and operations, thereby stimulating demand for digital talent. Corporations are actively integrating these talents into their structures, ensuring successful digital transformation.

Collaborations between government, business, and universities based on digital technologies are becoming a key factor in innovative development and digital transformation in many countries:

a. Russia: Innovation Center Skolkovo. The Skolkovo Innovation Center is one of the largest projects in Russia aimed at supporting innovation, developing startups and attracting investment in high-tech projects. Skolkovo cooperates with Russian and international universities, research institutes, as well as large companies and startups to implement scientific research and commercialize developments.

b. Singapore: Smart Nation Initiative. The Smart Nation Initiative in Singapore is an ambitious program aimed at maximizing the use of digital technologies in the economy and society to improve the quality of life of citizens. It involves close collaboration between government, the private sector and universities. For example, the National University of Singapore (NUS) is actively involved in research and development in the field of AI, cybersecurity and big data analysis, supporting government initiatives and interacting with businesses based on the created technologies.

c. Germany: Industry 4.0. Industrie 4.0 is a strategic initiative of the German government aimed at creating "smart factories" where digital technologies are integrated into production processes. This initiative includes the participation of universities and research institutes in the development of new technologies and training of specialists, as well as collaboration with industrial companies to introduce innovations. Examples include partnerships between Fraunhofer - Gesellschaft (a leading organization for applied research in Europe) and large industrial enterprises such as Siemens and Bosch to develop and implement intelligent systems and solutions for smart manufacturing.

These examples demonstrate how collaboration between government, business and universities can support the development and adoption of digital technologies, stimulating innovation, strengthening the economy and developing people.

Creating a digital culture within the enterprise, where flexibility, collaboration and innovation become the basis of daily work, is critical to developing the potential of staff. Continuous learning and skills development programs, including both technical and soft skills, are becoming an integral part of corporate strategy. Particular attention is paid to programs developed in collaboration with universities and government agencies aimed at closing digital competency gaps.

Thus, on the basis of educational platforms with the support of governments, powerful human resources potential is revealed, which should drive not only the innovative component of industrial companies, but also the development of industries and regions on the scale of state entities.

In addition to organizing platform interactions between various groups of stacked leaders in the enterprise ecosystem, the development of the digitalization potential of an industrial enterprise should be based on the integrated use of a wide pool of digital technologies. The next section proposes to discuss the directions of its development, taking into account the possibilities of digital technologies.

5 DIRECTIONS FOR DEVELOPING THE POTENTIAL FOR DIGITALIZATION OF AN INDUSTRIAL ENTERPRISE

The main goal of an industrial enterprise, like any other business organization, is to achieve sustainable profitability and increase value for its owners or shareholders. And at the next stage, as a derivative of the company's goal, other stakeholders receive their values - the business environment as a whole (the market) through the development of competition, authorities through the tax system, consumers through the consumption of competitive products, education and science through the formation of demand for innovation and highly professional specialists, mass media - through the formation of a transparent information field.

In this sense, in the context of digitalization of an industrial enterprise, the concept of "potential" can be perceived as a set of opportunities and prospects in relation to the growth of profitability and value of the company, which can be realized through the application of digital technologies to the enterprise ecosystem. This is not just a set of technical tools, but a wide range of improvements and transformations in various aspects of the enterprise. Below are the main aspects of this concept:

a. Untapped Opportunities: Potential indicates that there are certain areas or areas of the enterprise that can be improved or optimized through digital technology.

b. Long-term perspective: Potential is often associated with long-term opportunities. This means that investing in digitalization today can yield significant benefits in the future.

c. Innovation and Growth: Capacity includes the ability to develop new products, services, business processes and models that can lead to innovation and growth of the enterprise.

d. Overcoming limitations: Digitalization helps overcome traditional limitations associated with manual labor, slow processes and limited information, thereby expanding the capabilities of the enterprise.

e. Adaptability and Resilience: Capacity also reflects the ability of an enterprise to adapt to changes in the external environment, including market conditions, technological changes and environmental requirements.

f. Integrated approach: The concept of potential implies that to achieve maximum effectiveness, you need to take an integrated approach, integrating different digital technologies and strategies into the ecosystem.

In general, ecosystem digitalization potential is an assessment of how strongly and deeply digital technologies can transform an enterprise, improving its productivity, innovation and competitiveness.

The real potential from the digitalization of the ecosystem should generally affect two strategies: growth - that is, be aimed at increasing Income (Innovation Potential); and efficiency - to reduce the costs of the enterprise (Resource potential). Here, as a rule, the key impact of information technology affects the issue of optimizing the use of the resource part of the enterprise: material, labor, financial, information and time.

Let's look at how specific digital technologies can drive various potential improvements in the industrial enterprise ecosystem:

1. Artificial intelligence (AI), machine learning and cloud technologies:

a. Informed Decision Making: AI processes large volumes of data to provide accurate forecasts and analytics, helping to make informed decisions.

b. Improved product quality: AI can analyze production processes, identifying ineffective steps and suggesting improvements.

c. Innovativeness: Development of new products and services, adaptation to changes.

d. Cost reduction: Savings on IT infrastructure and increased scalability.

e. Security and reliability: Protecting against cyber threats and ensuring data security.

2. Additive technologies (AT):

a. Innovativeness: Allows rapid prototyping and testing of new product designs.

b. Sustainability: Reduce material waste through precision and resource-saving manufacturing.

3. Blockchain (BC):

a. Security and Reliability: Ensures data and transaction security, eliminating fraud risks and increasing transparency.

b. Digital Supply Chain Integration: Improves traceability and accounting, increasing the efficiency of logistics processes.

4. Internet of Things (IoT):

a. Increased productivity: IoT sensors and devices provide online data to monitor and optimize production processes. It also allows you to automate various processes and actions, such as lighting and temperature control, monitoring and control of production lines, automatic notification in case of emergency situations, etc.

b. Predictive Maintenance and Product Quality Improvement: Allows you to predict the need for equipment maintenance, preventing operational failures.

c. Integration with other technologies: IoT is often integrated with other technologies such as artificial intelligence, cloud computing and big data to improve data analysis and decision making.

5. Robotics (RB):

a. Automation of production processes: Robots increase the efficiency and speed of production, reducing labor costs and operation time.

b. Cost reduction: Replacing manual labor with automated processes leads to increased efficiency in the use of resources.

6. Social Networks (SM):

a. Improved customer experience: Allows you to interact with customers, collect feedback and offer personalized services.

b. Personnel development and training: Used to share knowledge and improve the skills of employees.

c. Improved communication: Allows you to expand the information field both within the company and with external counterparties (buyers - improved customer experience, personalized service and better interaction with clients, suppliers, the labor market, etc.).

7. Virtual (VR) or mixed reality:

a. Staff training and development: Virtual training and simulations help teach complex manufacturing processes.

b. Flexibility and Adaptability: Helps in visualizing and modeling production processes and products, improving planning and adaptation to change.

8. Enterprise resource planning (ERP) systems platforms:

a. Increased productivity: Efficient management of resources and processes.

b. Cost reduction: Optimization of inventory and logistics.

Each of these technologies contributes to creating a more efficient, innovative and resilient manufacturing ecosystem that can adapt to rapidly changing conditions and market demands. It is also important to take into account that the greatest efficiency is achieved with an integrated approach, when various digitalization tools are integrated and interact with each other.

6 CONCLUSION

A study of the digitalization of the industrial enterprise ecosystem demonstrates its key importance for sustainable development and competitiveness in the modern economy. Digital transformation allows enterprises not only to optimize existing processes and reduce costs, but also opens up new opportunities for innovation, deepening specialization and developing flexible cooperation. The main message of our research emphasizes that integration into digital ecosystems provides businesses with significant growth potential, which is especially important in an increasingly global competitive environment.

The advantages of digitalization cover not only the production and technological sphere, but also the financial, personnel, innovation, and also the sphere of products and services. Through interaction with banking digital platforms, social networks and marketplaces, enterprises can not only improve their financial performance, but also significantly increase their market and product potential. The key aspect is the creation of a full-fledged digital ecosystem that helps reduce transaction costs, improve interaction with customers and partners, and also stimulates the development and implementation of innovation.

It is important to emphasize that successful digitalization requires a strategic approach and the active involvement of all participants in the ecosystem. Collaboration between business, government and universities is a powerful catalyst for developing digital talent, strengthening innovation and enhancing enterprise competitiveness. Examples from countries including Russia, Singapore and Germany illustrate the successful use of digital technologies to create efficient ecosystems that support sustainable industrial and economic development.

In conclusion, digitalization of the industrial enterprise ecosystem is not just a technological upgrade, but a strategically important step towards creating sustainable, innovative and competitive business models. This process opens up new horizons for growth and development, while requiring an integrated approach to managing change and adapting to new market conditions.

ACKNOWLEDGEMENTS

The study was supported by the Russian Science Foundation grant No. 24-18-20036.

REFERENCES

Adner, R., 2017. Ecosystem as structure: An actionable construct for strategy. Journal of Management, vol. 43, no. 1, pp. 39–58.

Chirumalla, K., 2021. Building digitally-enabled process innovation in the process industries: A dynamic capabilities approach. Technovation. Vol. 105(1). P. 102256.

Cozzolino A., Corbo L., Aversa P., 2021. Digital platform-based ecosystems: The evolution of collaboration and competition between incumbent producers and entrant platforms. Journal of Business Research.

Dunenkova, E.N., 2022. Development of the innovative potential of enterprises in the conditions of digitalization. E. N. Dunenkova, S.I. Onishchenko. Economics: yesterday, today, tomorrow. T. 12, No. 5-1. – pp. 278-287.

Gawer, A., Cusumano, M.A., 2014. Industry platforms and ecosystem innovation. Product Innovation Management, vol. 31, pp. 417–433.

Jacobides, M.G., Cennamo, C., Gawer, A., 2018. Towards a theory of ecosystems. Strategic Management Journal, vol. 39, issue 8, pp. 2255–2276.

Lippert, K., Cloutier, R., 2021. Cyberspace: A Digital Ecosystem. Systems.

Marshall, A., 1993. Principles of economic science. M.: Progress.

Moore, J.F., 1993. Predators and Prey: A New Ecology of Competition. Harvard Business Review.

Nelson, R.R., Winter, S., 1982. An evolutionary theory of economic change. Cambridge, MA: Harvard University Press.

Porter, M., 1990. The competitive advantage of nations. Cambridge, MA: Harvard University Press.

Ramenskaya, L.A., 2020. Application of the ecosystem concept in economic and management research. Manager. T. 11, No. 4. P. 16–28.

Savina, M.V., Stepanov, A.A., 2020. Features of the formation of the production potential of enterprises in the era of digitalization. Social policy and sociology. T. 19. 2020. No. 1 (134). WITH. 13–20.

Teece, D., 2018. Profiting from innovation in the digital economy: Enabling technologies, standards, and licensing models in the wireless world. Research Policy, vol. 47, no. 8, pp. 1367–1387.

The Use of Artificial Intelligence Algorithms to Improve the Evaluation Process of Project Documentation

Alexander Nikitin[a], Sergey Sinenko[b]
National Research Moscow State University of Civil Engineering (NRU MGSU), Russia, 129337, Moscow, Yaroslavskoe shosse, 26
A.Nikitin56@gmail.com, sasin50@gmail.com

Keywords: Artificial intelligence, project, project documentation, evaluation, BIM.

Abstract: The authors of the article consider the possibilities of using artificial intelligence (AI) algorithms in the evaluation of project documentation developed using information modeling technologies (BIM). The purpose of the study is to reflect the role of AI in evaluating design solutions in the current realities and in the future. During the research, the authors consider the main AI algorithms possible for use in the evaluation of project documentation, their advantages, and also emphasize the issues and difficulties associated with the introduction of AI technologies into the process of evaluating project documentation. As a result of the conducted research, the main risks of using AI in assessment, as well as prospects for the development and implementation of AI in the methodology of evaluating project documentation, have been identified.

1 INTRODUCTION

The digital transformation and reorientation of the construction business to the use of information modeling (BIM) technologies is taking place at an enormous pace (Verstina, 2022). The digital building model becomes an integral part of the building design and construction process and is used throughout the entire life cycle of the facility. The digital model is increasingly being used as the main tool for making important decisions related to the construction and operation of a building, helps to determine the technical and economic component of the future building, as well as to prevent possible risks. It helps to communicate quickly to all project participants, regardless of their location (Slavin, 2018).

The use of a complex information model requires a scrupulous assessment of the applied design solutions and can take up a large human and time resource. This affects the timing and cost of the project (Sinenko,2018).

Artificial intelligence (AI) technologies are actively being introduced into the project management and design process. Therefore, the use of AI algorithms significantly changes the approach to evaluating project documentation.

The volume of the global market for the use of AI in various spheres of life is shown in Figure.1

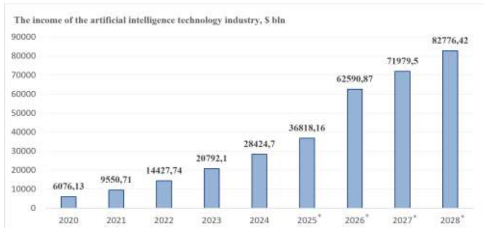


Figure 1: The volume of the global AI market.

Evaluation of project documentation is one of the important tasks in project management, which ensures that project documents are complete, accurate, and meet the requirements of the terms of reference and regulatory requirements. The introduction of AI algorithms into the evaluation process provides a wide range of capabilities that can automate and optimize the evaluation of project documentation (Cross, 2004).

The object of the study is artificial intelligence.

The subject of the study is artificial intelligence in the evaluation of project documentation.

[a] https://orcid.org/0009-0002-6755-8247
[b] https://orcid.org/0000-0002-2212-750X

The purpose of the study is to determine the role and capabilities of AI in evaluating project documentation.

Research objectives:

1. Analysis of scientific and practical work in the field of design and evaluation of project documentation using AI.

2. Analysis of the application of AI algorithms for the evaluation of project documentation

3. Identification of factors and risk analysis of AI implementation for project evaluation in project organizations.

2 METHODOLOGIES

The authors identify several AI algorithms that improve the evaluation of project documentation. Such algorithms include:

1. Machine learning. This is one of the most recognizable and widely used AI algorithms. The design industry has accumulated a huge reservoir of unstructured data and design solutions in paper form. Machine learning allows you to process and digitize all this information (Fuge, 2014). To properly configure the AI, it is necessary to involve experts in the field of design. Their skills and practical knowledge are needed primarily to create the cognitive part of AI. The main training material is also the accumulated database of typical and repetitive comments on the project documentation (Duffy, 1996).

2. Neural networks. Neural networks can be used to identify hidden dependencies between project parameters, which helps to more accurately determine the characteristics of the project, such as cost, risks, labor intensity, etc.

3. Natural Language Processing (NLP). Allows computers to process human language. NLP is used to analyze text, extract key information from documentation, and automatically generate reports. It is especially useful when evaluating project documentation prepared by international design teams (Brown, 2020).

4. Expert systems. This is an AI algorithm that includes expert knowledge in specialized areas of design (engineering systems, design solutions, architecture, etc.). Expert systems are useful for evaluating unique or technically complex objects, where the knowledge of a leading expert or group of experts may not be enough to correctly evaluate documentation.

An important role in deciding on the use of a particular AI algorithm is played by the level of the building information model provided for the evaluation of project documentation (Chahal, 2007). The ISO 19650 standard describes five levels of maturity of the information model (LOD) from LOD 100 to LOD 500, each level provides a different degree of detail and content of the model. LOD 100 usually represents conceptual solutions, LOD 500 information about each element of the model. Figure 2 shows the differences between the levels of the BIM model.

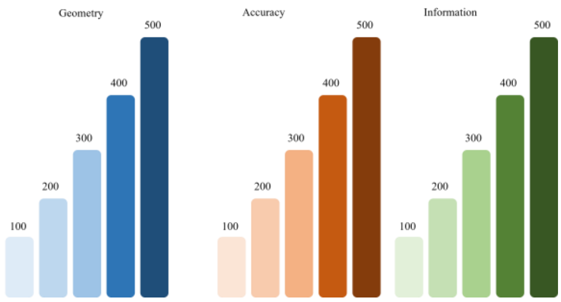


Figure 2: Differences between the levels of the BIM model.

For the successful transformation of the project business, when switching to the use of AI algorithms in project activities, including for evaluating project documentation, it is necessary to take into account the factors listed in table 1.

Table 1: Factors influencing the implementation of AI in design organizations.

The factor	Specifications
The strategy of the project office	Having a strategy and understanding how AI will be integrated into the business processes of a project organization plays a key role. Organizations must define goals, expectations, and plans for the implementation of AI.
Availability of resources and financial opportunities	Successful implementation of AI requires not only a sufficient amount of money, but also the availability of qualified specialists in the field of data processing, analytics and programming. Organizations must be prepared to invest in the necessary resources.
Availability of an archive of project documentation and comments on it	The quality and availability of project data are key indicators of successful AI implementation. Design organizations should have a high level of accumulated data in the field of design solutions.

Education and training of personnel	Designers should be prepared to use new technologies and methods of work related to AI. Education and training of specialists play an important role in the successful implementation of AI.
Organizational culture and organizational structure change	Implementation requires changes in the culture of the organization and its organizational structure.

3 RESULTS

Various algorithms and methods of artificial intelligence are used to assess the quality of the BIM model. Table 2 summarizes the application options for AI algorithms that can be useful in evaluating project documentation, depending on the maturity level of the BIM model.

Table 2: Application options for AI algorithms.

The level of the BIM model	The AI algorithm	Description
LOD 100, LOD 200	Image Processing	Computer vision algorithms are used to automatically analyze images and detect the main elements of the model at the initial levels of documentation development.
	Cluster analysis	Data clustering helps in grouping model elements by type or function at the lower LOD levels.
LOD 300	Neural networks	Neural networks are used to analyze elements and their relationships at a more detailed level of the model
	Genetic algorithms	Genetic algorithms are used to evaluate the optimal arrangement of model elements and their configuration at more advanced LOD levels in order to improve the quality of the model.
LOD 400 и LOD 500	NLP	Analysis of metadata and documentation of the model.
	Expert systems	Verification of the model's compliance with standards and requirements of regulatory documents.

During the research, the authors emphasize the advantages (Table 3) and risks (Table 4) of using AI in evaluating project documentation.

Table 3: Advantages of AI algorithms.

Advantages	Description
Increasing the speed and efficiency of project evaluation	AI algorithms including machine learning and neural networks are able to analyze and process large amounts of project documentation in a short time, which significantly speeds up the project evaluation process.
Improving the accuracy and quality of the assessment	It avoids human errors and bias in the evaluation of project documentation, which leads to more accurate and objective evaluation results.
Data analysis	Analyzes information from large volumes of structured and unstructured data, which makes the assessment more in-depth and detailed.
Automation of routine tasks	Automates routine tasks of evaluating project documentation, freeing up the time of experts and employees to perform more complex and important tasks.
Improving competitiveness	Organizations that use AI algorithms to evaluate project documentation are more competitive in the market due to increased productivity, quality of decision-making and efficiency.
Increasing the level of security	It can be used to detect potential threats and errors in project documentation, which helps to prevent emergencies.
More accurate forecasting	It helps to predict possible risks, problems or successes of a project based on the analysis of

	archived data and scenarios of development of events.
Increasing transparency	It helps to automate the process of verifying the compliance of project documentation with requirements and standards.
Cost reduction	Effective use in project evaluation helps to reduce personnel costs and increase productivity.
Increasing the level of analytics	Analyzes and interprets project data at a deeper level, which allows you to identify non-obvious dependencies and influences in the project documentation.

These advantages show that the use of AI in the evaluation of project documentation has great potential to improve management processes and improve the efficiency of the project organization. Having significant advantages over traditional assessment methods, AI has a number of disadvantages and when making a decision by a design organization in favour of using AI algorithms, it is necessary to clearly understand and structure the risks of implementing AI. The authors analysed the possible risks of using AI algorithms (Raina, 2019).

Table 4: Risks of using AI algorithms.

Risks	Justification
Insufficient quality of project documentation	The poor quality of project documentation, which analyzes AI algorithms in their work, strongly affects the accuracy of estimates. Incomplete, unreliable or untimely data can lead to erroneous results when evaluating project documentation.
The quality of training materials	If distorted data is used for AI training, the subsequent assessment will not be correct.
Conflict with experts	Specialists involved in the verification of project documentation may not understand how AI works and how exactly it performs its assessments. This may lead to a conflict in the interpretation of the verification results.
The need for constant updating and support	AI models require constant updating and support to ensure their accuracy and effectiveness. Making changes and updates can create additional costs.
Loss of control over the evaluation process	In case of incorrect implementation or provision of incorrect data, the organization may lose control over the project evaluation process.

4 CONCLUSIONS

The use of artificial intelligence algorithms in the evaluation of project documentation has great potential to improve the efficiency, accuracy and quality of project management processes (Ruhaak, 2021). Using artificial intelligence algorithms, project managers can simplify document analysis, improve decision-making capabilities, free specialists from routine tasks and ensure the success of the project (Berger, 2016). AI algorithms improve the quality of the assessment by automatically analysing a large amount of data and reducing human influence on the assessment results. This approach helps to improve the objectivity and reliability of the assessment process. At the same time, it is necessary to clearly understand the limitations and risks associated with the use of AI algorithms in the evaluation of project documentation. The main risk is the need for careful pre-configuration and control of the AI training procedure (Telichenko, 2023). The use of algorithms and automated systems is gradually changing the requirements for the skills and roles of professionals, reducing the need for manual data processing and increasing the need for analysis and interpretation of the results obtained from artificial intelligence. The project business gets much more benefits from using AI algorithms in the form of improving decision-making processes, reducing the time for the documentation evaluation procedure, improving the quality of the project, saving resources by optimizing production processes.

Continued research and development in the field of artificial intelligence for project management will further optimize the evaluation process and expand the capabilities of project teams to achieve a better product.

REFERENCES

Brown, T., B., Mann, B., Ryder, N., Subbiah, M., Kaplan, J., Dhariwal, P., et al., 2020, Language models are few-shot learners. *34th Conference on Neural Information Processing Systems (NeurIPS 2020)*, Vancouver, Canada.

Cross, N., 2004. Expertise in Design: An Overview Design Studies.

Duffy, A., H., B., Brown, D., C., Maher, M., L., 1996. Guest Editors. AI EDAM journal, Special Issue: Machine Learning in Design, Vol. 10, No. 2, Spring, Cambridge University Press, New York.

Fuge, M., Peters, B., Agogino, A., 2014. Machine Learning Algorithms for Recommending Design Methods.

Chahal, K. S., Emerson, P., 2007. Quality control and quality assurance in design and construction. Journal of the institution of engineers, Architectural engineering division. Vol. 88, No. 29, India.

Verstina, N. G., Kisel, T., N., Kulakov., K. YU., 2022. Introduction of innovative technologies at enterprises in the investment and construction sector: problems and determining factors, E-Management.

Berger, R., 2016. Digitization in the construction industry, Munich.

Raina, A., McComb, C., Cagan, J., 2019. Learning to Design from Humans: Imitating Human Designers Through Deep Learning, ASME. JMD.

Ruhaak, A., 2021. How data trusts can protect privacy.

Sinenko, S., Ahmetgaliev, A., Slavin, A. 2018. Practical aspects of construction of high-rise buildings in Russia. *Paper presented at the IOP Conference Series: Materials Science and Engineering*, 365(6)

Slavin, A., Sinenko, S., Yoshin, N, 2018. The evolutionary development of the methodology of operational planning of construction production. Paper presented at the IOP Conference Series: *Materials Science and Engineering*, 365(6).

Telichenko, V. I., Lapidus, A. A., Slesarev, M. Yu., 2023 Analysis and synthesis of images of environmentally oriented innovative technologies of construction production. Vestnik MGSU 18(8):1298-1305.

Strategies for Sharing Economy Development: International and Russian experience

Anna Veretennikova[a] and Anna Mokrushnikova[b]
Ural Institute of Management, Russian Academy of National Economy and Public Administration, 8 Marta St. 66, Yekaterinburg, Russia
vay_uiec@mail.ru, mokrushnikovaap@mail.ru

Keywords: sharing economy, strategies, models, control, competition.

Abstract: The development of the sharing economy has greatly impacted not only company processes but also industry transformations. The strategies used by these companies have features related to digital platform activities, the ability to reduce transaction costs, and the construction of social interactions that ensure trust between participants. This study described competitive, industry, operational, marketing, and management strategies used in the sharing economy, as well as how sharing economy models are reflected in the Russian market. The significance of this study lies in the development of provisions of the sharing economy in the field of strategic management.

1 INTRODUCTION

Recent advances in the development of digital technologies, as well as the emergence of new business models, have caused significant changes in society's social and economic areas (Pouri, Hilty, 2018). Business models based on collaborative consumption and resource utilization, such as crowdfunding, crowdworking, and crowdsourcing, which provide temporary access to limited resources, have been combined under the concept of the sharing economy that offeres alternatives to address existing issues (Reyes-Menendez, Saura, Palos-Sánchez, 2018).

The sharing economy lets people exchange goods and services, supporting social and sustainable consumption that usually happens through peer-to-peer connections (Delgado, Soares, Proença, 2023). This business model includes the exchange and collaboration consumption of different types of resources - information, material, labor, financial. At the same time, these companies have different development strategies in terms of how they organize economic activities and their main goals, guidelines, and priorities. In this regard, the study of strategies for the sharing economy development seems to be one of the important tasks to make the application of this model more transparent.

Therefore, this study aims to identify strategies for advancing the sharing economy in both global and Russian contexts using a matrix method. To reach this aim, the strategies of companies utilizing this model as outlined in the research literature were examined. While analyzing this, different types of strategies were considered, including economic and non-economic ones, competitive strategies by M. Porter, management strategies, operational and marketing strategies, and models using in the sharing economy.

2 STRATEGIES FOR THE DEVELOPMENT OF THE SHARING ECONOMY: LITERATURE REVIEW

2.1 Types of strategies in the sharing economy

Recent advances in new technologies, especially ICT, have brought about important changes in the social and economic spheres. New business models, including sharing economies, have emerged as alternatives to solving existing problems. The sharing

[a] https://orcid.org/0000-0003-1808-7856
[b] https://orcid.org/ 0009-0005-8817-2572

economy, involving peer-to-peer and consumer-to-consumer models (C2C, P2P) via digital platforms, often simplifies the exchange of goods and services among users, promoting social and sustainable consumption (Acquier, Daudigeos, Pinkse, 2017). This is achieved through interaction between users who freely share their opinions, recommendations and experiences online.

The sharing economy model is a business model that emerged in the late 1990s and has become a sustainable way of doing business in the 21st century (Puschmann, Alt, 2016). Digital platforms used in the sharing economy have given rise to new forms of interaction between people who share, exchange or rent underused goods (Diaz, 2020). Sharing can come in various forms, like peer-to-peer rentals, co-working spaces, car sharing, and peer-to-peer loans. Sharing economy initiatives are commonly supported by online platforms linking potential consumers and providers (Heo, 2016).

In a study of companies using this model, S. Curtis emphasizes the importance of utilizing business model patterners in the sharing economy (Curtis, 2021). These templates serve as a tool for identifying trends among existing business models (Remane et al., 2017). S. Curtis identified 8 types of platforms: collaborative community platforms, niche corporate platforms, commercial peer-to-peer platforms, niche peer-to-peer platforms, peer-to-peer space sharing platforms, peer-to-peer mobility sharing platforms, business-to-consumer sharing platforms, coworking space platforms. These platforms vary in their set of characteristics, grouped into categories such as platform type (peer-to-peer, business-to-business, business-to-peer, crowd / cooperative, business-to-consumer, public-to-citizen), practice(shared space, shared mobility, shared goods, shared consumables, shared resources), intellectual property (open source, communal, proprietary), governance model (cooperative, collaborative, commercial), price discovery (free, pay what you can, negotiation / bargaining, auction, bartering, set by resource user, set by resource owner, set by platform).

In addition, one feature of sharing economy platforms is the integration of organizational and market coordination methods to generate value on the platform. In this context, Constantiou I., Marton A., and Tuunainen V. K. identified four models of the sharing economy: Franchiser, Principal, Chaperone, and Gardener (Constantiou, Marton, Tuunainen, 2017). These models were categorized based on the level of control exerted by platform owner and rivalry between platform participants. The first criterion concerns how users are coordinated on the platform, while the second criterion focuses on the market coordination mechanism offered by the platform owner. The "Franchisor" type, exemplified by Uber, and the "Principal" type, exemplified by Handy, are distinguished by robust organizational coordination mechanisms. "Franchisors" use dynamic pricing to encourage intense competition on the platform, while "Principals" employ standard pricing methods. "Chaperones," like Airbnb, encourage competition, while "Gardeners," like Couchsurfing, emphasize service or goods exchange through barter with loose organizational coordination. The last group is characterized by a low level of competition between participants on the digital platform (Constantiou, Marton, Tuunainen, 2017).

The analysis also reveals that this business model is utilized in various sectors, including transportation and hospitality (e.g., Uber or Airbnb). Moreover, sharing economy companies are found in consumer goods sharing (such as Wallapop or Cash Converters) and media and entertainment (e.g., Spotify or SoundCloud) industries.

Over the past two decades, the experience gained from companies utilizing this model has demonstrated a notable influence on development of industries. This impact extends to both established market leaders and emerging businesses. For example, Uber and Airbnb have become leading players capable of changing the “rules of the game.” On the other hand, there are smaller startups focusing on various niches. In particular, several hundred sharing economy startups were founded in Europe in 2016 (Vaughan, 2016). Industry-specific features in the sharing economy led to the examination of industry strategies employed within this model.

Despite the debate in scientific literature about the pros and cons of this business model's expansion, the growth of the sharing economy shows a move towards better resource efficiency and utilization. These changes are driven by advancements in digital technology, shifts in consumer preferences, societal challenges, and evolving values (He M. D. et al., 2017). In this regard, the operational strategies employed by sharing economy firms have been analyzed.

Moreover, the sharing economy brings about new competitive benefits, such as saving costs, optimizing resource utilization, and offers new revenue streams for individuals. Thus, exploring the competitive strategies employed in the sharing economy serves as a complementary aspect of analyzing this business model.

In addition, it is crucial to focus on the marketing approaches implemented, as they made significant changes in the organization of activities of these companies, and also influenced the redistribution of resources in the industry.

2.2 Economic and non-economic models in the sharing economy

The sharing economy's evolution shows that sharing platforms aim to facilitate better exchange of goods and services. For example, torrent tech enables access to information, while Couchsurfing offers budget travel. These projects focus on social exchange over market transactions, and implement the principle of self-regulation. Emphasizing social connections, cultural exchange, and affordable resource access is central to their concept. In this case, they can be considered as non-economic models (Jung et. el., 2016).

Commercial digital platforms, including sharing platforms, facilitate the connection between service providers and consumers, generating revenue through transaction commissions. These platforms (such as Airbnb and Uber) do not own or manage the assets involved, like vehicles or accommodations, nor employ service providers directly. Instead, independent contractors or freelancers utilize the platform to offer services to clients.

2.3 Sharing economy and industry markets

The impact of the sharing economy on the development of industries is interpreted in different ways. On the one hand, the sharing economy is considered as a separate industry, but this approach is more typical for international practice. In Russian practice the focus made on how sharing economy companies transform existing industries. By creating new niches, these companies present both challenges and opportunities for traditional businesses. On the one hand, sharing economy companies affect traditional businesses by offering lower-cost services, reducing their competitiveness. On the other hand, they can open up new growth avenues, foster collaborations, and develop ecosystems. Considering the life cycle of the industry, the emergence of sharing economy companies indicates the industry's maturity stage. In addition, the integration of digital technologies contributes to the emergence of a new stage that aligns with ongoing institutional and technological changes.

At the same time, it's important to consider how these companies influence the value chain at the industry level. The activities of digital platforms in the sharing economy are part of the transaction sector. This activity can have two aspects. Firstly, digital platform operators help lower transaction costs at the industry level. In this case, service-providing companies gain a new distribution channel. The digital platform operator then acts as an aggregator. Secondly, digital platforms can create a space for interaction between participants who weren't previously involved in economic relationships within the industry. By freeing up unused resources, these companies pose a threat to the traditional market. Meanwhile, researchers have varying opinions on this topic. For example, R. Sainaghi и R. Baggio identify that Airbnb's customers differs from that of hotels during the week, on workdays and trade-fair days, when hotels work prevalently within the business segment, and when Airbnb listings mainly accommodate leisure guests. By contrast, a partial synchronization is revealed during weekends and holidays (Sainaghi, Baggio, 2020). Additionally, these initiatives notably broaden the consumer market, which is seen as a positive industry trend. Consequently, digital platforms and sharing economy firms facilitate resource reallocation and play a crucial role in the industry's value chain.

2.4. Competitive strategies in the sharing economy

When considering specific strategies used by sharing economy companies, we used the systematization of M. Porter, who identified the following types of strategies: cost leadership; differentiation strategy; focusing strategy (Porter, 1998).

First of all, this type of company is characterized by a cost leadership strategy that is possible due to the use of digital platforms and peer-to-peer relationships. Here, it is important to note the redistribution of transaction costs within the value chain. In other words, peer-to-peer digital platforms classified as part of the transaction sector of the economy undertake functions related to marketing, sales, some purchasing activities, and other processes. By charging a fee, the digital platform redistributes these costs efficiently, benefiting from economies of scale and offering lower prices to consumers. The above indicates a more effective implementation of the “cost leadership” strategy in comparison with traditional forms of doing business.

Besides focusing on cost leadership, companies also implement a differentiation strategy, which, according to M. Porter, "creates a strong position to confront the five competitive forces."Digital platforms of the sharing economy, due to cooperation with a wide range of consumers and suppliers, as well as the established platform policies, provide a combination of a wide range of services, the choice of which allows ensuring the uniqueness of the commercial offer. As an example, we can consider the company Airbnb, which allows the consumer to book a place to stay with a fairly wide range of related characteristics, organize leisure time or book an excursion, which meets the individual needs of a wide range of consumers. At the same time, the range of services provided is differentiated for both the consumer and the service provider. Thus, the service provider can delegate some services to the guest reception team, which handles tasks such as preparing the accommodation, managing the listing, communicating with guests, resolving booking issues, posting reviews, and providing cleaning and maintenance. Consumers in different price segments can receive customized services based on their preferences.

At the same time, the combination of these strategies is not typical for digital platforms of the sharing economy as a whole. For example, travel digital platform VRBO focuses on vacation homes, while Airbnb is more focused on business travel and short stays.

2.5 Management Strategies

In industry markets, sharing economy companies also use horizontal integration strategies to benefit from economies of scale. By broadening the range of suppliers and attracting more consumers, these companies can extend their reach across different regions. Moreover, there is a concept known as "consumption synergy," where travelers who book Airbnb accommodation in the USA are more likely, under similar circumstances, to choose Airbnb for their stays in Europe.

Airbnb's expansion strategy was driven by the goal of increasing accessibility and differentiation of the company's offers. The companies Airbnb acquired ranged from small-scale operations to larger competitors, including HotelTonight and Luxury Retreats. The implementation of this strategy allowed the company to enter an IPO and double the share price from $68 to $146 only on the first day of release. Acquiring Trooly and Deco Software helped Airbnb enhance its technology stack, attracting new customers and improving security and usability. This approach also allowed them to reduce risks company’s risks in terms of ensuring its information security, as well as in improving the usability of the website and application.

For instance, in 2017, Yandex Taxi consolidated its digital services under a new entity covering Russia, Azerbaijan, Armenia, Belarus, Georgia, and Kazakhstan.

The strategy of mergers and acquisitions of sharing economy companies can also be seen in the transport sector. In particular, in 2017, Yandex Taxi combined its digital services within a new company in Russia, Azerbaijan, Armenia, Belarus, Georgia, and Kazakhstan.

2.6 Operational strategies of sharing economy companies

The business model of sharing economy companies is based on running an online platform that connects service providers and consumers. Income is generated through commissions received by the digital platform operator for each booking. The company itself does not own or manage the assets used (such as vehicles or residential spaces) and does not employ service providers. Those offering services are independent contractors or freelancers who utilize a digital platform (such as Airbnb or Uber) to attract clients.

When looking at how platforms operate, we also look at M. Porter's research, focusing on the value chain. This chain involves core processes such as inbound logistics, operations, outbound logistics, marketing and sales, and after-sales service; along with support processes like infrastructure, human resources, research and development, and procurement. By using AirBnB as a case study, we can explore how these processes are put into practice within a sharing economy business.

The process of "inbound logistics" involves acquiring raw materials and resources for company use. " The inbound logistics" of Airbnb has informational features. The main “supplies” of Airbnb are lists of accommodation options with an accompanying list of services (excursions, etc.)

Processes of operational activities (“operations”) include making agreements with partners, organizing platform operations, and listing information about suppliers and available properties. The service provider directly creates value for consumers, while the digital platform takes on the function of ensuring its quality.

"Outbound logistics" on the digital platform aims to provide quality customer service and reliability during transactions. Marketing and sales processes are based on the design of reputation mechanisms. Compared to traditional business models, the focus of marketing changes in these processes. While traditional business models primarily aim to stimulate demand, for this type of digital platform, the main goal is to ensure consumer trust. Airbnb also allows guests to rate their host, and hosts can rate guests.

After-sales service is the final stage of the value chain. Airbnb provides its consumers with after-sales services such as air travel protection, cancellation policies, and customer service representatives. Depending on the property owner, cleaning services may be available.

Regarding supporting processes, the most significant process is providing the necessary infrastructure for the platform. Ensuring the functioning of the digital platform and its uninterrupted operations is a key condition for the functioning of this business model. In terms of human resource management, features such as remote work and flexible hours are notable. In summary, organizations utilizing the sharing economy model have distinctive features in their underlying and supporting processes that impact the value creation of the service offered.

2.7 Marketing strategy of sharing economy companies

It is recommended to analyze marketing strategies in the sharing economy through the lens of comprehensive marketing, which includes product, price, promotion, place, and personnel. The application of strategies for each aspect was explored separately. Ensuring product or service quality involves setting standards for suppliers. Thus, Airbnb requires “hosts” to comply with rules regarding advance reservations and ensuring reliable check-in, timely communication, accuracy of information provided, cleanliness, and security. Yandex Taxi sets requirements both for the car, in particular, the year of manufacture of the car, the number of doors, the presence of seat belts, the list of required documents, etc., and for the driver - age, experience, etc. Handy, a digital platform for household services, also enforces specific requirements on service composition, materials, and worker's appearance.

Regarding the "Price" aspect of the marketing mix, sharing economy companies in the transportation sector applies dynamic pricing in real-time, including rates and prices based on current supply and demand, weather conditions, time, and location of booking other factors.

The "Promotion" element of the marketing mix is evident in the transportation sector (Uber, Yandex Taxi) through sales promotions, including discounts and bonus points, to attract and retain customers. Companies also implement incentive programs for drivers, falling under the "Personnel" aspect.

The "Place" aspect is linked to the widespread use of the Internet and offerings from taxi companies and drivers. Economies of scale also play a role in ensuring service mobility and speed.

3 METODOLOGY

The study procedure consisted of 3 stages. Firstly, key strategies followed by sharing economy companies (Uber, Airbnb, Handy, Yandex Taxi, Ostrovok.ru) were identified through an analysis of scientific works, reports, and official websites. These strategies included industry, competitive, operating, and marketing strategies. Secondly, the matrix of sharing economy models based on I. Constantiou, A. Marton, V. Tuunainen was adapted. Finally, it was shown the behavior of sharing economy companies on in the Russian market.

4 RESULTS

Using the matrix of sharing economy models described above, it is showed the development of sharing economy platforms in Russian practice, and also revealed which strategies can be applied in each of the sharing economy models. When adapting the matrix of I. Constantiou, A. Marton, V. Tuunainen to Russian practice, the names of the models were modified (Fig. 1).

High Rivalry between platform participants	**Mediator** (Ostrovok.Ru, Airbnb)	**Franchisor** (Яндекс Такси, Uber)
Low	**Ideologist** (Bla Bla Car Couchsurfing Torrent)	**Manager** (Profi. Py Handy)
	Loose Tight Control Exerted by Platform Owner L	

Figure 1: Adapted matrix of sharing economy models.

The term “Chaperones” has been changed to “Intermediary.” This quadrant includes companies that connect sellers and buyers using digital platform.

Participants face strong competition and limited control. In Russia, online booking service for hotels, air tickets and other travel services called Ostrovok.Ru uses this type of model.

Companies that use model "Franchisor» maintain tight control over platform participants, while competition remains high. These companies charge a commission for transactions on the platform. In Russia, Yandex Taxi exemplifies this model. Yandex.Taxi allows users to easily take a car at competitive rates. The service offers convenient booking, quick car selection, fixed rates, cost estimates, cash or card payment, driver details, and car information. Yandex Taxi imposes strict requirements on drivers, including experience, license, and regular vehicle checks.

The "Principal" model has been modified as a "Manager". Companies with this model maintain a high level of control over platform participants, but competition on the platform is low. In Russia, an example of such a platform is "Profi.Ru". The platform allows people to find specialists for different tasks. Customers find tutors, driving instructors, plumbers, hairdressers, etc. In total, Profi.Ru has more than 2,600,000 specialists in 900 types of services. More than 21 thousand new orders pass through the website every day. Specialists present information about their skills and achievements. The customer can choose from many options. There is no fixed price on the platform. If an inadequate service is provided, the customer may file a complaint on the platform.

Blablacar can be considered an "Ideologist" BlaBlaCar is the world's leading travel community, enabling over 90 million members in 22 countries to travel together. Through technological solutions, BlaBlaCar connects people seeking rides and travel companions, helping to fill empty seats in private vehicles. This makes travel of any distance more accessible and convenient. Each year, BlaBlaCar's transportation network helps reduce carbon dioxide emissions by 1.6 million tons and brings 120 million people closer, serving as a driving force for the service's development. The platform only provides the ability to search for travel companions, there is no commission, and the platform also does not check participants. To register, people need only a phone number.

The model "Mediator" is similar to the model "Ideologist", but with the addition of a fee for services or products. Participants not only share but also gain economic benefits.

The model "Manager" differs from the model " Ideologist" in that participants want to have guarantees about the quality of the services or goods provided. Therefore, platforms introduce participant control.

The model "Franchisors" encompass all three aforementioned models. This model relies on a certain level of willingness to share.

At the same time, the level of desire for economic benefit is so high that it requires tight control by the platform. Control over pricing and quality is the main task of the platform of this model.

5 DISCUSSION

Among the presented models, the "Ideologists" primarily follow a non-economic strategy, driven by social aims. Mediators, Managers, and Franchisors usually adopt a commission-based strategy to earn revenue by linking partners with customers. These companies establish commissions for service providers, and some digital platforms may offer alternative tariffs. For instance, the company "Profi.Ru" offers two tariffs: "commission" and "response." Under the "commission" tariff, payment is made after service completion, while the "response" tariff charges a fee for service offers.

Due to the digital platform's ability to reduce transaction costs, a competitive strategy like "cost leadership" is common for all the models presented. Additionally, Franchisors and the Mediators also use a differentiation strategy. Companies offer a range of services to provide different customer needs. For example, Ostrovok.Ru provides accommodation options in apartments and hotels, while Yandex Taxi offers various tariffs such as economical, comfort, business, cargo, children, and pet transportation.

As for as marketing strategies, it is important to note that each sharing economy platform has a feedback and rating system. Thus, the higher the level of control, the more control over the participant's rating increases. With a low rating, there is a risk of losing access to the digital platform. On platforms with a low level of control, the rating is not so important; it only influences the customer's choice.

The Franchisor and Mediator spent funds for marketing and promotion. At the same time, there are cases of collaboration with other companies, such as offering discounts to bank clients or promotional codes for upgrading the service class. Companies representing Ideologists do not require advertising, as platforms have social aims. These platforms are self-regulated and promoted through «word of mouth».

When developing operational activities, sharing economy companies also focus on the technological development strategy, investing additional resources in teams of engineers and IT specialists to create software or applications. This strategy is typical for companies that use economic models and depend on economies of scale, which can also lead to the implementation of mergers and acquisitions strategies.

Industry strategies was examine using the example of Yandex Taxi. Initially, Yandex Taxi had low prices for trips in order to attract customers. This strategy negatively impacted traditional taxi operators, who had high costs associated with vehicle depreciation, fuel, taxi fleet maintenance costs, and salaries for drivers, operators and repairmen. Under these conditions, some taxi companies had to close because they became unprofitable. Yandex-Taxi did not have significant costs, since it did not have a taxi fleet and did not hire drivers. Self-employed people worked on the platform. Subsequently, this company also began to apply the strategy of classic taxis, so the company acquired its own branded cars, which can be rent out to drivers.

Based on the information provided, it follows that the sharing economy model is expanding its potential due to evolving needs and technological advancements. The sharing economy is expected to play a larger role in various sectors such as the IT industry, finance, and the innovation of new products. This economic approach introduces new opportunities across industries like manufacturing, construction, and services by optimizing unused resources, creating additional income streams, and enhancing social connections. Moreover, with the rising emphasis on sustainability and corporate social responsibility, the sharing economy is likely to progress towards sustainable investments and engagement in social initiatives.

6 CONCLUSION

In this study, to identify strategies for sharing economy development in global and Russian practice the following results were obtained.

Firstly, the study described the competitive, industry, operational, marketing, and management strategies employed by sharing economy companies.

Secondly, it was demonstrated how sharing economy models manifest in the Russian market, including a mix of Russian and international companies with varying scopes.

The novelty of this research lies in categorizing strategies utilized by sharing economy companies.

The theoretical significance of the results obtained lies in developing theoretical principles for the advancement of the sharing economy. The practical significance lies in studying the implementation experience of various strategies in Russian and international sharing economy companies.

ACKNOWLEDGEMENTS

The study was supported by the Russian Science Foundation grant No. 24-18-20036, https://rscf.ru/project/24-18-20036/"

REFERENCES

Acquier, A., Daudigeos, T., Pinkse, J., 2017. Promises and paradoxes of the sharing economy: an organizing framework, *Technological Forecasting and Social Change*, 125, 1-10.

Constantiou, I., Marton, A., Tuunainen, V. K., 2017. Four models of sharing economy platforms, *MIS Quarterly Executive*, 16: 4.

Curtis, S., 2021. Business model patterns in the sharing economy, *Sustainable Production and Consumption*, 27, 1650-1671.

Delgado, A.C., Soares, R.R., Proença, J.F., 2023. Motivations for Peer-to-Peer Accommodation: Exploring Sustainable Choices in Collaborative Consumption, *Sustainability*,15(13):10276.

Diaz, C. A. M., 2020. Consumo colaborativo: un pilar de innovación para crear start-ups, *Crecer Empresarial Journal of Management and Development*, 2:01.

He, M. D., 2017. Fintech and financial services: Initial considerations, *Staff Discussion Notes*, 005.

Heo, Y., 2016. Sharing economy and prospects in tourism research, *Annals of tourism Research*, 58, 166-170.

Jung, J., Yoon, S., Kim, S., Park, S., Lee, K.-P., Lee, U., 2016. Social or financial goals?: Comparative analysis of user behaviors in Couchsurfing and Airbnb, CHI EA '16: Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems May, 2857–2863.

Molz, J., 2013. Social networking technologies and the moral economy of alternative tourism: the case of couchsurfing, *Annals of Tourism Research*, 43, 210-230.

Porter, M., 1998. *Competitive strategy: techniques for analyzing industries and competitors*, Free Press, 397 p.

Pouri, M. J., Hilty, L. M., 2018. ICT-enabled sharing economy and environmental sustainability—a resource-oriented approach, *Advances and new trends in environmental informatics: Managing disruption, big data and open science*, Springer International Publishing, 53-65.

Puschmann, T., Alt, R., 2016. Sharing economy, *Business & Information Systems Engineering*, 58: 1, 93-99.

Remane, G., Hanelt, A., Tesch, J.F., Kolbe, L.M., 2017. The business model pattern database — a tool for systematic business model innovation, *International Journal of Innovation Management,* 21, 1750004.

Reyes Menéndez, A., Saura, J. R., Palos Sánchez P. R., 2018. Crowdfunding y financiación 2.0. Un estudio exploratorio sobre el turismo cultural, *International Journal of Information Systems and Tourism (IJIST),* 3 (1), 23-34

Sainaghi, R., Baggio, R., 2020. Substitution threat between Airbnb and hotels: Myth or reality? *Annals of Tourism Research,* 83, 0160-7383.

Vaughan, R.,2016. *Assessing the size and presence of the collaborative economy in Europe*. Luxembourg: Publications Office of the European Union.

The Integration of Digital Technologies into the Teaching of Russian Language at a Medical University in the Context of Sustainable Development

Nailya Abieva[1][a], Shahlo Djamaldinova[2][b]
[1]*Faculty of Foreign Students, Altay State Medical University, Barnaul, Russia*
[2]*Department of Uzbek Language and Literature, with the Russian Language, Samarkand State Medical University, Samarkand, Uzbekistan*
aceloti@yandex.ru, djamaldinovashaxlo@mail.ru

Keywords: Sustainable development, digital technologies, Russian language, medical university, teaching of the Russian language

Abstract: In the article, the author raises the important issue of integrating digital learning into teaching Russian to students at a medical university. The author conducted a survey with respondents, students at the medical university, to demonstrate the positive impact of integrating digital technologies into the educational process. The author proposes several methodological approaches that could be incorporated into teaching a foreign language, including thematic virtual tours of city and country sites, virtual interactive seminars, and work with video content. The article discusses the key aspects that a teaching methodology should focus on when choosing educational materials. These digital resources represent a modern, innovative way to develop students' professional skills and align with the current concept of sustainability.

1 INTRODUCTION

Russian language is a topic of interest due to the increased demand from foreign citizens in the Asia-Pacific region (India, Mongolia, China, etc.) and Arab countries (Morocco, Palestine, Iraq, Iran, Egypt, etc.) for Russian as a second language for educational purposes (Niyazova, Xaydarova, 2023). Russian language is being promoted, for example, through the establishment of specialized open centers dedicated to the advancement of education in Russian (Kopnina, 2020), federal target programs "Russian language" (Khan, 2021).

The current process of digitalization in education requires the introduction of new methods for teaching a foreign language.

It is well known that the digitalization of education has been a process that has taken place for some time, beginning with the establishment of distance learning programs, "with the growing skills mastered by students in the digital environment, they help to master foreign languages" (Tsoy, Maltseva, 2023). Today, distance education is becoming a viable option for learners and even an alternative to traditional education. A key feature of distance education is the ability to access learning from a distance, through an educational institution. This approach opens up the possibility of an accessible learning environment. Accessibility and the openness of educational spaces are crucial elements of a sustainable development. In addition, as the researchers note: "Equal access to all levels of education for all has already been achieved mainly due to the possibilities of international access to open educational programs provided via the Internet" (Zinchenko, 2022).

The aim of the research is to analyze the advantages and disadvantages of distance education in Russian as a foreign language among medical students. Based on the findings, conclusions will be drawn regarding the necessary implementation of digital technologies and educational resources in teaching Russian in a medical university for sustainable development.

[a] https://orcid.org/ 0009-0000-4061-3686
[b] https://orcid.org/ 0009-0005-4933-0275

These materials could be the basis for developing methodological databases and banks of digital educational resources.

2 MATERIALS AND METHODS

Theoretical methods such as analysis, synthesis, induction, deduction, content analysis, comparative analysis, and modeling were employed as research techniques. Additionally, a survey of respondents was conducted to identify the strengths and weaknesses of digital learning.

3 RESULTS

To provide an objective evaluation of the positive and negative aspects of distance education, a survey was conducted among students in the first to third years of a medical university. This group of students was selected because the subjects "Foreign Language" and "Professional Communication in a Russian-Speaking Environment" are taught from the first to the third year. Among the respondents were students who had received preparatory education through distance learning, as well as those who had partially studied remotely due to the COVID-19 pandemic in their first to third year of study. Sixty-eight students from various foreign countries participated in the survey, including India, Egypt, and Iran.

The following questions were included in the questionnaire:

1. Have you had any experience with online learning? Please describe these instances.

2. Which class format was more effective: full-time or online?

3. Did the remote preparatory courses assist you in your further education?

4. Please note the advantages of online learning (individualized work with a tutor, convenience of the platform, flexibility to work at your own pace, ability to study remotely).

5. Please note any disadvantages of online learning (lack of face-to-face interaction, lack of opportunity to interact with classmates, lack of motivation to learn material).

Of the 67 students, 45 reported having experience of online education, including learning Russian – 24 of them studied at the preparatory faculty, and 65 had online classes during the COVID-19 pandemic. Among these, 58 noted the significant effectiveness of face-to-face teaching. All respondents acknowledged the significant role of Russian language studies through online preparatory programs in facilitating adaptation to a Russian university and continued development of the language. The benefits of the online learning model included the convenience of platform access and the potential for remote learning. However, some drawbacks were identified, such as technical difficulties and the inability to interact live with fellow students. Disadvantages require teacher supervision, for more details see the article "Media platforms as influential tool of Russian language learning abroad" (Muzykant, Burdovskaya, Souhila, Ruiqi, 2021).

Based on the results obtained, the clear advantages of distance learning include the ability to work individually with each student and to organize their pace of study independently. This can be achieved through the technical support and organization of the learning process in the form of a well-structured work schedule that takes into account the specific needs of each student.

When designing a digital learning platform, it is essential to consider that distance learning relies on a specific digital medium, which on the one hand significantly reduces the amount of routine work for teachers, but also necessitates a particularly careful and expert approach to material selection. The remote setting provides a comfortable environment to some degree. This type of environment has a positive impact on academic achievement, particularly for students with introverted personalities, phlegmatic or melancholy temperaments, and auditory or visual learning styles. The disadvantages of distance learning include the limited opportunities for personal communication between students and teachers. The electronic medium cannot fully replace the physical presence of a teacher, which is an essential element in a successful educational process, particularly for students who have an extraverted personality type, a choleric temperament, and a kinesthetic learning style. From the teacher's perspective, intensive work on the motivational aspect is necessary, as the lack of face-to-face interaction in distance learning requires constant stimulation, not only internally but also externally. Additionally, strict time management for work and leisure activities is essential.

In this study, we will examine the criteria that should be met by digital materials in Russian as a foreign language provided to international students at a medical university.

Relevance of the Topic.

Digital materials must be original and provide up-to-date information relevant to medical topics. The content should correlate with the subject matter being studied in clinical disciplines, ensuring that the material is relevant and applicable to the specific field of study.

Accessibility of Perception. The material should include the vocabulary commonly used by medical students in their studies, embedded within the context of a narrative that is accessible to non-native speakers. It is essential to consider the level of English proficiency of the target audience when designing the material.

Semantic Integrity. The material must provide detailed insights into various cases relevant to medical practice, ensuring semantic completeness that allows for the structured and synthesized understanding of information.

Problematic. The presented material should have a problematic nature that encourages discussion and conversation in the classroom, facilitating the development of critical thinking and problem-solving skills among students. The materials that can be intensively used in order to successfully form the language and professional competencies of future doctors.

In the following, we will discuss the options we provide for digital materials that can be extensively utilized in order to effectively develop the language and professional skills of future physicians.

4 THEMED VIRTUAL TOURS

Themed virtual tours are relevant in the context of Russian as a Foreign Language classes for students at medical universities, as they provide additional information about sights related to the profession. Medical students benefit from tours of medical museums and canters, as well as attractions associated with the field of medicine, which are educational and informative, given the cultural aspect of these events. The need to help international students adapt to the social, cultural, educational, and linguistic environment of the host country is evident. The excursion-based approach is an innovative method of education and a progressive means of simulation training.

When organizing an excursion, it is important to consider that the information should be presented in various ways. Digital materials, such as textual material, audio accompaniment, and interactive forms of information processing, should be provided on the platform utilized by this university. Each element of the material should be verified through tasks. These may include a group of questions directly related to the information presented during the tour, as well as a second group of questions designed to test the ability to reason and discuss a given topic. These questions contribute to the development of communicative competence.

The virtual tour content may include information about the city facilities related to medical development and the names of notable doctors. These may be presented in the following informational blocks:

1. Monuments and memorials to doctors, plaques commemorating doctors, and dedicated memorial zones.
2. Museums, including city museums, university medical museums, and museums dedicated to medical history during the Great Patriotic War (World War II).
3. The original buildings of the first pharmacy stores, hospitals, and medical centers.
4. Modern medical centers and rehabilitation facilities, as well as well-known medical clinics.

The use of an excursion-based methodology implemented in a digital format addresses several educational objectives when working with foreign students. Firstly, the immersion into the cultural environment of the host country where the student is learning the target language is achieved. Secondly, the digital nature of the tour enables students to freely engage in the experience. Following their remote exploration of the sights, students become interested in visiting the locations in person, further enhancing the immersion experience. Thirdly, a regional component to the educational process is integrated, as the content of the digital tour is tailored to address the specific needs of medical students, focusing on medical infrastructure.

5 INTERACTIVE ONLINE COLLOQUIUMS

Such a format for presenting information – digital materials – has long been an object of interest for methodologists. So, in the 2021 article, the authors consider podcasts as a new format of the media sphere "have educational potential, which must be used to a greater extent for the formation of the human legal culture. At the same time, the educational potential reveals the cognitive and epistemological interest of the listener" (Tomyuk, Diachkova, Kerimov, Dudchik, 2021).

An interactive online forum will assist students in preparing for exams or tests, discussing challenging topics and assignments, and sharing experiences and knowledge with fellow students. During the forum, participants can pose questions to teachers for feedback on solutions to tasks. This format facilitates a more effective approach to learning the material and preparing for successful test completion. The interactive forum is a combination of digital resources on a particular topic (computer software, websites, live presentations, audio-visual materials), as well as the opportunity for real-time communication with the teacher.

The digital materials posted on the platform should be organized into thematic blocks. The algorithm for working with these materials should allow the student to receive answers to their questions during the preparation process for the exam or test. In case the amount of digital materials is insufficient, the teacher can be contacted online to clarify information and provide feedback and personalized guidance.

The general structure of the virtual colloquium is as follows:

1. An information block containing a database of frequently asked questions, which can be accessed by students.
2. A series of tasks to be completed by students, based on thematic blocks covered in the course.
3. Links to a live virtual meeting with the instructor for clarification or detailed consultation, if needed.

An interactive online forum is an educational tool that allows students to interact actively with information and learn through playful and hands-on activities. This method is modern, as it combines the accessibility of an online environment with the traditional format, while still maintaining the active involvement of teachers with students.

6 VIDEO CONTENT: MEDICAL FILM

The use of video material in foreign language classrooms is a common practice among teachers. As the researchers note, "multimedia technologies change the character of educational activities by increasing their efficiency" (Mikeshova, 2017) and "may be used in the formation of educational and cultural competence" (Slutskiy, 2021).

This includes authentic video material such as feature films, documentaries, and cartoons, as well as customized courses and workshops designed specifically for teaching a particular foreign language (Abieva, 2024).

The undeniable advantage of video-based materials is their relevance, particularly when it comes to authentic texts, i.e., materials created for native speakers by native speakers themselves. Natural immersion in language materials becomes attractive to students, as the initial goal is not academic, but rather a genuine product of the natural language activities of native speakers. The particularity of the audio-visual presentation of information lies in its direct impact on the imagination and emotional sphere, contributing to natural memorization. When working with video materials in the context of teaching Russian as a Foreign Language, it is essential to consider the following aspects:

1. The video content used in the lesson should correspond to the topic or part of the chosen topic.
2. The use of video resources should be carefully managed, as overuse can become ineffective.
3. Pre-production of video content, including thoughtful text writing, comments, and volume of information provided, is crucial. The use of video materials in teaching foreign students of medicine is a valuable technique that allows for maximum immersion in the language material.

The teacher will need to create their own collection of video materials for use in classes on Russian as a foreign language. These materials should be coordinated with the teachers of the clinical departments.

The subject matter of the video materials may vary, but in general, they should reflect the following themes and correspond to the level of language proficiency. For example: "Body Systems" – videos on the structure of various body systems (cardiovascular, digestive, respiratory and nervous systems etc.). "Fundamentals of Anatomy and Physiology" – videos covering the basic principles of human anatomy and physiology. "First Aid in Case of Emergency" – a video providing instructions for providing first aid in an emergency. "Prevention of Diseases of Different Body Systems" – a video covering recommendations for preventing various diseases.

The use of video resources in teaching Russian as a foreign language at a medical school can significantly enhance the effectiveness of the learning process and assist students in more effectively assimilating the necessary material at their own convenient pace, while taking into account each individual's unique abilities.

7 CONCLUSIONS

The aforementioned digital materials, in our view, constitute valuable resources that form the fundamental competencies of a professional. A student's proficiency in applying modern communication technologies denotes the ability to devise an appropriate communicative strategy for communicating in a foreign tongue for the purpose of professional engagement. This competence is developed in the classroom environment of medical students through the practice of oral dialogue based on the "doctor-patient" model and the solution of situational problems using the case method.

The ability to translate, compose, and edit academic texts in a foreign language requires a high level of proficiency in the language, so that students can independently produce articles, abstracts, essays, and work with scientific and educational materials. This competence is developed from the beginning, with the understanding of task instructions in a foreign language.

The ability to effectively and logically defend one's position in professional discussions conducted in a foreign language is an essential skill that contributes to a student's readiness to engage in debates and discussions at scientific conferences, roundtables, colloquia, and other events. In addition to mandatory discussions and colloquia included in the program, students also have the opportunity to present at student conferences and other forums.

The ability to select a communication style and adjust speech and body language according to the purpose of the communication is facilitated by mastery of professional terminology, which the student adjusts in the course of communication. When engaging in dialogue with patients, it is essential to be able to convert professional terminology into everyday language and vice versa, i.e., to translate everyday language into professional terminology.

The competence-based approach to teaching Russian as a foreign language is, by its very nature, driven by the use of digital technology. The successful implementation of digital learning can be achieved by carefully selecting materials and designing tasks that focus on grammar, vocabulary, and pronunciation. This approach should also take into account all forms of speech activities, with a gradual transition from reproducing to producing original content.

The integration of digital technology into Russian language instruction at a medical school not only enhances the quality of education but also promotes sustainable development. This is achieved by allowing for efficient use of resources, reduction of time and space expenditures, and making learning more environmentally sustainable.

REFERENCES

Abieva, N. M., 2024. Autentichnye teksty v obuchenii russkomu yazyku kak inistrannomu studentov meditsinskix vuzov. Inostrannyi student universiteta: adaptatsia, obuchenie, zdorovje: monorgafia. ChSU named after I.N. Ulyanov. Cheborsary.

Khan, Sh., 2021. Russian language as tool in foreign policy in CIS. Post-Soviet Studies.

Kopnina, G.A., Evseeva, I. V., Eremina, E. V., Verenich, T. K., Bashkova, I. V., 2020. Russian open education centre "Siberia.ru": the conceptual bases and prospects for development Journal SFU. Humanities.

Mikeshova, E.A., 2017. The use of multimedia technologies in teaching Russian as a foreign language: a film-viewing study. Journal SFU. Humanities.

Muzykant, V., Burdovskaya, E., Souhila, K., Ruiqi, H., 2021. Media platforms as influential tool of Russian language learning abroad. Mediaeducation.

Niyazova, F, Xaydarova, D., 2023. The role of Russian as a foreign language in education. SAI.

Slutskiy ,Y.., 2021. Video component of media education in direct and reverse acculturation at North Carolina State University and Texas Christian University. International Journal of Media and Information Literacy.

Tomyuk, O.N., Diachkova, A.V., Kerimov, A.A., Dudchik, A.Yu., 2021. The educational potential of podcasts in the context of formation human legal culture: a new format and new opportunities media sphere. PS&E.

Tsoy, N.G., Maltseva, K.G., 2023. Teaching Chinese on the base of digital platforms. IRJ.

Zinchenko, V.V., 2022. Implementation of sustainable development goals in the new institutional reality for education. PS&E.

Use of Laws of Quantum Thermal Radiation of Gas Volumes to Reduce Pollutant Emissions at Thermal Power Plants

A.N. Makarov[1]
Tver State Technical University (TSTU), Tver, Russia
tgtu_kafedra_ese@mail.ru

Keywords: scientific discovery, laws of thermal radiation, gas volumes, flares, steam boiler furnaces.

Abstract: The laws of thermal radiation from gas volumes of flares of steam boilerfurnaces of power plants, combustion chambers of gas turbine installations of power plants are described.Heat transfer is calculated in the furnace of a steam boiler of a power unit with a capacity of 800 MW.The distribution of temperature, heat fluxes of the flame and deposits in the tubes is significantly non-uniform, which adversely affects the operation of the furnace. A steam boiler furnace has been developed in which the flame temperature and pollutant emissions are reduced and heat fluxes across heating surfaces are equalized.

1 INTRODUCTION

In the world 45-50% of produced fuel is burned in steam boiler furnaces and 50-55% of electric power is produced, in Russia 65% of electric power is produced at thermal power plants (TPP). The sizes of furnaces in the form of rectangular parallelepipeds are approximately 7x14x40 m and 10x20x60(80) m. The surface of the furnace of steam boilers (SBF) is lined with pipes in which under the action of the heat of the fuel water turns into steam, the steam enters the steam turbine, the rotor of which rotates the rotor of the generator and in the stator electricity is generated. The SBF burns from 60 t/h fuel oil equivalent in a 300 MW unit to 180 t/h fuel oil equivalent in an 800 MW unit.

The complexity of calculating heat transfer in the TPP SBF is that, according to Bohr's postulates , it is necessary to take into account in calculations of heat fluxes from the flare to the calculated area the quantum radiation of each atom of the gas volume of the flare. Atoms in the SBF of the TPP are quintillions, 1030-1045 atoms. Atoms in the SBF are like grains of sand in the Sahara desert, the calculation is a supercomplex task, so this task has not been solved in Russia, Germany, France, the USA or other countries during the 20th century ((Timofeeva, 2001; Andreeva, Blokh, Zhuravlev, Rozhkov, 1991; Siegel, Howell, 1975; Sparrow, Sess, 1971; Chandrasekar, 1993; Adzerikho, 1975; Klyuchnikov, Ivantsov, 1976)).

2 THE PROBLEM OF HEAT TRANSFER CALCULATIONS IN THE FURNACESOF STEAM BOILERS

Throughout the 20th century, the Stefan-Boltzmann-Lawfor radiation from solid bodies, solid fuelwas used for determiningquantum thermal radiation fromthe torch on the heating surfaces in SBFs.In calculations of heat transfer of gas volume, flare correction factorswereintroduced, a number of methods were developed: Chandrasekar, Schwarzschild-Schuster, Eddington, zonal, numerical and others, but obtained the result of calculations with large errors of 200% and more percent, because the radiation of the flare does not obey the Stefan-Boltzmann law.

Throughout the 20th century, the flare in SBF was a "black box", the phenomena occurring in SBF were unclear, incomprehensible: non-uniformity of vaporization in pipes, non-uniformity of deposits in pipes, burnerburnout and other phenomena.

With the discovery by the authorof this article in 1996-2001 of the laws of quantum thermal radiation

[1] https://orcid.org/0000-0003-0737-6804

of gas volumes of flares (Makarov, 2022; Makarov, 2014), the problem of calculating heat transfer in SBFs was solved. Until 1996-2001, during 30 years the author developed the theory of heat transfer in electric arc steelmaking furnaces (EASFs), its experimental confirmation, its subsequent adaptation for use in metallurgical companies and for teaching students of metallurgical departments and universities (Makarov, 2022; Makarov, 2014; Makarov, Svenchansky, 1992; Dorofeev, Zinyagin, Makarov, 2021). The electric arc in EASF is modeled by a cylindrical gas volume. Thermal radiation of cylindrical gas volumes was investigated and the following regularities were discovered (Makarov, 2022).

2 LAWS OF THERMAL RADIATION OF FLARE GAS VOLUMES

The basic I law of thermal radiation of the gas volume of a flare of any shape and dimensions is derived mathematically and has the following form (Makarov, 2022; Makarov, 2014):

$$q = \frac{\varphi_{fF} P_f}{F e^{kl}}, \quad (1)$$

where q is the quantum heat flux from the flare to the design site; φ_{fF} is the angular coefficient, i.e., the fraction of flare radiation to the design site; P_f is the flare power; F is the area of the site; e is the number of natural logarithms; k is the absorption coefficient of the flare gas medium; l is the average length of the path of quanta from all atoms of the gas volume of the flare to the site.

It is a nearly impossible task to find the radiation fraction of the gas volume of a flare consisting of 1030 radiating atoms, filling a furnace of 10x10x40 m, to an area of 0.5x0.5 m.

During the 20th century this problem indeed had not been solved either in Russia, or in Western European Union (WEU), or other countries. The later discovery of the II law made it possible to solve this problem. Let us inscribe into a furnace a cylindrical gas volume of a flare, 10x10x40 m in size, with a diameter of 10 m and a height of 40 m, in which we will place all 1030 atoms of the gas volume (Fig. 1).

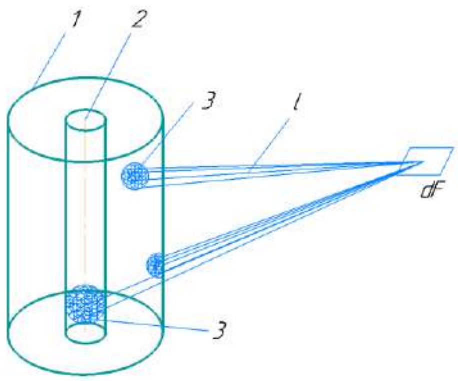


Figure 1: Radiation of a cylindrical gas volume of large diameter 1 and its axis of cylindrical symmetry 2 to the design site *dF*: 3- atoms; *l* – average path length of all quanta from the atoms of the gas volume to *dF*.

The II law of quantum thermal radiation of cylindrical gas volumes of flares is as follows: the angular coefficients, i.e., the radiation fraction, of a cylindrical gas volume of large diameter of 10 m to the design site and its axes of cylindrical symmetry are equal when the number of atoms of the cylindrical volume of a larger diameter and cylindrical axis is the same, i.e. when the same power is emitted in the cylindrical volume of a larger diameter and cylindrical axis:

$$\varphi_{fF} = \varphi_{0F} \quad (2)$$

where φ_{fF}, φ_{0F} are, respectively, the angular coefficient, i.e., the fraction of quantum radiation, of the cylindrical gas volume 1 of the flare and its cylindrical axis of symmetry 2 to the design area dF.

The unique physical phenomenon described in the II law occurs if all atoms of the large cylindrical gas volume 1 are compressed by radial force on the axis of cylindrical symmetry 2 of the gas volume, in which case the radiation powers and radiation fractions to the site of a large cylindrical gas volume and its axis of cylindrical symmetry are equal. The I and II laws of quantum thermal radiation of gas volumes of flares have been derived mathematically and repeatedly confirmed by experiments (Makarov, 2019; Makarov, 2019; Makarov, 2019; Makarov, 2015; Makarov, 2016; Makarov, Okuneva, Galicheva, 2017). Discrepancies in calculated and experimental data do not exceed 8-10%.

The II law is unique, as it allows us to move from the triple integral at a certain fraction of flare radiation to the calculation site to a single integration along the height of the axis of cylindrical symmetry. The triple integral in calculation of a radiation fraction of a large gas volume filling the SBF (steam boiler furnace) to a site is solved neither in Russia, nor in WEU, nor in the USA, nor in other countries. Single integrals for calculating the radiation fraction of a flare in the form of a cylindrical gas volume to the site are solved by the author for any position of the flare, i.e., any axis of cylindrical symmetry and heating surface (Makarov, 2022; Makarov, 2014). Thus, the problem of calculating the flare radiation fraction to the heating surface, which had not been solved during the 20th century, has now been solved in Russia in the Tver State Technical University.

The III law is also unique, as it allows us to solve another problem that was previously considered impossible: to determine the average length of the path of quanta l from all quintillion atoms 3 of the gas volume of the flame of a furnace, furnace, combustion chamber to the site (Fig. 1).

The III law of thermal radiation of gas volumes of flares is as follows: the average path length of quanta from all quintillions of radiating atoms of the cylindrical gas volume is equal to the arithmetic mean distance from the axis of symmetry of the cylindrical gas volume to the design site:

$$l = l_{fF} = l_{0F}, \qquad (3)$$

where l_{fF}, l_{0F} are, respectively, the mean path length of quanta from all atoms of the cylindrical gas volume of the flare and the arithmetic mean distance from its cylindrical axis of symmetry to the design site.

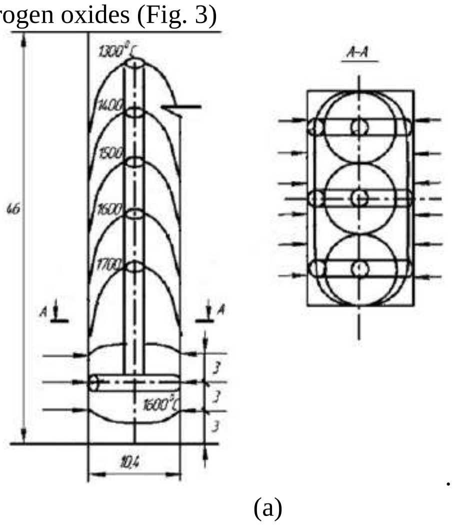
This is a unique physical phenomenon. The problem of determining the average path length of quanta from quintillions of atoms, as numerous in the furnace as grains of sand in the Sahara Desert, that had not been solved during the 20th century has now been solved in Russia, in the Tver State Technical University. With the discovery of the III law of thermal radiation of gas volumes, the solution was proven to be simple, fitting into a few algebraic operations.

The IV law of quantum thermal radiation of cylindrical gas volumes of flares is a direct corollary of the second and third laws and is as follows: Heat fluxes to the design area of a cylindrical gas volume of large diameter and a gas volume of its axis of cylindrical symmetry are equal if the number of radiating atoms and thermal powers of radiations are the same at these volumes. The discovered laws have led to a unique physical phenomenon: cylindrical gas volumes of any size can be inscribed in the gas volumes of radiating flares of any size, and the thermal radiation of the gas volume of the flare can be modelled by the radiation of its axis of cylindrical symmetry.

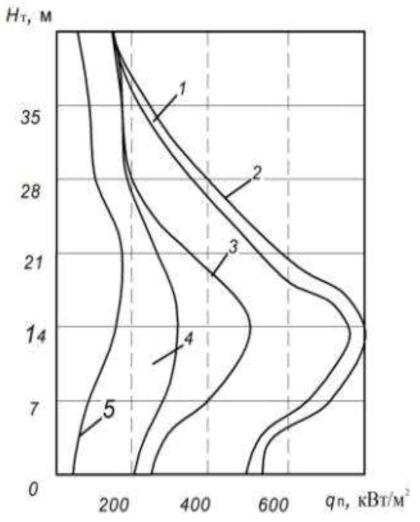
The flares created by single burners are ellipsoids of rotation, so in heat transfer calculations we model them by several radiating cylindrical gas volumes. The flares of the SBF are gas volumes in the form of rectangular parallelepipeds, into which, depending on the location of isotherms, we fit several dozens of cylindrical gas volumes in 2-3 rows and calculate heat transfer in the SBF (Makarov, 2022; Makarov, 2014).

3 USE OF LAWS OF THERMAL RADIATION OF GAS VOLUMESTO CLACULATE HEAT TRANSFER IN STEAM BOILER FURNACES

According to the laws of quantum thermal radiation of gas volumes and the calculation method developed on their basis for heat transfer in flare furnaces ,fire boxes and combustion chambers, heat transfer is calculated in the furnaces of steam boilers, of a power unit with a capacity of 800 MW and other power units. For the first time the full picture of the distribution of flare heating fluxes on all surfaces of steam boiler furnace walls has been got. The results of the calculation of heat transfer in the furnace of a steam boiler TGMP-204 are presented in Figure 2. The distribution of temperature, flare quantum radiation fluxes and deposits in the pipes along the perimeter and height of the furnaces are substantially uneven, which negatively affects the operation of the boiler (Figure 2(b)).Changes were made to the location of burners along the height of furnaces, in the design of furnaces in order to reduce temperature, uneven distribution of heat fluxes along the height and perimeter of furnace walls and emissions of nitrogen oxides (Fig. 3)

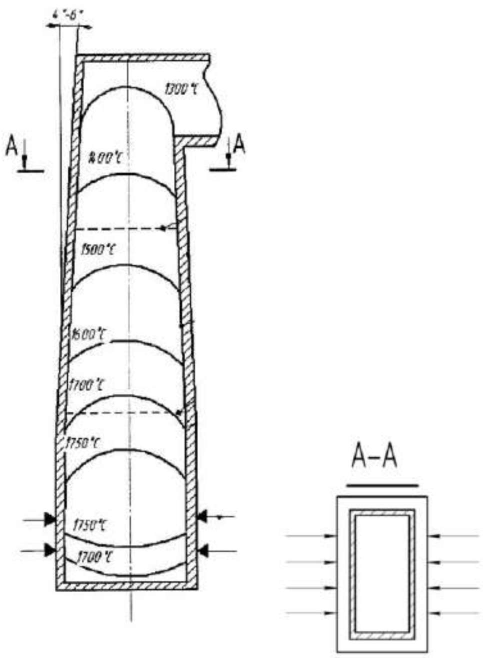


(a)

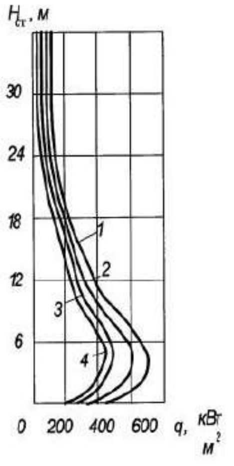


(b)

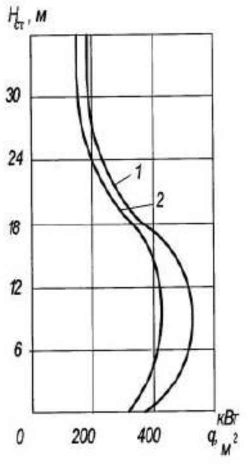
Figure 2: Distribution of isotherms in the furnace of the steam boiler TGMP-204 (a), distribution of the density of the total quantum radiation flux along the walls of the furnace (b): 1—along the vertical axis of symmetry of the front wall; 2—the same, the measurement result; 3—along the vertical axis of symmetry of the sidewall; 4—along the vertical axis at the periphery of the sidewall; 5—along the vertical axis on the periphery of the front wall.



(a)



(b)



(c)

Figure 3: Patent for the invention: the combustion chamber of a steam boiler for burning gas oil with tilting part of the walls inward (a); the calculated distribution of the heat flux of the flare before reconstruction (b); along the symmetry axis of frontal (1), side (2) walls, on the periphery of frontal (3), side (4) walls, after reconstruction (c) along the axis (1) and on the periphery (2) of frontal and side walls.

Calculation according to the laws of quantum thermal radiation of gas volumes allowed for the first time in the world practice to obtain complete information on the flare quantum thermal radiation fluxes falling on the front, rear, side walls along the perimeter and height of furnaces, on the causes of unevenness of deposits along the perimeter and height of furnaces, unevenness of steam formation in pipes, on the causes of burner burnout, and other physical phenomena occurring in the furnaces of steam boilers. The author and his colleagues have developed patent-protected innovative furnaces of steam boilers (Fig. 3), which reduce the above-mentioned negative phenomena occurring in furnaces, their description is set forth in textbooks, monographs (Makarov, 2022; Makarov, 2014; Makarov, Svenchansky, 1992; Dorofeev, Zinyagin, Makarov, 2021).

4 CONCLUSION

In the late XX and early XXI centuries, in Russia werediscovered the laws of quantum thermal radiation of gas volumes formed during the burning of an electric arc in electric arc steel melting furnaces, flaring of fuel in furnaces, fire boxes and combustion chambers.For the first time in world scientific practice, in the chaotic quantum thermal radiation of quintillions of atoms of flares of furnaces, fire boxes, combustion chambers, the laws determining the order in the chaos have been revealed, allowing calculations to take into account quantum thermal radiation on the heating surface of each atom of flares.

The laws of heat radiation of gas volumes, discovered by the author of this article, like all fundamental laws of physics, have multidisciplinary and applicability in a various sectors of economic activities: energy, metallurgy, various industries, education (Makarov, 2014; Makarov, 2019; Makarov, 2021).

With the scientific discovery of the laws of quantum thermal radiation of gas volumes of flares and electric arcs, it became possible to calculate the heat transfer in electric arc and flare furnaces, fire boxes, combustion chambers with high accuracy, to improve the heat transfer and design of electric arc and flare furnaces of industrial enterprises, fire boxes, gas turbine combustion chambers of power plants around the world, save million kWh of electricity and million tons of liquid, gaseous, pulverized fuel, reduce pollutant emissions into the atmospheric air, reduce the technological pressure on the environment in Russia and many cities around the world.

For similar in its significance scientific discovery of the author of the laws of quantum thermal radiation of gas volumes, for the discovery of the laws of quantum thermal radiation of solids, absolutely black solid, by Wien and Planck, Wien in 1911, Planck in 1918 was awarded the Nobel Prize in Physics.

Similarly, for Einstein's discovery of the law of the photoelectric effect of radiation in 1921 and for the development of the theory of the atom and radiation from it by Bohr in 1922 were awarded the Nobel Prize in physics. The laws of quantum thermal radiation of gas volumes, as well as the laws of quantum thermal radiation of solids, blackbody, belong to the fundamental laws of physics, its section "Quantum Physics". Bohr was the last scientist to receive the Nobel Prize in Physics for discovering the fundamental laws of physics.

The discovery of the fundamental laws of physics is an outstanding event in the life of mankind, which occurs once every 50 - 80 years. Confirmation of this fact is physics textbooks for schools and universities (Timofeeva, 2001; Andreeva, 2006), which set out a little more than 30 laws discovered by mankind over 3 thousand years, starting from the III century BC, from the law of Archimedes and ending with the last fundamental laws, postulates discovered by Bohr in 1913, the laws of quantum thermal radiation of gas volumes discovered by the author of this article in 1996-2001.

REFERENCES

Timofeeva, T.I., 2001. Course of Physics:textbook for university students,Vysshayashkola, Moscow, 369 p.

Andreeva, O.N., 2006. Physics: Reference Book of Necessary Knowledge,Martin,Moscow,408p.

Blokh, A.G., Zhuravlev, A.N., Rozhkov, A.N., 1991. Radiant Heat Transfer: A Handbook. Energoatomizdat, Moscow,432 p.

Siegel, R, Howell, Y, 1975.Thermal Radiation Heat Transfer, Mir, Moscow, 934p.

Sparrow, E.M., Sess, R.D., 1971. Radiation heat transfer, Énergiya,Leningrad,294 p.

Telegin A.S., Shvydkoi V.S., YaroshenkoYu.G. Heat and mass transfer. M.: Metallurgy, 400 p., 1995.

Chandrasekar, S.,1993. RadiationTransfer. M.: IL, 431 p.

Adzerikho, K.S., 1975. Lectures on the Theory of Transfer of Radiant Energy. Ed. M.A. Elyashevich. Minsk: BSU publishing house,192p.

Klyuchnikov, A.D., Ivantsov, G.P., 1970. Heat Transfer by Radiation in Fire Engineering Installations. M.: Energia,400p.

Makarov, A.N., 2022. Heat exchange in electric arc steelmaking and flare heating furnaces, furnaces of steam boilers, combustion chambers of gas turbine installations. Moscow-Vologda: Infra-Engineering, 452 p.

Makarov, A.N.,2014. Heat Transfer in Electric Arc and Torch Metallurgy Furnaces and Energy Plants. Lan, St. Petersburg. [CitationTime(s):4], 384 p.

Makarov, A.N., Svenchansky, A.D., 1992. Optimal thermal modes of arc steelmaking furnaces. M.: Energoatomizdat, 96p.

Dorofeev, G. A., Zinyagin, G. A., Makarov, A. N., 2021. Steel Production Based upon Direct Production Iron: Scientific Issue [in Russian], TNT, Starii Oskol,324p.

Makarov, A.N., 2019. Calculation of heat radiation from gas volume of the torch, Part II. Calculations of radiation from the on burner, JP Journal of Heat and Mass Transfer. 16(1): 43-52.

Makarov, A.N., 2019. Calculation of heat transfer in torch furnaces, JP Journal of Heat and Mass Transfer. 2019: 18(1): 1-20.

Makarov, A.N., 2019. Calculation of heat transfer infurnaces of steam boilers under laws of radiation ofgas volume, JP Journal of Heat and Mass Transfer. 18(2): 423-436.

Makarov, A.N., 2015. Radiation from Large Gas Volumes and Heat Exchange in Steam Boiler Furnaces.Power Technology and Engineering. 3(49):196-201.

Makarov, A.N., 2016. Flare Temperature and Nitrogen Oxide Emission Reduction and Heat Transfer in the

TGMP-314I Steam Boiler Firebox.Power Technology and Engineering. 2(50):200-203.
Makarov, A.N., Okuneva, V.V., Galicheva, M.K., 2017. Influence of the Length of a Torch Tongue on Heat Flow in a Burner Device.Power Technology and Engineering. 4(51):445-450.
Makarov, A.N., 2019. Calculation and analysis of the relationship between the efficiency and position of electric arcs and power consumption in clectrie arc furnaces (EAF) of smaller and larger capacity. Part.I. Calculation and analysis of the relationship between arc efficiently and power consumption. Metallurgist. №63 (3-4). P. 341-349.
Makarov, A.N., 2019. Calculation and analysis of the relationship between the efficiency and position of electric arcs and power consumption in clectrie arc farnaces (EAF) of smaller and larger capacity. Part 2. Calculation and analysis of the relationship between position arcs, walls and power consumption. Metallurgist. №63 (5-6). P. 441-450.
Makarov, A.N., 2021. Effect of the sloganeer thickness, gas composition, and furnace capacity on the arc efficiency and heat transfer in arc furnaces. Part I. Effect of the slag thickness and furnace capacity on arc efficiency. Metallurgist. №64(9-10). P. 987-996.
Makarov, A.N., 2021. Effect of the sloganeer thickness, gas composition, and furnace capacity on the arc efficiency and heat transfer in arc furnaces. Part II. Effect of the slag thickness on the magnitude of are heat radiation incident to the walls. Metallurgist. №64(11-12). P. 1121-1129.

Model for Managing Digitalization of Education in Higher Education Institutions

Ketoeva Natalya Leonidovna[a], Znamenskaya Maria Andreevna[b]
and Dranitsyna Victoria Konstantinovna[c]
National Research University "Moscow Power Engineering Institute", Krasnokazarmennaya street, Moscow, Russian Federation
KetoyevaNL@mpei.ru, ZnamenskayaMA@mpei.ru, KotelnyaVK@mpei.ru

Keywords: internet technologies, digital technologies, educational services, higher education institutions, digitalization of education, management model for digitalization of education

Abstract: The article is devoted to topical issues of developing a model for managing the digitalization of education in higher educational institutions. The article analyzes the level of penetration of Internet technologies at the international level and in the Russian Federation. The study showed the readiness of countries, including Russia, to accept digitalization, including in the educational environment. In the process of research, problems and paths to the digitalization of education were identified, which are mainly related to the communicative abilities of students. Based on this, the authors identified elements of the problem of reducing the communicative ability of students, such as: lack of skill in establishing contact with other subjects of learning, inability to behave in classes in a distance format, difficulties in perceiving the course material, lack of self-organization and self-education skills for independent work with educational material and a formal attitude towards completing assignments. All of the above aspects predetermined the formation of the model. The model for managing the digitalization of education in higher education institutions includes input and output data, as well as the creation of a digital educational environment with dedicated subjects. The developed model for managing the digitalization of education at universities will help solve problems that arise on the way to the digital transformation of education. All of the above will contribute to the formation of a digital educational environment, implying a set of digital learning tools, as well as a deep modernization of the educational process, which should ensure the preparation of a person for life and professional activity in a digital society and digital economy.

1 INTRODUCTION

Digital technologies are driving qualitative changes in manufacturing and global markets. These changes also cover the educational environment. The transition from mass education for all to quality education, including the comprehensive development of the personality of each student, is called the new technological (digital) revolution. Digital technologies are actively developing and opening up new opportunities for using digital tools, materials and services.

According to world statistics, in 2022 the level of penetration of Internet technologies in the world shows that Europe's Internet coverage is already 89.2%. The fastest Internet penetration is in North America - 93.4%, and the slowest in Africa - 43.2%. This can be seen in Figure 1.

Compared to 2000, in Europe this figure has increased by 611% by 2022, which indicates the readiness of European states for digitalization and the introduction of modern methods and tools for managing it.

As for the Russian Federation, as of 2020, 81% of the total population – 118 million people – have access to the Internet. Moreover, active network users in the Russian Federation are 48%, which is 70 million people. According to forecasts, for 2021, the

[a] https://orcid.org/0000-0001-6652-522X
[b] https://orcid.org/0000-0001-9574-1298
[c] https://orcid.org/0000-0003-2026-214X

share of people using Internet technologies will reach 85%, and social networks – 52%. In education, for the period from June 2021 to August 2021, the number of Internet users by students and trainees is 9.3%, although this period occurred during the holidays.

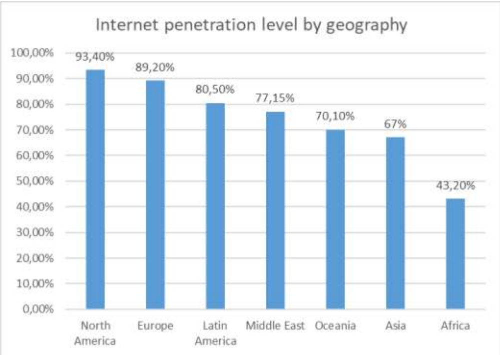


Figure 1: Penetration level of Internet technologies in the world by geography, %.

The problems of digitalization of education were dealt with by such authors as I.E. Semenko, V.N. Minina, B.E. Starichenko, P.I. Gairbekova, M.L. Berkovich, E.A. Butina, A.Yu. Uvarova, I.D. Frumina and others (Minina, 2020; Butina, 2020; Uvarova, Frumina, 2019).

In connection with the analysis, we can say that the digitalization process has already been launched throughout the world. This process also applies to education. It is also necessary for our domestic education. The digital economy puts forward a requirement for every student to master 21st century competencies. All students must have critical thinking, be capable of self-learning, be able to fully use digital tools, and also be capable of creatively applying existing knowledge in the context of the rapid development of the digital environment. Thus, the key problems of the study are to explore and identify ways and means to transform higher education institutions in the digital economy.

The study includes the following sections: introduction, materials and methods, results, discussion, conclusion and list of references.

2 MATERIALS AND METHODS

The scientific novelty of the research lies in the development of a model for managing the digitalization of education in higher educational institutions, which differs from existing developments by the comprehensive inclusion in it of the formation of the content of education, the organization of the educational process, the identification of the results of educational activities and the assessment of the results of the educational activities of universities.

In this regard, the purpose of the study is to develop a model for managing the digitalization of education in higher education institutions, which includes the formation of a digital educational environment.

To achieve this goal, the following tasks were set and solved:

- analyzed the level of penetration of Internet technologies in the world and in the Russian Federation by geography and in the field of education;
- analyzed the regulatory and methodological framework for the digitalization of education in the Russian Federation;
- identified problems on the way to digitalization of education in higher educational institutions;
- a model for managing digitalization in universities has been developed.

The object of the study is the digitalization of education in higher educational institutions.

The subject of the study is the processes and models of digitalization management in higher education institutions.

The methodological apparatus consisted of research methods: dialectical scientific knowledge and particular scientific ones (analysis, synthesis, comparison, logical and system-structural analysis, formalization, analysis of legal documents), modeling.

When studying the transformation of higher educational institutions from the point of view of their digitalization, universities of the Russian Federation were studied, which represents a sufficient reference sample.

3 RESULTS

Digital transformation of education is the process of updating the planned results of education, its content, methods and organizational forms of educational work, as well as assessing the results achieved in the context of the rapid development of the digital environment to radically improve the educational results of each student.

At the moment, digitalization of education is one of the priority areas for the development of state policy of the Russian Federation. The state is implementing the following programs for the digitalization of education: “Strategy for the development of the information technology industry in the Russian Federation for 2014–2020. and for the future until 2025”, approved by Order of the Government of the Russian Federation of November 1, 2013 No. 2036-r; “Strategy for the development of the information society in the Russian Federation for 2017–2030”, approved by Decree of the President of the Russian Federation of May 9, 2017 No. 203; priority national project “Modern digital educational environment in the Russian Federation” within the framework of the State program “Development of Education”, approved by the Presidium of the Council under the President of the Russian Federation for strategic development and priority projects, protocol dated October 25, 2016 No. 9; national project “Education” for the period from 2019 to 2024, approved by the Presidium of the Council under the President of the Russian Federation for Strategic Development and National Projects dated September 3, 2018 No. 10.

The goals and objectives established in the listed regulatory documents suggest considering the process of digitalization of education from two sides: on the one hand, as the formation of a digital educational environment and digital technologies, and on the other hand, as a deep transformation of the educational process, which ensures that a person is prepared to live and implement their professional activities in the digital society and digital economy.

Let us highlight three main problems on the way to the formation of a digital educational environment (Fig. 2).

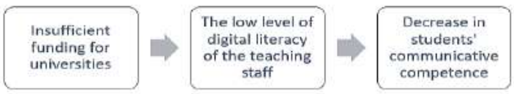


Figure 2: Problems on the way to digitalization of education.

The first problem is related to the insufficient level of funding for universities. Not all educational institutions are fully equipped with all the necessary equipment and software to carry out educational activities in the context of digitalization.

The second problem is caused by the low level of digital literacy of teachers. Digitalization of education requires teachers to competently and professionally use information technologies and information resources, which in some cases is a difficult task, since some university teachers are aged and do not have a high level of knowledge in the use of modern technologies. In this regard, it is necessary to attract additional resources to train teachers and improve their qualifications.

The third problem is the decline in students' communication ability. Due to the current epidemiological situation, the transition to distance learning has shown that most students are not ready to study in this format. Communication between teacher and student has become difficult. Traditional face-to-face communication is significantly different from communication using information technology.

Figure 3 reflects the elements that unite the problem of reducing the communicative ability of students.

Figure 3: Elements of the problem of reducing the communicative ability of students.

All of these components of the problem, presented in Figure 3, lead to a decrease in the quality of education and, as a consequence, to a decrease in the quality of graduates.

The problems arising on the path to the digital transformation of education determine the need to form a new model for managing digitalization in universities.

Figure 4 presents a model for managing digitalization in universities.

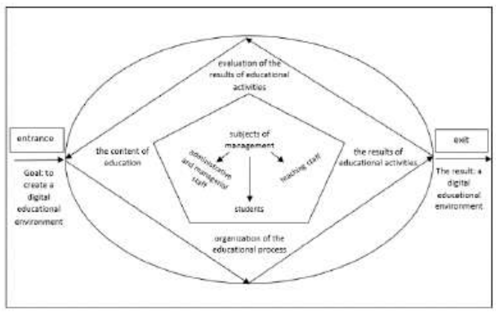


Figure 4: Model for managing digitalization in universities.

The content of education in our time is no longer based only on textbooks; moreover, literature published in the last five years is recommended for study. Nowadays, everyone has access to a huge amount of information from the Internet. Teachers independently determine and approve the content of training courses, taking into account current federal educational standards.

The most important task of digital transformation of education (Alexandrov, Vereshchak, Ivanova, 2019; Golovchin, 2021) for the education content block is the preparation of high-quality educational and methodological material. An effective solution to this problem is open educational resources (Pashkov, Pashkova, 2022), which include textbooks, scientific articles, educational games, various videos, etc. But, open educational resources themselves are useless if teachers do not receive the necessary retraining in their professional development for quality training and work with modern educational resources. To do this, administrative and managerial staff must assist in creating a digital educational environment (platform) of the university, where various tests, educational lectures, cases, etc. will be posted, as well as conduct gradual and consistent preparation of teachers and students for the transition to a digital format work.

The organization of the educational process in modern realities should involve not only the transfer of knowledge from teacher to student (Sunnatova, 2021), but also the creation of motivation for the student to independently acquire knowledge. It is important to interest the student in the educational process and direct him to independent work and setting goals and objectives in the learning process. Previously, to meet the needs of society and the labor market, it was enough to provide knowledge to students. In the modern world, a specialist is valued who has not only knowledge, but also creative thinking, a desire for constant development, self-education and the search for new solutions. This component of the model is a continuation of the first component. The creation of a digital educational environment, including all kinds of interactive teaching methods, will help raise the level of interest among students; in addition, in the conditions of digitalization, regardless of where they live, opportunities for receiving education are opening up anywhere in the world.

It is very important to monitor the results of educational activities and, if necessary, make adjustments. In the traditional educational process, all students must learn the material at the same pace, someone is ahead and becomes uninterested, while someone else cannot keep up with everyone and his interest in learning also disappears. The digital educational environment will give everyone the opportunity to work at their own pace, so some will be able to understand the material in more detail, while others will study additional material, and all participants in the educational process will remain interested. Also, the teacher should arrange meetings with students to discuss the material studied and develop communication skills.

The next component is the assessment of educational activities. This component follows from the previous one; the results of educational activities must not only be monitored and adjusted, but also evaluated.

After mastering a section of the discipline, each student must pass an intermediate control. This will help identify students who have not mastered any material well enough and carry out individual work with them. Thus, an individual approach improves the quality of the produced personnel.

4 DISCUSSION

In the works of I.E. Semenko, V.N. Minina, B.E. Starichenko, P.I. Gairbekova, M.L. Berkovich, E.A. Butina, A.Yu. Uvarova, I.D. Frumin, which are devoted to the “Digitalization of Higher Education,” describe trends associated with the introduction of digital technologies, processes and tools into the educational process (Minina, 2020; Butina, 2020; Uvarova, Frumina, 2019). Based on these aspects, the article has developed a model for managing the digitalization of higher education, characterized by the formation of the content of education, the organization of the educational process, the identification of the results of educational activities and the assessment of the results of the educational activities of universities.

The authors note that the digitalization of education carries a number of positive aspects, such as increasing the openness and flexibility of education, increasing student involvement in the educational process, etc. But digitalization can also lead to negative consequences. In this we agree with the authors, and our proposed model for managing the digitalization of education is aimed at solving the problems identified at the beginning of the study.

5 CONCLUSIONS

The digital educational environment is a set of information systems, sources, tools that contain new technologies for obtaining education in an interactive form, which is not only interesting, but also useful, as it increases the involvement of students in obtaining knowledge, rather than an education diploma.

The paper presents the development of a model for managing the digitalization of education, the purpose of which is to create a digital educational environment. This model can be used in further research to expand it to a mechanism for managing the digitalization of higher education. And also, it is worth noting that the implementation of the resulting model in the organization will allow us to evaluate the effectiveness of this development, both economically and socially.

REFERENCES

World Statistics Website Internet World. States [Electronic resource].URL: https://www.internetworldstats.com/stats.htm.

Report Special Report Digital 2020. [Electronic resource].URL:https://wearesocial.com/blog/2020/01/digital-2020/.

Analytical center Monthly Reach. [Electronic resource].URL: https://mediascope.net

Minina, V.N., 2020. Digitalization of higher education and its social results. *Bulletin of St. Petersburg University. Sociology.* T. 13. Issue. 1. pp. 84–101.

Decree of the President of the Russian Federation dated 05/09/2017 No. 203 On the Strategy for the Development of the Information Society in the Russian Federation for 2017 – 2030. [Electronic resource].URL:http://kremlin.ru/acts/bank/41919

Passport of the priority project “Modern digital educational environment in the Russian Federation” (approved by the presidium of the Council under the President of the Russian Federation for strategic development and priority projects, protocol dated October 25, 2016 No. 9) (with amendments and additions). [Electronic resource].URL: http://government.ru/projects/selection/643/25682/

Butina, E. A., 2020. Digitalization of the educational space: risks and prospects. *Professional education in the modern world,* T. 10, No. 2 P. 3695–3701

Uvarova, A. Yu., Frumina, I. D., 2019. Difficulties and prospects for digital transformation of education. Nat. research University "Higher School of Economics". M.: Publishing house. House of the Higher School of Economics.

Alexandrov, A.Yu., Vereshchak, S.B., Ivanova, O.A., 2019. Digitalization of the Russian educational space in the context of guarantees of the constitutional right to education. *Higher education in Russia,* No. 10.

Pashkov, M.V., Pashkova, V.M., 2022. PROBLEMS AND RISKS OF DIGITALIZATION OF HIGHER EDUCATION. Higher education in Russia, No.3.

Golovchin, M.A., 2021. INSTITUTIONAL TRAPS OF DIGITALIZATION OF RUSSIAN HIGHER EDUCATION. *Higher education in Russia.* No.3.

Sunnatova, R.I., 2021. ENVIRONMENTAL FRIENDLINESS OF TEACHERS' COMMUNICATIVE BEHAVIOR IN THE CONTEXT OF DIGITALIZATION OF EDUCATION. PNiO. No.5 (53).

Vector of Sustainable Development of the Agro-Industrial Complex of the Russian Federation

Yuliya A. Kuzlyakina[1], Valentina S. Zamula[2], Irina V. Petrunina[3], Oksana A. Kuznetsova[4]

The V.M. Gorbatov Federal Research Center for Food Systems of RAS, Moscow, Russia

yu.kuzlyakina@fncps.ru, v.zamula@fncps.ru, i.petrunina@fncps.ru, o.kuznecova@fncps.ru

Keywords: Sustainable development, sustainable development goals, agro-industrial complex, food security, indicators, strategic interaction.

Abstract: The article analyzes and provides information on the indicators for achieving SDG 2 "Eliminating hunger, ensuring food security, improving nutrition and promoting sustainable agricultural development" in the Russian Federation. The main monitoring indicators are highlighted and outlined. The transformation of agri-food systems is embedded in the long-term development documents of the country. The definition of the current situation of agro-food systems and their sustainable development in the Russian Federation is considered.

1 INTRODUCTION

The 2030 Agenda for Sustainable Development (Agenda 2030) is a large-scale transformation plan that includes 17 interrelated and inseparable goals (17 SDGs) aimed at eliminating poverty and hunger, maintaining and preserving the planet's environmental resources, ensuring the well-being of the population, and, with additional adjustments adopted in 2021–2023, contains 231 SDG indicators.

The Russian Federation is committed to the 2030 Agenda and is actively working to monitor indicators of achievement of the SDGs. In December 2016, a group of experts on information and statistical support for SDG monitoring was created. Currently, 116 of the 231 global SDG indicators are being developed, including 31 with regional disaggregation.

Worldwide, special attention is being paid to achieving SDG 2 "Eliminating hunger, ensuring food security, improving nutrition and promoting sustainable agricultural development."

The state agricultural policy of the Russian Federation is aimed at unconditionally preventing the onset of hunger and all forms of malnutrition. The strategic goal of food security is to provide the country's population with safe, high-quality and affordable agricultural products, raw materials and food in volumes that ensure rational norms of food consumption (Liu, 2023).

Thus, the key sector of the country's economy is the agro-industrial complex (AIC), which provides the basis for ensuring food security and supplying the population with food. With the high growth of urbanization, agriculture becomes paramount (Kadomceva, 2024).

In this regard, legislative regulation has been adopted in the field of sustainable development of agro-industrial complexes (Figure 1).

Legislative regulation of the Russian Federation in the field of sustainable development of agro-industrial complexes

[1] https://orcid.org/0000-0002-2152-620X
[2] https://orcid.org/0000-0003-1634-1486
[3] https://orcid.org/0000-0001-7287-3511
[4] https://orcid.org/0000-0002-5048-9321

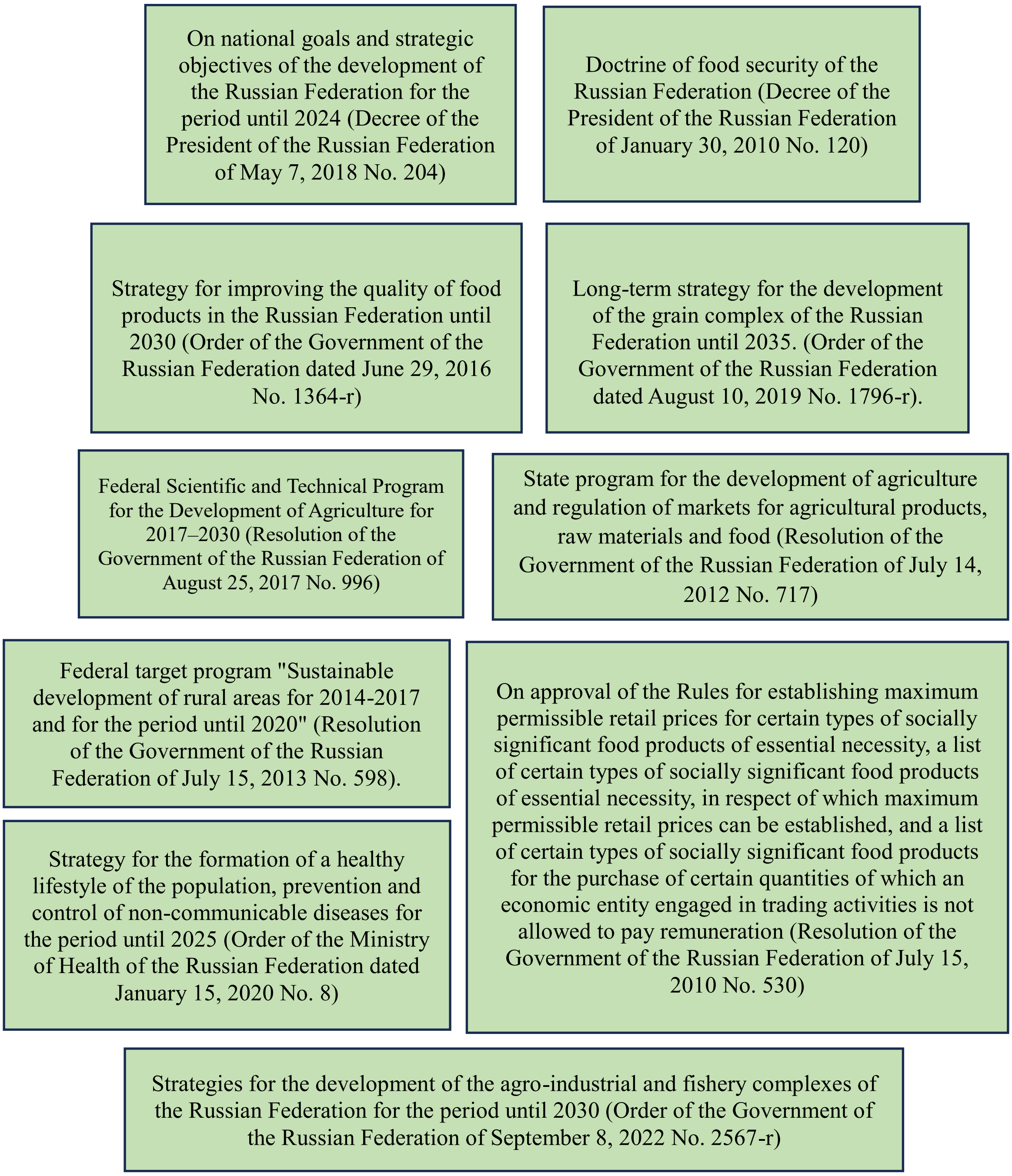


Figure 1: Legislative regulation of the Russian Federation in the field of sustainable development of agro-industrial complexes.

In addition, the level of food security is currently increasing within the framework of interstate interaction between the EAEU member States on the basis of agreed directions and measures, which meets the main goal of the coordinated (coordinated) agro—industrial policy of the Union (Liu, 2023).

May 2024 marked the 20th anniversary of the Treaty on the Eurasian Economic Union (hereinafter referred to as the Union, EAEU). This Agreement contains a special section defining the tasks and directions of the coordinated agro-industrial policy of the countries of the Union. The main goal of this policy is the effective realization of the resource potential of the EAEU member states to optimize the volume of production of competitive agricultural products, food and increase exports. The Agreement, in particular, provides for the balanced development of production and markets of agricultural products and food; ensuring fair competition between constituent entities of the EAEU member states, including the creation of equal conditions for access to the single agricultural market.

As is known, over the past 20 years, many joint decisions have been made regarding the further development of trade and production projects in the agro-industrial complex. Let us recall some of them. Thus, in 2020, the heads of state of the Union determined the Strategic Directions for Developing the Eurasian Economic Integration until 2025, which provide for the formation of a balanced agricultural market through the development of integration processes in this area. The result of such development should be a significant increase in agricultural production and an increase in its competitiveness. In addition, one of the directions is the development of general principles for ensuring food security based on methodological approaches of the Food and Agriculture Organization of the United Nations. Taking into account these tasks, already in 2021, the decision of the Council of the Eurasian Economic Commission (hereinafter referred to as the EEC) defined general principles and approaches to ensuring food security of the Union member states (Andronova, 2022).

It is also worth noting the Declaration on Further Development of Economic Processes within the EAEU "Eurasian Economic Path" adopted at the end of 2023. In accordance with this Declaration, the EEC, together with the states of the Union, is developing and submitting for approval in 2025 a draft roadmap that should contain specific measures to develop economic cooperation in areas with integration potential.

It is obvious that almost all of the above documents have defined, basically, a long-term strategy of state cooperation within the framework of the EAEU. Therefore, to truly implement the intended goals, not only new solutions are needed, but also ensuring the effective application of specific economic instruments that take into account current political and social realities (Glazyev, 2020).

2 RESEARCH METHODOLOGY

The theoretical and methodological basis was the research presented in scientific articles and published in English and Russian in the Scopus, Elsevier, Google Scholar, Science Direct, eLibrary (RSCI) databases, as well as data from the Federal State Statistics Service of the Russian Federation, official legislative and regulatory acts of state bodies of the Russian Federation and specialized organizations aimed at solving the problems of sustainable development management and management of the agro-industrial complex.

The advanced literature search methodology used for the study consisted of two stages. At the first stage, a literature search was conducted in order to collect representative studies to achieve the purpose of this article; the second stage included a source selection process performed by analyzing the title and abstract of each publication by key words and phrases.

3 RESULTS OF THE STUDY

The sustainable development of agro-industrial systems is crucial for ensuring global food security. Using statistical data for the period 2010, 2015-2022, the indicators of sustainable development of agriculture in Russia are analyzed and presented.

It is worth noting a positive trend in the study of the prevalence of malnutrition. At the same time, in 2018, only 0.3% of the Russian population experienced acute food insecurity, and 6.2% experienced moderate or acute food insecurity (Talerchik, Zajcev, Shavanov, 2021). In 2020, 0.3% of the Russian population experienced acute food insecurity, and 5.7% experienced moderate or acute food insecurity. In 2021, 0.3% of the Russian population experienced acute food insecurity, and 4.6% experienced moderate or acute food insecurity. In 2022, 0.2% of the Russian population experienced acute food insecurity, and 4.1% experienced moderate or acute food insecurity (Figure 2).

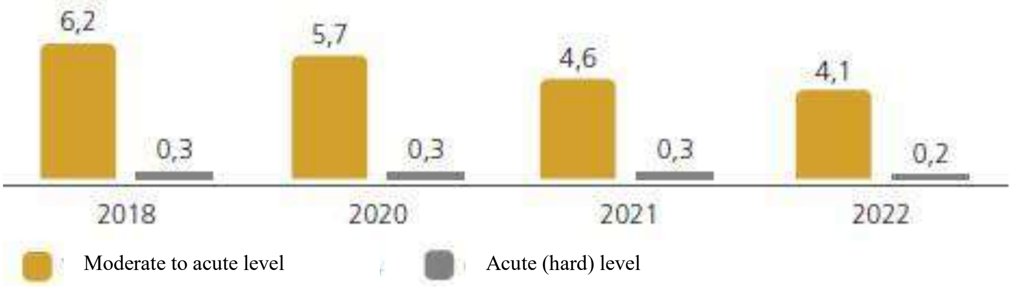


Figure 2: Food insecurity rates 2018-2022 (FIES, %).

The index of agricultural production in comparable prices to the previous year for the period 2010, 2015–2022 is shown (Figure 3) (Egorenko, 2022). In 2022 we see a sharp rise of 111.3%, in 2021 - 99.6%, in 2020 - 101.3%, in 2019 - 104.3% (Egorenko, 2022), in 2018 - 99.8% (Talerchik, Zajcev, Shavanov, 2021), in 2017 - 102.9%, in 2016 - 104.8%, in 2015 - 102.1%, in 2010 - 87.9%.

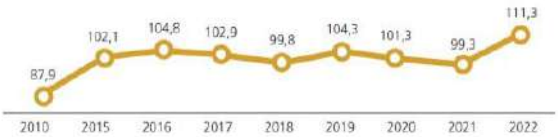


Figure 3: Agricultural production index for the period 2010, 2015-2022 (in comparable prices to the previous year, %).

It is necessary to highlight stability in reducing the value of the lack of money for food. In 2022, only 0.1% of households reported this, the same as in 2021 (Figure 4), compared to previous years where the data was significantly higher: 2020 - 0.2% of households, 2019 - 0.5% of households (Egorenko, 2022), 2018 - 0.9% of households (Talerchik, Zajcev, Shavanov, 2021), 2017 - 0.9% of households, 2016 - 1.0% of households, 2015 - 1.2% of households, 2010 - 1.8% of households.

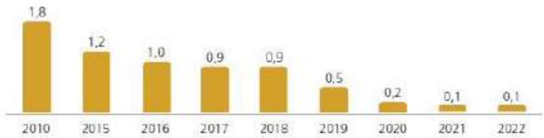


Figure 4: Households experiencing a lack of money for food for the period 2010, 2015–2022 (%).

Based on the data presented, the number of cases of anemia associated with pregnancy, childbirth and the postpartum period has decreased by almost a third in 2022 (Figure 5). Thus, in 2022, cases of anemia that preceded or occurred during pregnancy amounted to 414.1 thousand units, and cases of anemia that complicated childbirth and the postpartum period amounted to 313.2 thousand units. In 2021 – 457.1 thousand units and 350.0 thousand units. In 2020 – 473.8 thousand units and 365.1 thousand units. In 2019 – 497.0 thousand units and 379.3 thousand units. In 2018 – 531.7 thousand units and 400.8 thousand units. In 2017 – 537.0 thousand units and 420.9 thousand units. In 2016 – 577.1 thousand units and 457.1 thousand units. In 2015 – 592.7 thousand units and 446.6 thousand units.

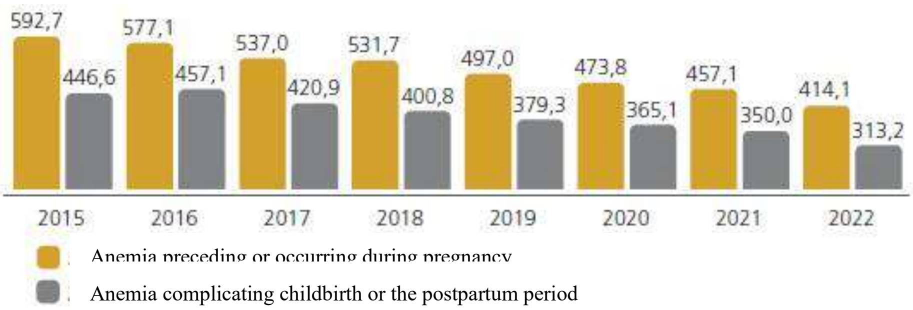


Figure 5: The number of cases of anemia (thousand units).

The share of domestically reproduced animals for agricultural production has increased significantly in 2022 - 96.9%, compared to the figures in 2021 - 94.3%, in 2020 - 93.4%, in 2019 - 93.4% (Egorenko, 2022), in 2018 - 93.5% (Talerchik, Zajcev, Shavanov, 2021). (Figure 6).

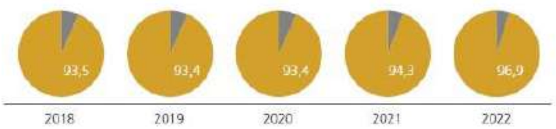


Figure 6: Share of domestically reproduced animals for agricultural production purposes for 2018-2022 (%).

4 RESULTS AND DISCUSSION

From the perspective of the strategic development of the state, the rational use of the agro-industrial complex determines the state of the national economic potential and the socio-economic situation of society. In this context, the AIC industries determine not only the economic security of the territory, but also the stability of the entire country, that is, the set of socio-economic parameters and their dynamics (Glazyev, 2020).

In the Russian Federation, continuous work is constantly underway to develop, form, expand and adjust national indicators of sustainable development and their compliance with the tasks of the agro-industrial complex.

Based on the considered analysis of the main indicators for monitoring the achievement of Sustainable Development Goal 2 in Russia, stable progress can be noted (Figure 7):

- sustainable reduction in the level of food insecurity of the population;
- reduction in the number of cases of anemia associated with pregnancy, childbirth and the postpartum period by almost a third;
- 0.1% of households report a lack of money for food;
- a significant increase in the agricultural production index in comparable prices compared to previous years;
- the share of domestically reproduced animals for agricultural production has increased significantly in 2022 - 96.9%.

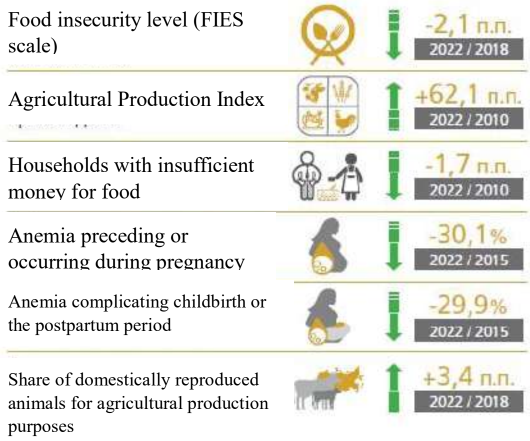


Figure 7: Comparative data of SDG 2 indicators.

5 CONCLUSIONS

Global agricultural systems are currently facing unprecedented challenges, in particular climate change, increased natural disasters, soil degradation and shortage of agricultural inputs, which together have led to insufficient diversity and low productivity, thereby impeding the achievement of Sustainable Development Goals.

The level of sustainability of the agricultural system of the Russian Federation demonstrates a constant trend towards stable growth. One of the key factors is the creation and implementation of strategic program documents at the legislative level.

For a long time, the assessment of sustainability in agriculture has focused mainly on environmental and technical aspects, thereby neglecting the economic and, above all, social aspects of sustainability, the versatility of agriculture and the applicability of results.

In modern realities, when Russian food security depends on many factors and challenges, various trends and topics of sustainable development and the achievement of SDG 2 were considered when evaluating and selecting indicators.

REFERENCES

United Nations. Department of Economic and Social Affairs. Sustainable Development, 2015. Transforming our world: the 2030 Agenda for Sustainable Development. Retrieved from https://sdgs.un.org/2030agenda Accessed January 15, 2023

United Nations. Department of Economic and Social

Affairs. Sustainable Development, 2015. The 17 goals. Retrieved from https://sdgs.un.org/goals Accessed January 15, 2023

Sustainable Development Goals in the Russian Federation, 2023. Short stat.sat. / Rosstat – M., 2023 – 100 p.

https://rosstat.gov.ru/storage/mediabank/SDG_Russia_2023_RUS.pdf

Liu, S., 2023. Towards a sustainable agriculture: Achievements and challenges of Sustainable Development Goal Indicator 2.4.1. Global Food Security 37,100694 .

Analytical Center under the Government of the Russian Federation, 2020. Voluntary national review of the implementation of the 2030 Agenda for Sustainable Development. https://www.economy.gov.ru/material/file/dcbc39abeafb0418d9d48c06c958e454/obzor.pdf Accessed January 23, 2023 (In Russian)

Kadomceva, M.E., 2024. Sistema indikatorov ustojchivogo razvitiya nacional'nogo APK. Problemy prognozirovaniya. № 1 (202). S. 144-156.

FAO, MFSR, YUNISEF, VPP i VOZ, 2023. Polozhenie del v oblasti prodovol'stvennoj bezopasnosti i pitaniya v mire – 2023. Urbanizaciya, preobrazovanie agroprodovol'stvennyh sistem i zdorovyj racion pitaniya v sel'sko-gorodskom kontinuume. Rim, FAO. https://doi.org/10.4060/cc3017ru

Andronova, I.V., 2022. Ekonomicheskaya bezopasnost' stran EAES. / Aktual'nye problemy evrazijskoj integracii. Materialy mezhdunarodnoj nauchno-prakticheskoj konferencii «Evrazijskie integracionnye proekty: vyzovy i perspektivy» (Moskva, 15.10.2021). Institut diaspory i integracii (Institut stran SNG). 264 str.

Glazyev, S.Y., 2020. On the Strategic Directions of the EEU Development. EURASIAN INTEGRATION: economics, law, politics.(1):11-30.

Talerchik, S.M., Zajcev, A.A., SHavanov, M.V., 2021. Obespechenie ekonomicheskoj bezopasnosti v kontekste ustojchivogo innovacionnogo razvitiya agropromyshlennogo kompleksa v regionah Rossii. Fundamental'nye issledovaniya. № 2. S. 57-65.

Sustainable Development Goals in the Russian Federation, 2019. Short stat.sat.Rosstat , 39 p. https://rosstat.gov.ru/storage/mediabank/SDG_in_Russia_2019_rus.pdf

Voluntary national review of Russia's achievement of sustainable development, 2021. https://infogram.com/sdg-yearbook-2021-1hxr4zx9v8q7q6y?live

Egorenko, S.N., 2022. Sustainable Development Goals in the Russian Federation. Moscow: Rosstat, 2022.

Sustainable Development Goals in the Russian Federation, 2020. Short stat.sat.Rosstat, 79 p. https://rosstat.gov.ru/storage/mediabank/ERqpLbXV/%D0%A6%D0%B5%D0%BB%D0%B8%20%D1%83%D1%81%D1%82%D0%BE%D0%B9%D1%87%D0%B8%D0%B2%D0%BE%D0%B3%D0%BE%20%D1%80%D0%B0%D0%B7%D0%B2%D0%B8%D1%82%D0%B8%D1%8F%20%D0%B2%20%D0%A0%D0%BE%D1%81%D1%81%D0%B8%D0%B9%D1%81%D0%BA%D0%BE%D0%B9%20%D0%A4%D0%B5%D0%B4%D0%B5%D1%80%D0%B0%D1%86%D0%B8%D0%B8,%202020%20-%20%D1%81%D0%B1%D0%BE%D1%80%D0%BD%D0%B8%D0%BA.pdf

Selection of Efficient Product for Sludge Disposal Based on the Pairwise Comparison Method

Filippova Farida M.[a], Averianova Iuliia A.[b]
Department of Environmental Engineering and Occupational Safety,Kazan State Power Engineering University, Kazan, Russia
filippovafer@yandex.ru, bgdkgeu@yandex.ru

Keywords: wastewater, efficient product, sludge, sewage treatment, waste water treatment, fuel briquettes, biogas

Abstract: In the light of increasing global consumption, there has been an increase in the amount of waste generated, but the issues of recycling and recycling remain under-reported. In this situation, it is necessary to actively seek effective approaches to waste management. The work presents a comparative analysis of modern methods of wastewater sludge utilization, considers the use of one of the methods of pair comparisons for choosing the most effective product of waste treatment. More specifically, the algorithm used is considered in the context of the selection of the optimal treatment of sludge from wastewater according to the main criteria, and an example of the application of this method to the problem is given. The study revealed that fuel briquettes, within the accepted criteria, are an economically profitable product.

1 INTRODUCTION

The urgency of the work is due to the aggravation of the environmental situation in the world and the strict requirements imposed on industrial enterprises that use biological treatment of water in their composition. In world practice about 95% of wastewater is treated biologically (Nikolaeva, Iskhakova, 2021). The main, most effective stage of the process of cleaning household sewage is biological cleaning in aerotenics (Stepanov, Strelkov, Shvetsov, Morozova, 2017). More than 2.3 bln m3 of wastewater is annually treated at modern aeration plants, forming more than 11 million m3 of precipitation (Patrakova, 2017). In this case, an excess amount of sludge (active sludge) is formed, which is stored in the deposit areas, with further adverse effects on the environment and human (Burenkov, Grachev, Zabelkin, 2016).

One of the most acute is the issue of efficient disposal of excess sludge industrial and household waste with a humidity of no more than 80%. The modern landfill is a complex system equipped to prevent contact with the environment, which makes it difficult to decompose the waste and it poses a serious environmental threat (Klinkov, A. S., Belyaev, P. S., Odnolko, Sokolov, Makeev, Shashkov, 2015).

In the absence of oxygen, the organic waste is subjected to anaerobic fermentation, resulting in the formation of combustible gas. A very toxic liquid (leachate) is also formed in the interior of the landfill, the entry of which into water bodies or groundwater is extremely undesirable (Nikolaeva, Iskhakova, 2021).

Silt sludge from cleaning city sewage contains pathogenic microflora, parasitic agents, pathogenic viruses, intestinal sticks and Koch sticks, as well as smelling substances. All this threatens the penetration into soil, ground and surface waters of toxic organic compounds and heavy metal compounds, pathogenic microflora and helminth eggs (Burenkov, Grachev, Zabelkin, 2016).

So, obviously, That sludge storage should be recognized as not an effective way of waste management and there is an urgent need to develop new technical methods and means of preparing deposit sites for the effective management of sludge.

The aim of the work is to substantiate the efficiency of the disposal of sludge sewage by processing it into fuel briquettes.

[a] https://orcid.org/0000-0003-3138-7212
[b] https://orcid.org/0009-0000-4552-4228

2 RESEARCH MATERIALS AND METHODS

The urgency of the work is due to the aggravation of the environmental situation in the world and the strict requirements imposed on industrial enterprises that use biological treatment of water in their composition. In world practice about 95% of wastewater is treated biologically (Nikolaeva, Iskhakova, 2021).. The main, most effective stage of the process of cleaning household sewage is biological cleaning in aerotenics (Stepanov, Strelkov, Shvetsov, Morozova, 2017). More than 2.3 bln m3 of wastewater is annually treated at modern aeration plants, forming more than 11 million m3 of precipitation (Patrakova, 2017). In this case, an excess amount of sludge (active sludge) is formed, which is stored in the deposit areas, with further adverse effects on the environment and human (Burenkov, Grachev, Zabelkin, 2016).

One of the most acute is the issue of efficient disposal of excess sludge industrial and household waste with a humidity of no more than 80%. The modern landfill is a complex system equipped to prevent contact with the environment, which makes it difficult to decompose the waste and it poses a serious environmental threat (Klinkov, Belyaev, Odnolko, Sokolov, Makeev, Shashkov, 2015).

In the absence of oxygen, the organic waste is subjected to anaerobic fermentation, resulting in the formation of combustible gas. A very toxic liquid (leachate) is also formed in the interior of the landfill, the entry of which into water bodies or groundwater is extremely undesirable (Nikolaeva, Iskhakova, 2021).

Silt sludge from cleaning city sewage contains pathogenic microflora, parasitic agents, pathogenic viruses, intestinal sticks and Koch sticks, as well as smelling substances. All this threatens the penetration into soil, ground and surface waters of toxic organic compounds and heavy metal compounds, pathogenic microflora and helminth eggs (Burenkov, Grachev, Zabelkin, 2016).

So, obviously, That sludge storage should be recognized as not an effective way of waste management and there is an urgent need to develop new technical methods and means of preparing deposit sites for the effective management of sludge.

The aim of the work is to substantiate the efficiency of the disposal of sludge sewage by processing it into fuel briquettes.

3 RESULTS OF THE RESEARCH

At present, the main method of sludge disposal is its storage and insulation at deposit stands (Burenkov, Grachev, Zabelkin, 2016). In order to increase the efficiency of the use of landfill volumes available for storage, direct incineration is used.

However, direct incineration of waste is also economically unsustainable, as in this case the actual destruction of the material and energy potential possessed by sludge (Lovtsova, Pidenko, 2023). As a result, the state loses huge funds of the so-called «lost economic profit» from non-use of these wastes and spends money on elimination of consequences of environmental pollution.

Therefore, as part of the study, the term «recycling» was not meant to isolate the sediment from the outside environment or its destruction (for example, by burning), but processing with the production of valuable, marketable products.

In order to ensure the consistency of the approach, a classification of methods of sludge utilization based on its properties and the resulting products (fig. 1) has been developed.

Sludge of municipal wastewater is rich in the basic elements of organic, total nitrogen, phosphorus and potassium, as well as trace elements - S, Cu, Zn, Mn, therefore it can be the raw material for obtaining highly effective, complex organominary fertilizer. And the presence of a large volume of organic substances in the precipitate implies its use as energy raw material .

Thus, it is clear that sewage sludge, if properly treated, is not a hazardous waste but a valuable raw material.

From this diagram (fig. 1), it can be seen that the existing solutions can be divided into two large groups: products to improve the fertile or other properties of the soil (or to create an artificial soil layer where it is needed) and energy carriers.

To ensure the reliability of the choice of the most effective product of disposal, we consider in more detail the methods presented in the classification.

The first direction - by heat treatment (also in combination with pressure and chemical reagents) pre-dried (up to 85-90% humidity) sludge.

Another well-developed approach is sludge treatment using mainly chemical reagents (often flocculants or coagulants), which in some cases are secondary products of other waste treatment.

A third approach is the use of biological effects on sediments (e.g., the use of micro-organisms to treat active silt mixed with waste).

The application of residue recovery techniques with the production of humic substances or organominary compositions could help to solve the problem of transferring sediment from toxic waste to a safe product intended for land reclamation, urban use, road construction and organominary fertilizer production, but the heavy metal salt content in the initial sludge significantly limits their use.

In addition to the production of humic substances, the methods of soil improvement also include backfill materials, which are also called technogrunts. The production process of technogenic fortified (GRP) soils is based on the formation of mechanically resistant structures (also called blocks), with specified strength characteristics.

To ensure the environmental safety of the finished product, hazardous components (heavy metal salts and others) contained in the sludge are bound into stable compounds. This approach also blocks the natural fermentation of the sediment with the release of combustible gas.

The main method for preparing GUTs from sediments is to mix pre-dried sediments with binders such as liquid glass and inorganic acid. The units produced from the mixture shall be rigid after a certain time.

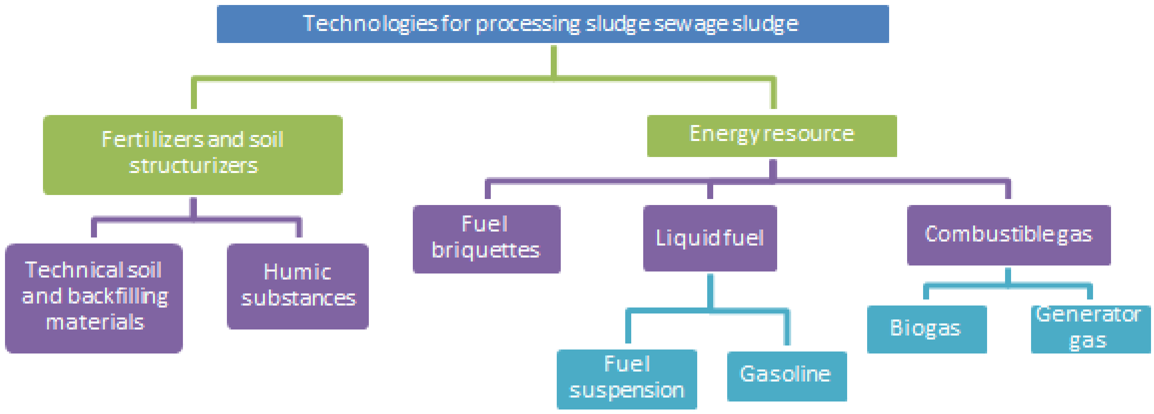


Figure 1: Classification of sludge disposal methods.

The resulting product may be disposed of, deposited, or used in the future not only in the above applications of humic substances, but also for the production of backfill and insulation materials, and for the recovery of solid domestic waste (SDW) landfills.

The disadvantages of these methods include discretionary and limited consumption (only during the period of new construction or landscape recultivation of territories), as well as a lack of study of the processes of aging technogrunt, its change over time, Migration processes of hazardous substances related in the State Customs Inspectorate as a result of long-term environmental impact.

When considering energy carriers, we will identify two main directions in this group of methods. The first involves grinding, completely drying the sludge (up to 10% humidity) and subsequent pelletizing (forming) of fuel briquettes. The second direction is partial drying of the original sediment (up to ~60%-80%), mixing and grinding with some SDW species and subsequent pelletizing (formation) of fuel briquettes.

The advantage of the second approach is that there is less energy loss associated with thermal sludge drying or that there is no need to apply large amounts of flocculants to mechanical sludge drying. The addition of SDW and some energy additives reduces the moisture and calorific content of the fuel.

Finished briquettes may contain pulp-containing materials, powder crumbs, clean wood sawdust, tobacco dust, grain husks, traces of straw, peat, coal waste and others as energy additives.

The disadvantages of the second approach are the inclusion of a waste sorting line and the additional cost of energy additives (coal dust, heating oil and others).

In both cases, the final step is compression in the form of fuel cells (briquettes or granulates) at a specific pressure between 30.0 and 40.0 MPa.

These methods allow to solve the issues of ecology, saving of natural resources, utilization of sludge and to obtain fuel materials that can be used in homes, boiler houses, thermal power plants, railway wagon furnaces.

In addition to the use of sludge for the production of solid fuel, it is necessary to consider its use as a raw material for producing energy carriers in the liquid and gaseous state.

Both fuel sludge and gasoline are produced from sewage sludge. There are generally two ways to obtain fuel suspension from sludge. In the first case, the suspension is made directly from the sludge, without pre-drying, by mixing it with additional energy additives. The resultant mixture is heated to 90°C and homogenized in a mixing agent, a rotary pulsation apparatus, a colloid mill or a disintegrator.

The advantage of this approach is the monostage and relative simplicity of the process. The disadvantage is energy consumption and the need for external energy additives to increase the calorific value of the working fuel.

The second approach involves the production of a fuel slurry based on a pre-extracted combustible gas sludge. This process is carried out under low temperature pyrolysis. Because pyrolysis takes place at a low temperature, the risk of toxic heavy metal salts evaporating is eliminated. The main output product is a fuel slurry. All other products are either secondary (hot air) or by-products (semi-coke).

The disadvantages of this approach include the multi-stage and complexity of the technological process, which entails an increase in capital and labour costs.

The method for producing gasoline from silt sludge consists of two stages: the first is the production of synthesis gas from silt sludge and natural or associated petroleum gas, and the second is the conversion of the resultant synthesis gas into petrol with octane number 80-92. Experimental plants can process raw materials with a humidity of 80%. Capacity on silt - about 180-200 thousand t/year.

The main advantage of the technology could be the demand for the output product, however, due to the significant amount of antidote and octane-enhancing additives, the resulting product is undesirable for use in modern internal combustion engines (ICE).

The disadvantages of this technology include the high cost of gasoline (almost double the cost of oil), the need to apply anti-detoponic and octane-boosting additives (up to 70% of the base amount of gasoline) and the complexity of the technology.

Thus, this method of disposal is recommended for use in hard-to-reach regions and in the operation of obsolete equipment.

In order to produce biogas, the sludge is placed in a tank isolated from the external environment (completely sealed), then, when exposed to methane-binding bacteria, a biological process begins, at which a combustible gas is formed.

To date, more than 50 different biogas technologies are known. The most common method is anaerobic fermentation in methants.

The advantages of this group of methods include refinement and relative simplicity (the basic principle of operation has long been known).

The drawbacks are the complexity of technical implementation in the conditions of landfills of deposited silt sediments, the need to track the optimal composition of raw material and temperature (these parameters have the most significant impact on the productivity of the line);

The generator gas generation method is universal and can be used for both initial sludge and briquettes. For the gasification of sediments (or briquettes), a straight-line or vortex gas generator is loaded into the hopper. The technology is based on pyrolysis - thermal decomposition under conditions of oxygen deficiency. As a result, the main combustible constituents of the CO and H_2 generator gas are formed.

The use of generator gas in the internal combustion engine (ICE) is similar to the use of natural gas, including the concentration of harmful emissions, which meet the norms of «Euro-5». Table 1 contains experimental tests of the ICE operation on generator gas.

Table 1: Toxic substances contained in the exhaust of internal combustion engines running on generator gas.

Substance	Actual, mg/m^3	Norms «Euro-5», mg/m^3
CO	34-41	50
NOx	64-93	200
SOx	25-32	50
HCl	5-9	25
HF	0,73-0,9	1
Dioxins, dibenzofurans according to DE	0,015-0,02	0,1
dust	7-9	10

Sludge or briquette gasification ash refers to wastes in classes 4 and 5, i.e. is a low-risk waste and potentially can be used as a binder in road construction.

Because it is difficult and expensive to transport gas to the final consumer (road transport is expensive and there are no gas pipelines from the deposit sites), this method of sludge disposal will not be feasible in most cases.

In order to make an informed choice of the most effective method of sludge disposal, it is necessary to consider several competing solutions: there is a problem of their comparison, which is solved by the method of pair comparison (MPC).

The method consists of comparing several sludge recovery products (call them a1a2...an; n is the number of estimated products) in pairs. For each pair, it is necessary to determine which product from this pair is preferable within the criteria considered.

The resulting data (0 and 1) are summarized in a square matrix. The number of rows and columns that equals the number of objects to consider. The elements of the matrix are obtained as follows: at the intersection of the i-th row of the j-ro column of such a matrix, the j-product is 1 if the j-th is preferable to the i-th product and is 0 if, on the contrary, the i-th product is preferable to the j-i. Let's call it a matrix of pair comparisons.

The first step was to collect data on paired comparisons of all products (table 2).

The obtained information is then combined into matrices of paired comparisons (table 3).

According to the results of the first two stages the final matrix is built (table 4).

Table 2: Data on the preference of products within the selected criteria.

	Liquid fuel	Briquettes	Gas	Briquettes	Gasoline	Briquettes
Transportation	0	1	0	1	0	1
Keeping	0	1	0	1	0	1
Sales	0	1	0	1	0	1
Exploitation	0	1	1	0	0	1

	Liquid fuel	Gasoline	Liquid fuel	Gas
Transportation	1	0	1	0
Keeping	1	0	1	0
Sales	1	0	1	0
Exploitation	1	0	0	1

	Gas	Gasoline
Transportation	0	1
Keeping	0	1
Sales	0	1
Exploitation	1	0

Table 3: Matrices of paired comparisons.

Transportation				
	Briquettes	Liquid fuel	Gas	Gasoline
Briquettes	×	0	0	0
Liquid fuel	1	×	0	0
Gas	1	1	×	1
Gasoline	1	1	0	×
Keeping				
	Briquettes	Liquid fuel	Gas	Gasoline
Briquettes	×	0	0	0
Liquid fuel	1	×	0	0
Gas	1	1	×	1
Gasoline	1	1	0	×
Sales				
	Briquettes	Liquid fuel	Gas	Gasoline
Briquettes	×	0	0	0
Liquid fuel	1	×	0	0
Gas	1	1	×	1
Gasoline	1	1	0	×
Exploitation				
	Briquettes	Liquid fuel	Gas	Gasoline
Briquettes	×	0	1	0
Liquid fuel	1	×	1	0
Gas	0	0	×	0

Gasoline	1	1	1	×

Table 4: Summary matrix.

	Briquettes	Liquid fuel	Gas	Gasoline
Transportation	3	2	0	
Keeping	3	2	0	1
Sales	3	2	0	1
Exploitation	2	1	3	0
Total	11	7	3	3

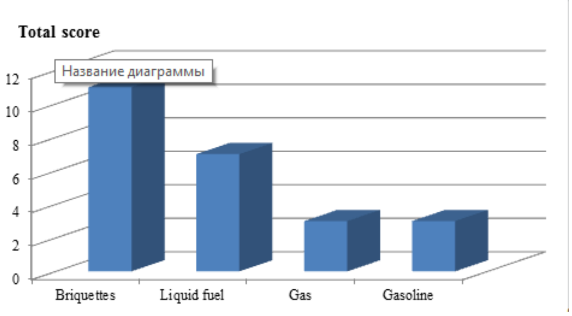


Figure 2: The results of comparing different products.

The results of the comparison are presented in fig. 2, we interpret them for each of the criteria:

- Transportation - the most inconvenient product for transportation is combustible gas, due to the fact that separate gas pipelines are not built to the landfills, and transport by road implies the presence of compressor stations and other special equipment, including for fire safety. Gasoline under this criterion is inferior to fuel suspension because of the high fire risk, which must be compensated with special equipment and a high degree of control of the loading and unloading and transport operations performed. Fuel briquettes do not require special transport trucks, which means, among other things, the possibility of transporting briquettes from the firing range to deliver consumables to the firing range;

- Storage - the most convenient to store are fuel briquettes, they require specially equipped premises for this purpose, for storage of fuel slurry will need sealed storage tanks. Such receptacles will be needed to organize the storage of petrol, only more complex, given the explosion, stored in them product. And the most difficult thing is to equip a gas storage area, gas holders, compressors for denser gas packaging, leak control equipment and more;

- Fuel briquettes are the most attractive potential market - a relatively large number of large consumers (boilers and solid fuel boilers) can be exported. Fuel slurry also has a large potential sales volume among industrial enterprises.

Sludge-based gas consumers are gas users who are not connected to a centralized gas supply line (due to the lack of pipelines at deposit stands, gas is actually delivered either in packaged form or in tankers for small gas filling stations). Sludge-based gasoline contains a large number of antidepressant and octane-enhancing additives, which does not allow its use in modern ICE. As a result, marketing is limited to consumers using obsolete equipment;

- Use - the most convenient to use is combustible gas (there is no need to change the equipment installed by consumers and working at the present time on natural gas). Fuel briquettes are worse than most of their analogues due to their relatively high ash content. During use, -12% of ash belonging to hazard class 4-5 (low-hazard) is formed, which must be disposed of.

The consequences of using fuel suspension and sediment-based gasoline have not been sufficiently studied. There is a possibility that when using these types of fuels, the contamination (or wear) of the nozzles of boilers (suspension) and carburettors of internal combustion engines (gasoline) will increase in comparison with the use of traditional fuels.

Thus, the most effective product, within the accepted criteria, are fuel briquettes. We believe that technical solutions for the disposal of sludge at landfills should be based on this product.

4 CONCLUSIONS

The classification of methods and means of utilization of sludge into fuel and organomineral products developed within the framework of the study is based on the physico-chemical properties of sludge and allows us to systematize the methods known to date in a visual form.

Based on these studies, a system of criteria combined with the method of paired comparisons allowed us to scientifically substantiate the choice of the most effective sludge disposal product - fuel briquettes.

REFERENCES

Nikolaeva, L. A., Iskhakova, R. Ya., 2021. Biological treatment of wastewater from petrochemical and energy enterprises. Kazan, 2021.

ITS 8-2015. Wastewater treatment during the production of products (goods), performance of work and provision of services at large enterprises. Moscow, 2015.

Stepanov, S. V., Strelkov, A. K., Shvetsov, V. N., Morozova, K. M., 2017. Biological treatment of wastewater from oil refineries. Moscow. Publishing House of the Association of Construction Universities, 2017.

Patrakova, G. R., 2017. Industrial ecology of energy facilities and industrial safety. Nizhnekamsk: Nizhnekamsk, Institute of Chemical Technology – Federal State Budgetary Educational Institution of Higher Education “Kazan Research Technological University”, 2017.

Burenkov, S.V., Grachev, A.N., Zabelkin, S.A., 2016. Thermal utilization of sewage sludge by fast pyrolysis in a grid reactor. Bulletin of the Technological University, 2016, vol. 19, no. 22, pp. 40-43.

Klinkov, A. S., Belyaev, P. S., Odnolko, V. G., Sokolov, M. V., Makeev, P. V., Shashkov, I. V., 2015. Recycling and processing of solid household waste.Tambov. Publishing house of the Federal State Budgetary Educational Institution of Higher Professional Education "TSTU", 2015.

Proceedings of the 54th International Students Scientific Conference. Biology. Novosibirsk State University. Novosibirsk, Russian Federation. 2016. 172 pp.

Lovtsova, L. G., Pidenko, S. A., 2023. Complex organomineral fertilizers and meliorants – a new eco-friendly approach to phosphogypsum utilization. Izvestiya of Saratov University. Chemistry. Biology. Ecology, 2023, vol. 23, iss. 2, pp. 166–174.

Modern methods of sludge treatment. https://nauchniestati.ru/spravka/obrabotka-osadka-stochnyh-vod/.April 26, 2024.

Technogenic soils. https://fireman.club/inseklodepia/texnogennye-grunty/ April 26, 2024.

The National Index of Sustainable Noospheric Development

Ekaterina Shamaeva[a], Andrei Golovin[b]
Center for Sustainable Development of Civil Society Institutions, State University of Management, Ryazansky Prospekt, Moscow, Russia
ef_shamaeva@guu.ru, aa_golovin@guu.ru

Keywords: Sustainable Noospheric Development, Non-subjective Evaluation Criteria, Temporal Approach, Composite Development Index, Green Economy, Environmental Compliance, Demographic Development, Creativity of Space, Labour Potential.

Abstract: The article presents a new model for regional sustainable development assessment, the composite Index of Sustainable Noospheric Development. It describes the principle of constructing the index, its uniqueness, and advantages compared to other criteria and evaluation methods. The index is calculated by accounting 5 sub-indices which reflect the level of region's economy greening, creativity of space, environmental compliance, the demographic development, the use of labour and time potential of the population. Analysis based on this index showed that regions that maintain environmental sustainability are more competitive in the long term than regions focused on economic development. During the analysis process, a rating was formed that divides regions into clusters of leaders and outsiders using Russia as an example. The results of the analysis indicate the need to address the balance of environmental, social and economic processes in the group of outsider regions. As important advantages of the index, it is worth noting the temporal approach, the launch of a trend towards preserving nature and the capabilities of the biosphere, tracking the consumption of resources in proportion to their production, and reflecting the values of the population.

1 INTRODUCTION

The National Index of Sustainable Noospheric Development (hereinafter referred to as the Index) presents a new model for assessing the sustainability of regional development. It represents a complex approach towards the analysis of balancing environmental, social, demographic, economic, energy, labour indicators, as well as to the use of time budget by the population (Golovin, 2020; Shamaeva, 2023).

It is built on the basis of 5 subindices which reflect the level of region's economy greening, the efficiency of scientific and educational sector, the growth of anthropogenic pressure, the demographic development, the use of labour and time potential of the population (Shamaeva, 2023). It allows us to see the key constraints and competitive advantages for transition to the management of the regional sustainable development model.

The **uniqueness** of the Index:

It is based on the methodology of the domestic scientific school of sustainable development (V.I. Vernadsky, N.N. Moiseev, P.G. Kuznetsov, etc.). The index is a sovereign measurement tool and an alternative for the UN indices (correction factor) in the sustainable development field;

It allows to evaluate the regional imbalance of environmental, social and economic aspects between the interests of business, the population, and government bodies;

It identifies clusters of regions according to the degree of proximity to the regional model of sustainable development of a noosphere-oriented type;

It forecasts changes taking into account the interests of future generations;

It helps to maintain a balance of interactions between man and nature as a guarantee of a high quality of life.

[a] https://orcid.org/0000-0002-1070-8550
[b] https://orcid.org/0000-0003-3976-6540

2 WHY IS THERE A NEED FOR A NEW INDEX?

The Index offers a new perspective on measuring balanced regional development. In terms of development, there are usually two approaches. The first one deals solely with economic indicators, dismissing social and environmental aspects (Alferova, 2021; Korshunov, 2023; Kurganov, 2021; Shaikin & Omirzhan, 2023; Timofeev et al. 2020). The second one is on the contrary concerned only with the environmental component (DuBose et al. 2023) and analyses separate regions (Kern, 2011; Ozkan & Schott, 2013). Furthermore, economic indicators are measured in monetary terms (GRP per capita, income level, etc.).

However, cost indicators are volatile, loosely connected with real life processes, and do not reflect the objective dynamics of changes in various areas, including the connection between natural and social processes (Shamaeva, 2023). This ultimately leads to incorrect assessments and beget crises. A new physical and economic approach is required to develop non-subjective criteria for assessing development (Golovin, 2020; Shamaeva, 2023; Stiglitz et al., 2016).

For example, today statistics provide thousands of different indicators. The problem is to select the optimal set of indicators that characterize regional development most objectively. This is a navigation system that includes the requirements of a balance between the needs and capabilities of society, the economy and the natural environment. Each sub-index in the general rating of noospheric development has a scientific basis and allows not only to carry out a current assessment, but also to project long-term development over time.

The National Index of Noospheric Development provides the means to show the degree of balance between the economic, social and environmental aspects of regional development.

3 THE INDEX CALCULATION METHODOLOGY

The National Index is built on the basis of 5 subindices which reflect the level of region's economy greening, creativity of space, environmental compliance, the demographic development, the use of labour and time potential of the population (fig. 1).

The economic greening index takes into account the average rate of reduction in the energy intensity of regional GRP. It is clear that the production of goods and services is impossible without expending energy. Therefore, the energy efficiency of the economy is improved by reducing energy intensity. This makes it possible to talk about the level of transition to a regenerative economy, including the areas of "green" and circular economy.

The Environmental Compliance Index takes into account the average rate of reduction in anthropogenic pressure on the natural environment. The index is connected with waste generation, wastewater discharge, and air pollution. It should be noted that here that the basis of this index is not the "clean up after yourself" principle, but the principle of absence (reduction) of waste, emissions, discharges, the principle "nature has no waste."

The vitality index is based on the median age of the region's population, average life expectancy and birth rate. The index shows the level of life preservation and development, demographic vitality.

The Creative Society Index characterizes the scientific and educational potential of the region. It is related to the level of investment of the region's budget in the development of education and science.

The constructive society Index is associated with the possibility of creative development and self-realization of the population. This opportunity is determined by the presence or absence of free time among citizens and the degree of realization of labour potential.

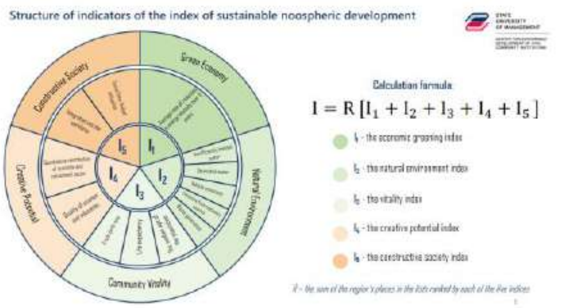


Figure 1: Structure of indicators of the index of sustainable noospheric development.

4 CALCULATION RESULTS AND ANALYSIS OF REGIONAL RATING

Using available national statistics data (Shamaeva et al., 2023), the rating of regions for 2019-2021 was calculated. The calculation of the rating revealed the subjects with the greatest potential for forming balanced connections between the needs of the economy, society and nature (Fig. 2).

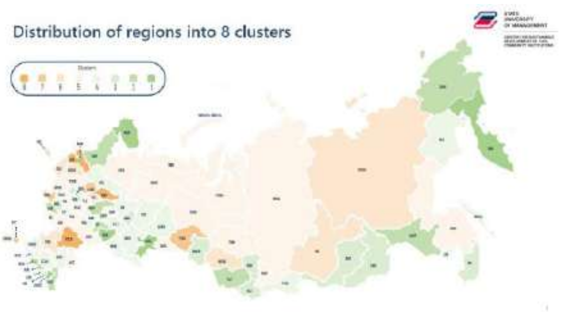


Figure 2: Distribution of regions into clusters based on the results of calculating the index of sustainable noospheric development (using the example of Russian regions).

The conducted analysis has shown that the regions with high demographic indicators which were able to preserve environmental sustainability are beginning to overtake the regions which have high economic indicators but dismiss environmental and demographic issues. Therefore, in the index, the cluster of leading regions for 2021 includes, in addition to the self-sufficient Sverdlovsk region, St. Petersburg, Nizhny Novgorod region, such regions as the Chechen Republic, Karachay-Cherkess Republic, Kamchatka Territory, Amur Region, etc., while such regions as Leningrad region, Volgograd region, Yaroslavl region, Rostov region, etc. in the overall ranking were in the group of outsider regions. That is, despite the fact that according to a number of indicators these subjects of Russia may be in the middle, in integral terms, due to the comparability of data, they ended up at the bottom of the list. This indicates the need to focus on the balance of environmental, social and economic processes in these regions (Fig. 3).

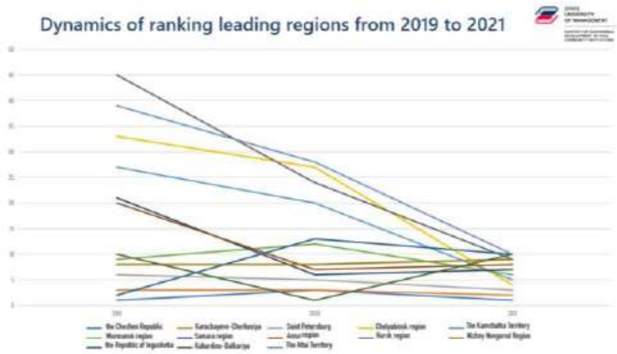


Figure 3: Dynamics of ranking leading regions from 2019 to 2021.

5 THE DISCUSSION OF THE RESULTS

The National Index of Sustainable Noospheric Development demonstrates that economic development can not be considered as the sole factor in improving the quality of life of the population. To form a new model of regional development, a request is being made for an ecologically clean environment, opportunities for self-realization for children and youth, and a creative space for harmonious social relations.

The Index comprises a number of features: the use of temporal approach, that is, taking into account the speed of economic, environmental and social processes in addition to the absolute values of indicators; setting trends in preserving nature and the capabilities of the biosphere; tracking resource consumption in proportion to their production according to the principle of the UN sustainable development goals "to live by meeting present needs without compromising the chances of future generations to meet their needs"; reflection of the population's values enshrined in Decree of the President of the Russian Federation of November 9, 2022 No. 809 "On approval of the Fundamentals of State Policy for the Preservation and Strengthening of Traditional Russian Spiritual and Moral Values."

REFERENCES

Alferova, T., 2021. Sustainable development of the region: approaches to selecting evaluation indicators. In *Bulletin of Perm University. Ser. "Economy". No. 15(4).*

DuBose, T., Himes Boor, G., Fields, M., Kalies, E., Castillo, A., Moskwik, M., Marcus, J., Walters, J.

2023. Remotely sensed habitat quality index reliably predicts an umbrella species presence but not demographic performance: A case study with open pine forests and red-cockaded woodpeckers In *Ecological Indicators, Volume 154.* Retrieved from https://www.sciencedirect.com/science/article/pii/S1470160X23006222

Golovin, A., 2020. Modeling the development of complex systems using power parameters and social time budget. In *Sustainable innovative development: design and management. T. 16. No. 2 (47).*

Kern K. 2011. Governance for sustainable development in the Baltic Sea Region. In *Journal of Baltic Studies. Special Issue: Transnational Governance and Policy-Making in the Baltic Sea Region.*

Korshunov, I., 2023. Sustainable development in regional strategies: approaches and solutions. In *Economy of the region. T. 19. No. 1.*

Kurganov, M., 2021. A mechanism for managing regional sustainable development based on value-driven approach. In *Bulletin of PNIPU. Socio-economic sciences. 1*.

Ozkan, U., Schott S., 2013. Sustainable Development and Capabilities for the Polar Region. In *Social Indicators Research. 114(3)*.

Shaikin D., Omirzhan S. 2023. The role of the AIC in the sustainable regional development: economic assessment. In *Problems of AgriMarket. № 1.*

Shamaeva, E., 2023. Methodological aspects of constructing an ecological-socio-economic model for assessing the dynamics of regional development. In *Bulletin of the Russian Academy of Natural Sciences.T. 23. No. 3.*

Shamaeva, E., Golovin, A., Perevozchikova, A., Popov, E., Golubkov, A., Shadrov, K., Batkaeva, I., Reshetnikova, V. 2023. Energy and environmental indicators. Database registration certificate No. 2023620545 dated 02/13/2023. Application No. 2023620216 dated 02/03/2023. In *Situation center for modeling sustainable socio-economic and spatial development.*

Stiglitz, J., Sen, A., Fitoussi, J-P., 2016. *Mis-measuring Our Lives. Why GDP Doesn't Add Up. The report by the Commission on the Measurement of Economic Performance and Social Progress*, Publishing House of the Institute Gaidar. Moscow.

Timofeev, R., Yachmenev, E., Timaev, R., 2020. Components of sustainable development of the regional socio-economic system. In *Scientific Bulletin: Finance, banks, investments. No. 2.*

Prospects of Growing the Fast-Growing Energy Crop Pavlovnia in Russia in the Context of Sustainable Development and Closed-Cycle Economy

Nikonorova P.P. [1], Kim A.A. [2], Volkov A.R. [3], Igumnov M.A. [4]
ITMO University, St. Petersburg, Russia
p.nikonorowa@yandex.ru, kim-anastasia@bk.ru, volkovra@yahoo.com, sim4ikgood@mail.ru

Keywords: Pavlovnia tree variety, climate agenda, sustainable development, carbon farms, carbon sequestration, sustainable production, circular economy.

Abstract: Climate agenda, sustainable development and circular economy have multiple interconnections. The key areas of transformation of various economic sectors such as energy, construction and industrial sectors are the reduction of greenhouse gas emissions into the atmosphere, as well as minimization of negative environmental impact. In this paper we analyzed the existing problems in the timber industry of the Russian Federation, which limit its development, studied the characteristics of the fast-growing tree variety "Pavlovnia", thanks to which it is possible to obtain high-quality wood in a short time, evaluated the prospect of growing Pavlovnia in Russia as a multipurpose renewable resource, and proposed the use of Pavlovnia as the main species for carbon farming, carbon dioxide capture and carbon offsetting, as well as the use of carbon dioxide sequestration and carbon sequestration.

1 INTRODUCTION

The UN predicts that the world population will reach 8.5 billion by 2030, 9.7 billion by 2050 and 10.4 billion by 2100. To maintain an optimal standard of living for this number of people it will require a volume of resources that can be produced by a total of 3 planet Earths. These resources include not only essential resources such as food, but also energy and building materials, which are the raw materials for many factories and industries. In addition to the energy and production sectors, the concept of sustainable development and decarbonization policies have also affected the construction sector. More and more innovative building materials that can be called sustainable are appearing on the market. These include materials made from recycled plastic or other waste materials, green concrete used after demolition of old buildings. But in addition to new materials, one of the traditional, yet sustainable and renewable resources is still wood.

In 2022, wood processing and production of wood products in Russia decreased by 10% YoY, while logging reached its lowest level in the last 9 years, down 13% YoY to 194.6 million m^3. At the end of 9 months of 2023, timber production decreased by 6% y/y to 2022. At the same time, there is a growing demand for timber and various timber products; at the state level, there is a tendency to increase the share of timber industry in the country's GDP by increasing the production of cellulose, paper and cardboard products, sawn timber and furniture, which, accordingly, generates the problem of a shortage of quality raw materials and an increase in their cost.

Thus, we can conclude that in the next decade Russia needs to develop and implement effective mechanisms for reforestation and cultivation of fast-growing woody crops in order to provide sawn timber for the construction and manufacturing sector, while taking into account sustainability requirements in the context of the climate agenda.

[1] https://orcid.org/0009-0002-5058-3091
[2] https://orcid.org/0009-0007-7493-1755
[3] https://orcid.org/0000-0002-1671-6236
[4] https://orcid.org/0009-0000-3733-8062

2 MAIN PART

The geographical location of the Russian Federation has a number of advantages for growing timber for various needs, but there are no effective mechanisms for sustainable forest reproduction in already developed areas, which leads to the fact that the availability of raw materials is decreasing, which means that the costs of forest development are increasing, respectively, the price of quality wood and wood products is also increasing. And if under favorable market conditions it is possible to solve this problem through supplies from remote corners of our country, then under unfavorable conditions such wood for many industries will be economically inaccessible due to the high cost of its transportation, which will lead to a shortage of raw materials and as a consequence either to a shortage of wood products, or to a decrease in their quality, or to a strong increase in prices for these products.

In addition, we can identify several other problems in the timber industry complex of Russia, which limit its development:

1. An extensive model of forest development, which consists of cutting down wild forests, rather than planting and further cutting down forests specifically for production purposes, as is already being done in countries where there is a state-level moratorium on cutting down wild forests;

2. The world's lowest rate of timber removal per 1 hectare of area, despite the large number of areas occupied by forests;

3. Low profitability, as there is a high volume of waste and a low level of recycling;

4. Low efficiency of reforestation. Effective reforestation in already developed areas is absent or partially applied. Often the process of reforestation is recognized as unprofitable, as the costs can be recouped only after 40-60 years (provided that coniferous tree species are used for reforestation);

5. A large number of forest fires, as well as an inefficient system of forest inventory, which results in a high level of illegal logging, lead to Russia losing up to 500,000 hectares of forest annually;

6. Deficit of accessible forest areas with valuable timber species. The problem is solved by sourcing them from remote areas, which leads to high prices for such tree species, as well as increased transportation costs for companies;

7.The forest industry is not attractive for investors due to the long turnover of funds, and state support cannot cover all companies in the industry, which leads to slow modernization of existing production facilities and few openings of new ones. In addition, advanced equipment and spare parts are often purchased abroad, which leads to high costs;

8. Russian products are inferior to foreign products in some parameters, as in our country in this sector of the economy there is physical and moral deterioration of the main equipment, which leads to an increase in resource and energy intensity of production, as well as to a decrease in quality and, consequently, greater lagging behind the quality standards approved abroad.

According to Roslesinforg, a total of 38.9 million m^3 of sawn timber was produced in Russia in 2023, of which 20.7 million m^3 was exported. In the geography of foreign shipments, Asian markets, in particular China, Uzbekistan and Kazakhstan, accounted for a 98% share. At the same time, the key sawn timber products were planks and beams made of coniferous trees such as pine, spruce and larch used for construction purposes.

In 2023, the Siberian Federal District accounted for 44.7% or 9.2 million m^3 of sawn timber exports. The Northwestern Federal District ranked second with 5.3 million m^3, the Far Eastern Federal District with 2.8 million m^3, the Urals Federal District with 1.5 million m^3, and the Volga Federal District with 1.2 million m^3

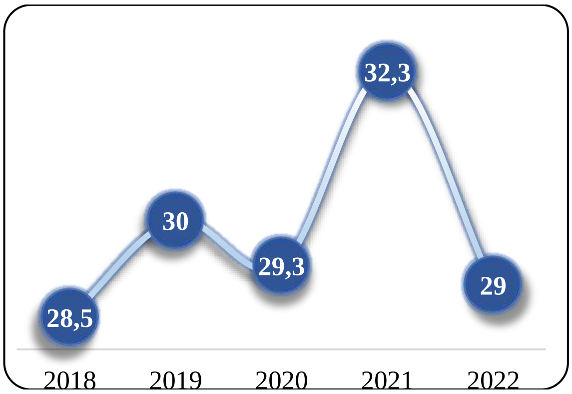


Figure 1: Dynamics of sawn timber production in Russia, mln. cu. m.

Among fast-growing crops in Russia, the most common today are black poplar and hybrid willow, characterized by annual growth of 2.5-3.5 m and 1.5-4 m, respectively. According to the data shown in Table 1 and Figure 3, the maximum height is characteristic of pine, a widespread tree crop in Russian forests, but the annual growth in the first years after planting, as well as in other conifers, is extremely low. It is known that the phase of active growth in conifers begins only 6-7 years after planting

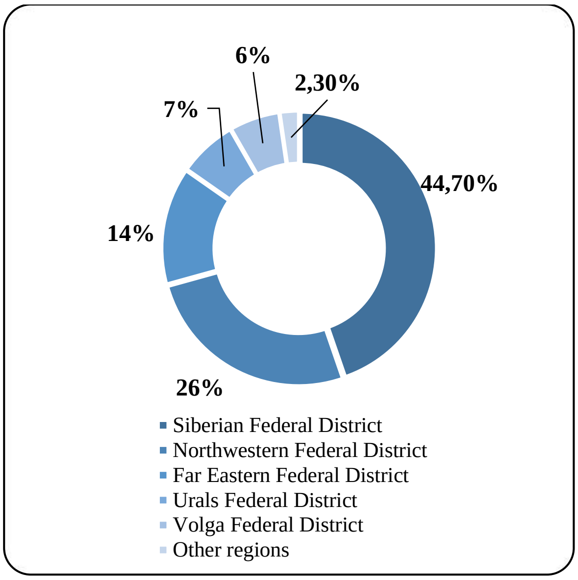


Figure 2: Share of sawn timber exports by constituent entities of the Russian Federation.

Table 1: Comparative table of increments and maximum height of tree crops.

Species	Annual growth in height	Height of three-year old tree	Maximum height of an adult tree
Paulownia	3-5 m	10,5-15,5 m	15-28 m
Hybrid willow	1,5-4 m	7,5-12 m	15-25 m
Black poplar	2,5-3,5 m	9-12 m	20-25 m
Larch	0,3-0,6 m	1-2 m	40-50 m
Pine	0,2-0,5 m	1-2 m	50-60 m
Spruce	0,2-0,4 m	0,6-1 m	40-50 m

Black poplar and hybrid Willow are also widely used as raw material for sawn timber and unlike conifers, they are characterized by higher growth rates in the first years. However, comparative analysis revealed that Pavlovnia shows higher performance in the context of annual growth and growth during the first three years, i.e. faster and more efficient biomass growth.

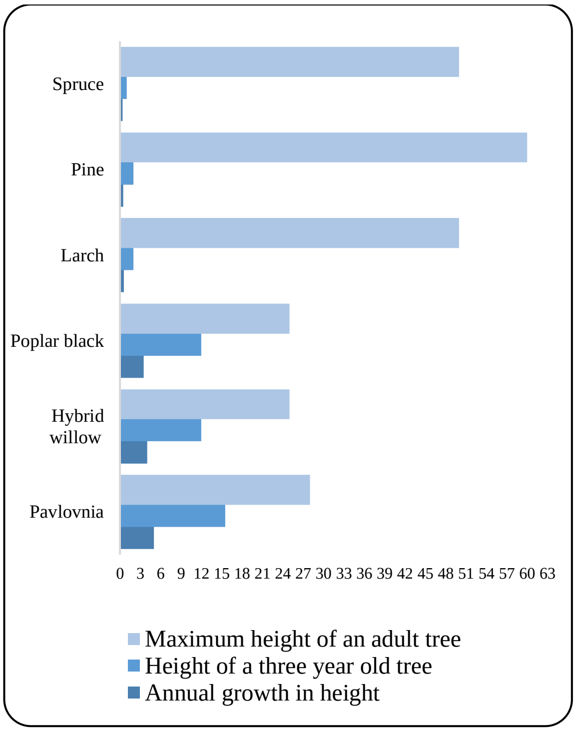


Figure 3: Comparative characteristics of different tree types.

The genus Paulownia (Paulownia) belongs to the family Paulowniaceae and is characterized by its unpretentiousness and high biomass yield. The growth rate is from 3 to 5 meters per year. All parts of the tree can be recycled and have economic value. Pavlovnia wood has low weight and density, so it is called aluminum wood, which does not rot, does not deform during drying, has high breaking strength, is easy to process, has high aesthetic characteristics, much the same as those of expensive and rare tropical species, wood such as balsa (Yavorov, 2015). Today, Pavlovnia wood is used to build yachts, produce furniture, musical instruments, snowboards, skis, window frames, doors, and finishing materials with a characteristic texture. The leaves of this tree can reach 70-80 cm in diameter and are characterized by high protein content and lack of bitterness, which makes them a valuable fodder resource for farm animals. All other parts of the tree can be processed into fuel pellets, which are a sustainable and renewable biofuel that can compete with traditional hydrocarbons. With a low concentration of sulphur, nitrogen and ash in its composition, Pavlovnia produces only half a kilogram of ash when burning 280 kilograms of wood, which corresponds to about 1 cubic meter, and 2 kilograms of pellets can be equivalent to 1 liter of diesel fuel.

The application area of Pavlovnia is quite wide, which increases the scalability of the business (Fig. 4).

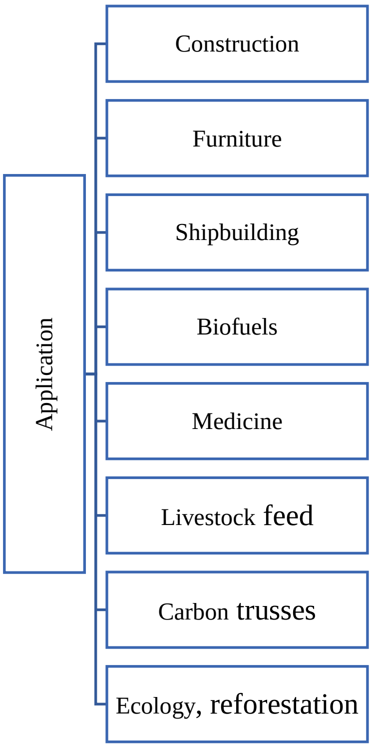


Figure 4: Applications of Pavlovnia.

In the context of the climate agenda and global decarbonization policies, Pavlovnia could be a promising crop for the formation of carbon farms, whose function is to absorb significant amounts of carbon dioxide. Pavlovnia leaves reach 70 centimeters in diameter and each tree can absorb 22 kilograms of carbon dioxide and produce 6 kilograms of oxygen. In addition, Pavlovnia can be used as an effective tool for phytoremediation, i.e. purification of soil and groundwater from a number of toxic elements such as mercury and arsenic.

Why will this product be relevant in the market? First of all, according to the strategy until 2030, wooden house building will be among the top 5 most popular areas. In addition, the Ministry of Industry and Trade has implemented a special social program to stimulate demand for wooden houses. The demand for board products and plywood is also forecast to increase.

In modern times, both ordinary people and enterprises try to pay great attention to environmental issues. It can be assumed that, according to this trend, packaging and bags made from wood products, biofuels made from wood pellets, as well as furniture and other household goods made from environmentally friendly wood will be especially relevant. The data in Table 2 confirms that at the state level the trend of increasing the production of wood products is being established, which means that it will be necessary to increase the production of quality wood.

Table 2: Dynamics of growth rates of production of types of timber industry products (forecast).

Type of FSC products	Average value for the period				
	2018	2019 - 2024	2025 - 2030	2031 - 2036	2036 to 2018
Unprocessed timber	1,9	1,1	1,0	0,9	20,0
Wood processing and wood products	5,1	2,4	1,4	1,4	35,9
Processed timber	4,3	2,4	2,0	1,8	28,3
Paper and paper products	6,8	3,6	3,8	3,8	93,9

Let's conduct a SWOT analysis to evaluate the strengths and weaknesses of the new product - Pavlovnia wood in the market.

Table 3: SWOT analysis of the fast growing trees project.

Strengths	***Weaknesses***
1. Better quality products, as a fast-growing tree is not subject to pests and rotting processes; 2. Regeneration of the tree, which reduces the cost of buying seedlings; 3. Short payback period compared to growing "classic trees"; 4. Creation of a replenishable natural resource; 5. Contributing to the changing economics of the country's timber industry;	1. Unknown product on the timber industry market, consumers will have to be educated, the product will have to be presented, which will be associated with high advertising and promotion costs; 2. Availability of an alternative product - wood and its derivatives from wild-growing trees, which is associated with difficulty in establishing relations with the main consumers and investors; 3. Logistics service, as mostly wood processing plants are often located in remote parts of our country; 4. Personnel problem - also related to the remoteness of production; 5. Risk of buying low-quality seedlings of fast-growing trees, as there are

	few seedling producers in Russia at the moment, as well as death of small trees due to climatic and other factors;
Opportunitie	***Threats***
1. Emergence of new markets for timber and its derivatives due to sanctions; 2. Foreign companies leaving the Russian timber market; 3. Development of technologies in bioengineering, which allows developing the market for biofuels from fast-growing trees;	1. The emergence of competitors using the same technology of fast-growing trees, as this niche in the market is not yet heavily occupied, which allows companies to freely enter the market and copy others' experience;

3 CONCLUSIONS

As a result of the analysis, the authors highlighted a number of unsolved problems in the timber processing industry:

1. Low timber removal from 1 hectare. This indicator is the lowest in the world, which makes the forest industry unattractive for investors, and logging in general inefficient;

2. Low efficiency of reforestation, which entails the problem of raw material shortage and high costs of forest development;

3. Low investment attractiveness of the timber industry due to the long turnover of funds, namely the growth period of trees, financial support is mainly provided only through government programs, which is reflected in the slow modernization of production and lagging behind in terms of technology.

However, at the state level the positive dynamics of the Russian LPC development is being laid down, namely the growth of the LPC share in the country's GDP, the growth of demand for sawn timber. The growing demand for wood products will stimulate modernization and expansion of existing production facilities, as well as the launch of new ones.

Pavlovnia is a promising energy fast growing tree crop carrying significant economic value. In the context of the global climate agenda, the rapid growth of the world's population, the energy crisis, the transition to a circular economy and the implementation of sustainable development strategies and concepts, major economic sectors are in the process of global transformation. Given the high carbon dioxide absorption capacity of Pavlovnia leaves, the crop can be considered as a high yielding species in the formation of carbon farms to offset the carbon footprint for organizations with an unmitigated carbon footprint, and its wood will be a quality base for the production of various wood products.

Having gained acceptance as a biofuel, the production of pellets from Pavlovnia, with its low cost and high energy efficiency, also carries high economic and social potential. As an additional, but possible, direction for economic benefits, large-scale plantations of Paulownia can be considered as a honey crop.

REFERENCES

Costea, M., 2021. Genus Paulownia: versatile woodspecies with multiple uses-a review. *Life Science and Sustainable Development.* T. 2. №. 1. C. 32-40.

Dżugan, M., 2021. Antioxidant activity, polyphenolic profiles and antibacterial properties of leaf extract of various Paulownia spp. clones. *Agronomy.* T. 11. №. 10. C. 2001.

Barbu, M. C., 2023. Lightweight Solid Wood Panels Made of Paulownia Plantation Wood. *Applied Sciences*. T. 13. №. 20. C. 11234.

Nelis, P. A., 2018. Kiri wood (Paulownia tomentosa): can it improve the performance of particleboards? *European journal of wood and wood products.* T. 76. C. 445-453.

Yavorov, N., 2015. Potential of fast growing poplar, willow and paulownia for bioenergy production. *Bulg. Chem. Commun.* T. 47. C. 5-9.

Shen, L., 2023. Densification of fast-growing paulownia wood for tough composites with stab resistance property.

Szabó, F. M., Juhász, L., 2023. Ecological value of wood energy plantations in the support of some animal groups. *Acta Agraria Debreceniensis.* №. 2. C. 143-148.

Sedlar, T., 2020. Physical properties of juvenile wood of two paulownia hybrids. *Drvna industrija.* T. 71. №. 2. C. 179-184.

Forecast of socio-economic development of the Russian Federation for 2024 and for the planning period of 2025 and 2026 years [Electronic resource] / Mode of access: https://www.economy.gov.ru/material/file/310e9066d0eb87e73dd0525ef6d4191e/prognoz_socialno_ekonomicheskogo_razvitiya_rf_2024-2026.pdf (date of address 19.03.2024).

Forecast of socio-economic development of the Russian Federation for the period up to 2036 [Electronic resource] / Mode of access: https://www.economy.gov.ru/material/file/a5f3add5deab665b344b47a8786dc902/prognoz2036.pdf (date of address 19.03.2024).

Strategy of development of the forest complex of the Russian Federation until 2030 [Electronic resource] / Mode of access:

cA4eYSe0MObgNpm5hSavTdIxID77KCTL.pdf
(yandex.ru) (date of access: 18.03.2024).

Assessing the Effectiveness of Government Measures for the Development of Small and Medium-Sized Enterprises in the Russian Federation in the Context of Foreign Economic Sanctions

Sergey Korobov[a], Irina Usacheva[b], Veronica Epinina[c] and Viktor Moseiko[d]
Volgograd State University, Volgograd, Russia
cint@volsu.ru, zeppelin89@volsu.ru, epininavs@volsu.ru, vikmos59@volsu.ru

Keywords: small and medium-sized entrepreneurship, foreign economic sanctions, government measures, entrepreneurship support program, entrepreneurship promotion.

Abstract: The aim of the study is the conceptual development of tools for assessing the effectiveness of government measures for the development of small and medium-sized enterprises in the context of foreign economic sanctions, based on the econometric analysis of the indicators of small and medium-sized enterprises (the number of small and medium-sized enterprises, the number of people employed in the field of entrepreneurship) and the allocated financial resources under federal and regional programs to support entrepreneurship («My Business», «Social Entrepreneurship»). The scientific proposal of the authors, used in this article, is to substantiate the importance in the conditions of foreign economic sanctions to expand the access of small and medium-sized businesses to financial resources. This is done through the priority implementation of state support programs for entrepreneurship. Based on the available statistical data, the authors proved that government initiatives to implement federal and regional programs to support entrepreneurship contribute to the increase in the number of small and medium-sized enterprises, which indicates their effectiveness.

1 INTRODUCTION

Small and medium-sized entrepreneurship plays an important role in the economy of any country, including the Russian Federation. It helps to create new jobs, increase tax revenues to the budget, and stimulate innovation.

As part of the state policy for the development of small and medium-sized enterprises in Russia, various support measures are being implemented. These include, for example, subsidies for business development, soft loans, tax preferences, training and counselling of entrepreneurs. However, in the current conditions of economic development of the Russian Federation, the issue of support and development of small and medium-sized entrepreneurship becomes particularly relevant. One of the key factors affecting the activities of entrepreneurs is foreign economic sanctions imposed on the country as a result of political conflicts.

Foreign researchers state the growing global interconnectedness of countries and assess the unfavorable consequences of sanctions that disrupt economic ties between countries and lead to significant welfare losses (e.g., Bagheri S., Akbarpour H.R., 2016; Felbermayr G., Morgan T.C., Syropoulosc C., Yotov Y.V., 2021). Economic sanctions are considered by foreign researchers as the use of economic instruments to achieve political goals by restricting trade and economic interaction between countries for political and military reasons (e.g., Chevalier M., 2023; Moteng G., Njangang H., Nvuh-Njoya Y., Ndeffo Nembot L., 2023). Researchers (Du X., Wang Z., 2022; Nguyen T.T., Do M.H., 2021) have identified the negative mechanisms underlying decisions to impose economic sanctions as foreign policy instruments, as well as the consequences of

[a] https://orcid.org/0000-0003-1899-4237
[b] https://orcid.org/0000-0002-5554-254X
[c] https://orcid.org/0000-0002-8771-3198
[d] https://orcid.org/0000-0001-5217-2363

these decisions on the world economy.

Indeed, under the conditions of sanctions, the effectiveness of implemented government measures for the development of small and medium-sized enterprises is limited. Sanctions lead to deterioration of the foreign economic situation, which, in turn, affects the turnover of small and medium-sized enterprises. Many entrepreneurs as a result of sanctions find themselves in a difficult financial situation and cannot function effectively.

According to the studies of Russian scientists (Aliev O.M., Ibragimova D.M., 2022; Bezugly E.A., Tkachenko V.V., Mikhailikov V.L., 2022; Ivanov O.B., Buchwald E.M., 2022; Levkina N.N., 2022; Sedrakyan, G.S. 2022), the implementation of a set of economic sanctions against the Russian Federation in early 2022 negatively affected the activities of most entrepreneurs, especially small and medium-sized enterprises, many of which are engaged in retail trade. Researchers suggest that mitigating the effects of anti-Russian sanctions will be helped by promoting the growth of domestic production and supporting businesses through government initiatives.

Critical analysis of published research on this issue shows that entrepreneurs face a number of reasons that hinder the use of state support measures in the context of economic sanctions. The main factors identified by researchers (Antyushin M.V., Guskova I.V., Serebrovskaya N.E., 2022; Kolchugina A.V., 2022; Shipova E., 2023) are the lack of information about available support tools, lack of confidence in government programs, insufficient financial assistance and doubts about the effectiveness of economic policy. Other authors (Ermolov N.S., 2022; Gurash S.V., 2022; Nguyen T.T., Do M.H., 2021) also note problems in understanding support programs, the lengthy process of preparing the necessary documents, difficulties in reporting after receiving assistance, strict checks on the targeted use of funds, and the sharing of negative experiences among entrepreneurs.

2 MATERIALS AND METHODS

The study is based on a unique database on the amount of funding for each region from 2019 to 2022 under federal and regional programs to support entrepreneurship («My Business — Self-Employed», «Social Entrepreneurship», «My Business – Involvement», «Export Support Centers», «Monocities», «Industrial Parks», «Guarantee Funds», «Microfinance Institutions», «Popularization of Entrepreneurship», etc.). The differentiation of the number of small and medium-sized enterprises by regions of Russia was assessed by means of descriptive statistics indicators and taken into account in the calculations by including dummy variables in the regression equations. To quantify the impact of state support measures on the development of small and medium-sized enterprises, we used generally recognized econometric models: linear, hyperbolic, step and exponential. Each of the equations was estimated in the study by the method of least squares using the program «STATISTICA». Also, each of the regressions obtained was evaluated by correlation index, mean relative error, coefficient of determination and Fisher's F-criterion. All parameters of regression equations were tested by Student's t-test and p-value.

3 RESULTS AND DISCUSSION

To assess the effectiveness of government measures for the development of small and medium-sized entrepreneurship in the context of foreign economic sanctions, we will conduct an econometric analysis based on the indicators of small and medium-sized entrepreneurship (the number of small and medium-sized enterprises and the number of people employed in entrepreneurship) and the financial resources allocated under federal and regional programs to support entrepreneurship («My Business», «Social Entrepreneurship», «Export Support Centers», «Mono-entrepreneurship»).

The data on the distribution of small and medium-sized enterprises in the constituent entities of the Russian Federation were used as the initial statistical population. The number of subjects is 85.

In order to analyze the effectiveness of state programs to support entrepreneurship in the conditions of foreign economic sanctions, conducted in 2019, let us consider the number of small and medium-sized businesses (including newly created entities) in 2020 as a resultant attribute. Let us carry out descriptive statistics of this initial statistical population. The results are presented in Table 1.

Table 1: Indicators of descriptive statistics on number of small and medium-sized enterprises in the Russian Federation for 2020.

Indicators	Result
minimum	1 390
maximum	748 354
variation range	746 964
mean	69 611
geometric mean	40036,63636

median	42 544
dispersion	9 850 535 885,73
skewness	4,447942465
skewness error	0,259541265
excess	24,72610003
excess error	0,486855425
n	85
standard deviation	99249,86592

Source: compiled by the authors.

The minimum value was 1,390 units in Chukotka Autonomous region, which is associated with the smallest population in this subject. The maximum value was 748,354 units in Moscow and 359,777 units in St. Petersburg. The range of variation is 746,964 units, which indicates an uneven distribution of small and medium-sized enterprises among the regions of the Russian Federation. Asymmetry characterizes the degree of asymmetry of the distribution relative to its average and is 4.45. As >0, i.e., $\bar{x}$>Mo, hence the skewness of the series is right-sided. The error of asymmetry is 0.26 < 3, hence asymmetry is insignificant, and its presence is explained by the influence of random factors. The kurtosis is 24.7, which is greater than 0 and characterizes the relative sharpness of the distribution in comparison with the normal distribution. The excess error is 0.48, the value < 2, therefore the distribution can be considered normal.

To quantitatively assess the effectiveness of state programs to support entrepreneurship in the context of foreign economic sanctions in 2019, we will conduct an econometric analysis based on the indicators of small and medium-sized entrepreneurship activity in 2020 (the number of small and medium-sized enterprises and the number of people employed in entrepreneurship). The allocated financial resources under federal and regional programs to support entrepreneurship («My Business – Self-Employed», «Social Entrepreneurship»). One subject – Moscow — was excluded from the analysis, as there is no funding for this subject.

The volumes of financial resources under federal and regional programs of entrepreneurship support were used as factor attributes:

X1 – volume of implementation of the program to support small and medium-sized businesses, as well as individuals applying a special tax regime “Tax on professional income” for their accelerated development in single-industry towns;

X2 – the volume of implementation of the program to ensure access of small and medium-sized businesses to export support;

X3 – volume of implementation of the federal project «Popularization of Entrepreneurship»;

X4 – volume of implementation of the program of special tax regime «Tax on professional income» in the centers «My Business»;

X5 – volume of implementation of the program of the state (municipal) microfinance organization;

X6 – volume of implementation of the program of regional guarantee organizations;

X7 – volume of implementation of the program «Acceleration of small and medium-sized enterprises».

Let us calculate the correlation coefficients (closeness of connection) between Y and factor attributes using the «STATISTICA» program (see Table 2).

Table 2: Indicators of correlation between Y and factor traits.

	Y	X1	X2	X3	X4	X5	X6
Y	1,00						
X1	0,01	1,00					
X2	0,16	0,38	1,00				
X3	0,50	0,22	0,69	1,00			
X4	0,36	0,25	0,75	**0,93**	1,00		
X5	0,07	0,29	0,20	0,05	0,12	1,00	
X6	0,13	0,07	0,22	0,33	0,42	0,44	1,00
X7	0,08	0,38	0,45	0,35	0,41	0,08	0,12

Source: compiled by the authors.

According to the results of correlation analysis, multicollinearity between factors X3 and X4 is observed. Since the factor X4 is more strongly correlated with other factor attributes, it is necessary to exclude it from further econometric analysis. Let us evaluate the indicators when excluding factor X4 (see Table 3).

Table 3: Correlation indices between Y and factor traits without factor X4.

	Y	X1	X2	X3	X5	X6
Y	1,00					
X1	0,07	1,00				
X2	**0,52**	0,37	1,00			
X3	**0,90**	0,21	0,69	1,00		
X5	0,02	0,28	0,19	0,04	1,00	
X6	0,26	0,07	0,22	0,33	0,44	1,00
X7	0,27	0,37	0,44	0,34	0,07	0,11

Source: compiled by the authors.

According to the results of the second correlation analysis, we can conclude that there is no multicollinearity between the factor variables. Let us assess the closeness of the relationship between the resultant and factor characteristics: the greatest impact on the number of small and medium-sized enterprises is exerted by the programs of the federal project «Popularization of Entrepreneurship» (X3) and providing access to export support (X2), while the programs of special tax regime (X1) and «Acceleration of small and medium-sized enterprises» (X7) have an insignificant impact.

To quantify the impact of the volume of financing under foreign economic sanctions of state programs on the number of small and medium-sized enterprises in the Russian Federation, we consider the following multiple regression models:

- linear;
- stepwise;
- exponential;
- hyperbolic.

Each model will be evaluated according to the indicators:

- correlation index;
- mean relative error;
- coefficient of determination;
- Fisher's F-criterion;
- parameters by Student's t-criterion and p-value.

The results of the linear model are presented in Table 4.

Table 4: Results of the linear regression model.

Indicators	Free component	X1	X2	X3	X5	X6	X7
Coefficients	57976,96	-0,10	-1,72	7,67	-0,02	-0,05	-0,01
Standard error	23021,54	0,27	0,75	1,43	0,13	0,18	0,06
t-statistic	2,52	-0,38	-2,27	5,36	-0,17	-0,25	-0,15
P-value	0,01	0,70	0,03	0,00	0,87	0,80	0,88
Multiple R	0,561						
R-square	0,315						
F-criterion	5,99						
Standard error	85704,602						

Source: compiled by the authors.

The correlation between the resultant and the selected factors is significant according to the F-criterion. The coefficient of determination shows that the share of variation of the dependent variable is due to the variation of the explanatory variables by 31.5%. The free term, X1, X5, X6 and X7 are insignificant by t-criterion and p-value.

The results of linear and nonlinear models modelling are presented in the summary Table 5.

Table 5: Summary of modelling results.

Model	R	R-squared	F
Linear	0,56	0,31	5,99
Hyperbolic	0,47	0,22	3,83
Indicative	0,67	0,55	16,45
Stepped	0,75	0,56	51,41

Source: compiled by the authors.

According to the results of modelling, we can conclude that the degree model best describes the relationship between the resultant and factor attributes. However, the correlation and determination indices show a significant influence of unaccounted factors, which are associated with the uneven distribution of the initial resultant attribute. In this regard, it is necessary to identify clusters by small and medium-sized enterprises of the initial statistical population. We can distinguish 3 groups of regions with different numbers of small and medium-sized enterprises according to the Y indicator: 1 cluster 0-100000; 2 cluster 100000-200000; 3 cluster more than 200 000.

Let us introduce dummy variables for 1 and 3 clusters of the distribution of Russian regions by the number of small and medium-sized enterprises. Let us consider ANCOVA – a model that will contain both quantitative and qualitative variables. Let us introduce 2 dummy variables: Z1 (=1 for subjects of cluster 1, 0 –otherwise). Z2 (=1 for subjects of cluster 3, 0 – otherwise).

Thus, the model with initial quantitative (factor) signs and dummy variables will have the following form:

$$\hat{y} = a + \sum_{i=1}^{n} bixi + g_1 z_1 + g_2 z_2 + e$$

where y is the number of small and medium-sized enterprises in the i-th constituent entity of the Russian Federation, xi is the amount of funding for small and medium-sized entrepreneurship support programs, zi – is dummy variables.

Then private regression equations for individual clusters are formed:

-for regions of cluster 2:

$\hat{y} = a + \sum_{i=1}^{n} bixi\ (z_1 = z_2 = 0);$

-for regions of cluster 1:

$\hat{y} = (a + g_1) + \sum_{i=1}^{n} bixi\ (z_1 = 1, z_2 = 0);$

-for regions of cluster 3:

$\hat{y} = (a + g_2) + \sum_{i=1}^{n} bixi\ (z_1 = 1, z_2 = 1).$

The basic value of the qualitative variable is the value

«2 clusters», g_1, g_2 are differential free terms.

Let us consider two types of models: linear and steppe models. The programs of implementation of the federal project «Popularization of Entrepreneurship» (X3) and access to export support (X2) are selected as factor attributes.

The results of the linear model with dummy variables are presented in Table 6.

Table 6: Results of linear regression model with dummy variables.

Indicators	X2	X3	Z1	Z2
Coefficients	0,21	4,96	-495,15	49935,89
Standard error	0,18	0,69	293,65	14805,38
t-statistic	2,45	7,13	2,76	3,37
P-value	0,02	0,00	0,01	0,00
Multiple R	0,93			
R-square	0,87			
F-criterion	144,33			
Standard error	32378,97			

Source: compiled by the authors.

The results of the modelling illustrate the increase in the quality of the model after the introduction of dummy variables that take into account the unevenness of the resultant sign. The correlation coefficient increased to 0.93. The coefficient of determination shows that the share of variation of the dependent variable is due to the variation of the explanatory variables by 87%. The model is significant by Fisher's F-criterion (calculated value is higher than the tabulated value at 95% probability level), also all parameters are significant by Student's t-criterion and p-value.

The obtained linear multiple regression model:

$$\hat{y} = 0{,}21x_2 + 4{,}96x_3 - 495z_1 + 49936z_2 + e$$

It can be concluded that an increase in the financing of small and medium-sized enterprises under the program to provide access to export support by 1 thousand rubles will lead to an increase in the number of small and medium-sized enterprises by 0.21 units. An increase in the financing of small and medium-sized enterprises under the program for the implementation of the federal project «Popularization of Entrepreneurship» will lead to an increase in the number of small and medium-sized enterprises by 4.96 units. At the same time, the number of small and medium-sized enterprises of the 1st cluster is 495 units lower than the number of small and medium-sized enterprises of the 2nd cluster. The number of small and medium-sized enterprises of the 3rd cluster is on average 49,336 units higher than the number of small and medium-sized enterprises of the 2nd cluster.

To assess the elasticity of the influence of factor characteristics on the resultant one, we construct a step model with dummy variables (see Table 7).

Table 7: Results of a stepwise regression model with dummy variables.

Indicators	X2	X3	Z1	Z2
Coefficients	0,29	0,94	-523	46784
Standard error	0,11	0,09	236,43	15060,6
t-statistic	2,45	10,75	3,1	4,21
P-value	0,002	0,00	0,01	0,00
Multiple R	0,99			
R-square	0,99			
F-criterion	6503,31			
Standard error	0,455			

Source: compiled by the authors.

The simulation results illustrate the better quality of the steppe model compared to the linear model. The correlation coefficient increased to 0.99. The coefficient of determination shows that the share of variation of the dependent variable is due to the variation of the explanatory variables by 99%. The model is significant by Fisher's F-criterion (calculated value is higher than the tabulated value at 95% probability level), also all parameters are significant by Student's t-criterion and p-value.

The obtained stepped multiple regression model:

$$\hat{y} = {x_2}^{0,29} + {x_3}^{0,94} - 523z_1 + 46784z_2 + e$$

It can be concluded that an increase in the financing of small and medium-sized enterprises under the program to provide access to export support by 1% will lead to an increase in the number of small and medium-sized enterprises by 0.29%. An increase in the financing of small and medium-sized enterprises under the program to implement the federal project «Popularization of Entrepreneurship» by 1% will lead to an increase in the number of small and medium-sized enterprises by 0.29% to 0.94%. At the same time, the number of small and medium-sized enterprises of the 1st cluster is on average 523 units lower than the number of small and medium-sized enterprises of the 2nd cluster. And the number of small and medium-sized enterprises of the 3rd cluster is, on average, 46784 units higher than the number of small and medium-sized enterprises of the 2nd cluster.

Further, to analyze the effectiveness of state programs to support entrepreneurship under foreign economic sanctions, conducted in 2021, let us consider the number of small and medium-sized enterprises (including newly created entities) in 2022 as a resultant attribute. Let us conduct descriptive statistics of the initial data of the resultant attribute for

2022. The results are presented in Table 8.

Table 8: Indicators of descriptive statistics on the number of small and medium-sized enterprises in the Russian Federation for 2022.

Indicators	Result
minimum	1453
maximum	389450
variation range	387997
average	41235.5
geometric mean	38017.20
median	41235.5
dispersion	4617441070
skewness	2.93
skewness error	0.27
excess	6.66
excess error	0.54
n	85

Source: compiled by the authors.

The minimum value was 1,453 units in Chukotka Autonomous region, which is 63 units higher than the figure for 2019. The maximum value is 389,450 units in Moscow, which is almost 2 times less than the 2019 quantity and 354,201 units in St. Petersburg. The variation spread is 387,997 units, which indicates an uneven distribution of small and medium-sized enterprises among the regions of the Russian Federation. Asymmetry is 2.93, which is > 0, hence the skewness of the series is right-sided. The error of asymmetry is 0.27 < 3, hence asymmetry is insignificant, and its presence is explained by the influence of random factors. The kurtosis is 6.66, which is greater than 0 and characterizes the relative sharpness of the distribution in comparison with the normal distribution. The excess error is 0.54, the value < 2, hence the distribution can be considered normal. In general, the distribution is characterized by less variability compared to 2019, which is associated with a sharp reduction in the maximum values, i.e., the largest number of small and medium-sized enterprises in the constituent entities of the Russian Federation.

In 2021, an additional measure to support small and medium-sized enterprises was introduced in the form of the «Social Entrepreneurship» program. Let us introduce the following indicators of the volume of funding of programs for 2021 as factor attributes:

X1 – the volume of implementation of the program to support small and medium-sized businesses, as well as individuals applying a special tax regime «Professional Income Tax" for their accelerated development in single-industry towns;

X2 – the volume of implementation of the program to ensure access of small and medium-sized businesses to export support;

X3 – volume of implementation of the federal project «Popularization of Entrepreneurship»;

X4 – volume of implementation of the program of special tax regime «Tax on professional income», in the centers «My Business»;

X5 – volume of implementation of the program of the state (municipal) microfinance organization;

X6 – volume of implementation of the program of regional guarantee organizations;

X7 – volume of implementation of the program «Acceleration of small and medium-sized enterprises»;

X8 – volume of implementation of the program «Social Entrepreneurship».

Let's calculate the correlation coefficients (closeness of connection) between Y and factor attributes (see Table 9).

Table 9: Correlation indices between Y for 2022 and factor attributes for 2021.

	Y	X1	X2	X3	X4	X5	X6
Y	1,00						
X1	0,08	1,00					
X2	0,49	0,38	1,00				
X3	0,81	0,20	0,68	1,00			
X4	0,79	0,24	0,77	**0,91**	1,00		
X5	0,67	0,29	0,72	0,79	**0,84**	1,00	
X6	0,26	0,07	0,27	0,31	0,42	0,32	1,00
X7	0,35	0,06	0,45	0,42	0,49	0,47	0,18
X8	0,40	0,16	0,32	0,47	0,41	0,39	0,08

Source: compiled by the authors.

According to the results of correlation analysis, multicollinearity between programs X3, X5 and X4 is observed. Since the factor X4 is more strongly correlated with other factor attributes, it is necessary to exclude it from further econometric analysis. Let us evaluate the indicators when excluding the factor X4 (see Table 10).

Table 10: Correlation indices between Y and factor traits without factor X4.

	Y	X1	X2	X3	X5	X6	X7
Y	1						
X1	0,08	1,00					
X2	0,49	0,38	1,00				
X3	0,81	0,20	0,68	1,00			
X5	0,67	0,29	0,72	0,76	1,00		
X6	0,26	0,07	0,27	0,31	0,32	1,00	
X7	0,35	0,06	0,45	0,42	0,47	0,18	1,00
X8	0,40	0,16	0,32	0,47	0,39	0,08	0,21

Source: compiled by the authors.

According to the results of the second correlation analysis, we can conclude that there is no multicollinearity between the factor attributes, but there is a fairly high correlation between the programs X2, X3 and X5. The greatest influence on the number of small and medium-sized enterprises in 2022 is exerted by the programs of the federal project «Popularization of Entrepreneurship» (X3) and state (municipal) microfinance organization (X5), while the programs «Professional Income Tax» (X1) and programs of regional guarantee organizations (X6) have an insignificant influence.

To quantify the impact of the volume of financing of state programs in 2021 on the number of small and medium-sized enterprises in the Russian Federation in 2022, multiple regression models were built: linear, steppe, exponential and hyperbolic. The results of modelling of linear and nonlinear models are presented in the summary Table 11.

Table 11: Summary of modelling results.

Model	R	R- squared	F
Linear	0,88	0,77	52,08
Hyperbolic	0,81	0,65	9,33
Indicative	0,71	0,50	23,39
Stepped	0,32	0,10	77

Source: compiled by the authors.

According to the results of modelling, we can conclude that the step model also best describes the relationship between the resultant and factor attributes. However, the determination indices show the influence of unaccounted factors, which are associated with the uneven distribution of the initial resultant attribute. In this regard, clusters of small and medium-sized enterprises of the initial statistical population by the indicator Y were identified: 1 cluster 0-50000; 2 cluster 50000-100000; 3 cluster includes values over 100 000.

We introduced dummy variables: Z1 (=1 for subjects of cluster 1, 0 — otherwise). Z2 (=1 for subjects of cluster 3, 0 -otherwise) and built ANCOVA — a model that contains both quantitative and qualitative variables. X2, X3, X7 and X8 are selected as quantitative factors that have the greatest influence on the resultant attribute.

A linear multiple regression model with dummy variables:

$$\hat{y} = 0{,}12x_2 + 7{,}47x_3 + 0{,}09x_7 + 0{,}11x_8 - 3368z_1 + 72696z_2 + e$$

The correlation coefficient was 0.91. The coefficient of determination shows that the share of variation of the dependent variable is due to the variation of the explanatory variables by 83%. The model is significant by Fisher's F-criterion (calculated value is higher than the tabulated value at 95% probability level), also all parameters are significant by Student's t-criterion and p-value.

It can be concluded that the impact of the program of financing small and medium-sized enterprises to provide access to export support decreased and the impact of the program of the federal project «Popularization of Entrepreneurship» increased. So at increase in volume of financing under the program X3 on 1 thousand roubles will lead to growth of quantity of subjects of small and average business on the average of 7,47 units. At the same time, programs X7 and X8 also became significant, but with a smaller share of impact.

To assess the elasticity of the influence of factor characteristics on the resultant one, a stepwise multiple regression model was constructed:

$$\hat{y} = 8{,}965{x_2}^{0{,}435} + {x_3}^{0{,}99} + {x_7}^{0{,}156} + {x_8}^{0{,}245} + e$$

The correlation coefficient was 0.91. The coefficient of determination shows that the share of variation of the dependent variable is due to the variation of the explanatory variables by 83%. The model is significant according to Fisher's F-criterion (the calculated value is higher than the tabulated value at a probability level of 95%), and all parameters are also significant according to Student's t-criterion and p-value.

It can be concluded that an increase in funding for small and medium-sized enterprises under the program to provide access to export support by 1% will lead to an increase in the number of small and medium-sized enterprises by 0.42%. An increase in funding for small and medium-sized enterprises under the program to implement the federal project «Popularization of Entrepreneurship» by 1% will lead to an increase in the number of small and medium-sized enterprises by 0.42% to 0.99%. At the same time, a 1% increase in the amount of funding under the program «Acceleration of small and medium-sized enterprises» will lead to an increase in the number of small and medium-sized enterprises by 0.156%, and an increase in funding under the program «Social Entrepreneurship» by 0.245%.

4 CONCLUSIONS

Government measures to develop small and medium-sized enterprises play an important role in creating a favorable environment for entrepreneurship, stimulating innovation, improving competitiveness and promoting economic growth. However, in the context of foreign economic sanctions, these measures may face additional challenges and constraints, making it more difficult to support small and medium-sized enterprises.

Sanctions imposed by countries against other states have a serious impact on the economic development of the latter. Under the conditions of foreign economic sanctions imposed on the Russian Federation, the development of small and medium-sized enterprises as one of the key sectors of the economy is of particular importance.

The econometric analysis of the effectiveness of government measures (allocated financial resources under the federal and regional programs to support entrepreneurship «My Business», «Social Entrepreneurship», «Export Support Centers», «Monocities», «Microfinance Institutions», «Promotion of Entrepreneurship», etc.) for the development of small and medium-sized enterprises in the context of foreign economic sanctions in the dynamics from 2019 to 2022 showed that in 2020, the greatest impact on the number of small and medium-sized entrepreneurship entities was made by the programs of the federal project «Promotion of Entrepreneurship» and state (municipal) microfinance institutions. In 2022, the programs of the federal project «Popularization of Entrepreneurship» and state (municipal) microfinance organizations had the greatest impact on the number of small and medium-sized enterprises, while the programs «Professional Income Tax» and programs of regional guarantee organizations had an insignificant impact.

The data obtained as a result of the study correspond to the results previously obtained by the authors (Korobov S.A., Moseiko V.O., Korobova S.I., 2022; Korobov S.A., Epinina V.S., Usacheva I.V., Moseiko V.O., 2023) and confirm the importance in the conditions of foreign economic sanctions of expanding the access of small and medium-sized businesses to financial resources through the priority implementation of state support programs for entrepreneurship, primarily «Popularization of entrepreneurship».

ACKNOWLEDGEMENTS

The study was supported by the Russian Science Foundation grant No. 23-28-01145, https://rscf.ru/project/23-28-01145/

REFERENCES

Aliev, O.M., Ibragimova, D.M., 2022. Problems of the Russian economy in the context of sanctions and special operations. Economics and Entrepreneurship, 8, 129-136.

Antyushin, M.V., Guskova, I.V., Serebrovskaya, N.E., 2022. Factor analysis of the functioning of small businesses and their development prospects under sanctions. Entrepreneur's Guide, 15(2), 35-43.

Bagheri, S., Akbarpour, H.R., 2016. Reinvestigation of the West's Sanctions against Russia in the Crisis of Ukraine and Russia's Reaction. Procedia Economics and Finance, 36, 89-95.

Bezugly, E.A., Tkachenko, V.V., Mikhailikov, V.L., 2022. Measures of state support for Russian entrepreneurship under sanctions. State and municipal administration. Scientific notes, 3, 92-97.

Chevalier, M., 2023. International sanctions enacted against Russia as overriding mandatory rules – on which foot should international arbitrators stand? Journal of International Dispute Settlement.

Du, X., Wang, Z., 2022. Multinationals, global value chains, and the welfare impacts of economic sanctions. Economics Letters, 220, 110870.

Ermolov, N.S., 2022. Preferential lending to small and medium-sized businesses as a measure of financial support in the context of international sanctions. Banking Law, 3, 7-13.

Felbermayr, G., Morgan, T.C., Syropoulosc, C., Yotov, Y.V., 2021. Understanding economic sanctions: Interdisciplinary perspectives on theory and evidence. European Economic Review, 135, 103720.

Gurash, S.V., 2022. Institutional model for supporting Russian entrepreneurship under sanctions. Economics: yesterday, today, tomorrow, 12(5A), 39-45.

Ivanov, O.B., Buchwald, E.M., 2022. Sanctions and countermeasures in the Russian economy (regional aspect). Stage: economic theory, analysis, practice, 4, 7-27.

Kolchugina, A.V., 2022. Small and medium-sized businesses under sanctions. Scienceosphere, 9(2), 174-180.

Korobov, S.A., Epinina, V.S., Usacheva, I.V., Moseiko, V.O., 2023. Regional business management in the context of foreign economic sanctions: online survey methodology. E3S Web of Conferences 403, 08018.

Korobov, S.A., Moseiko, V.O., Korobova, S.I., 2022. State development of entrepreneurship in the Volgograd region in the context of external sanctions: a resource-based approach. Bulletin of Volgograd State University. Economy, 24(2), 111-122.

Levkina, N.N., 2022. The main problems of small businesses in the context of new sanctions against the Russian Federation. Research and development. Economy, 10(4), 47-52.

Moteng, G., Njangang, H., Nvuh-Njoya, Y., Ndeffo Nembot, L., 2023. International sanctions and economic complexity in developing countries. Revue d'Economie Politique, Vol.133, №3, 409-452.

Nguyen, T.T., Do, M.H., 2021. Impact of economic sanctions and counter-sanctions on the Russian Federation’s trade. Economic Analysis and Policy, 71, 267-278.
Sedrakyan, G.S., 2022. Ukraine war-induced sanctions against Russia: Consequences on transition economies. Journal of Policy Modeling, 44(5), 863-885.
Shipova, E., 2023. International organizations’ role in sanctions in Russia-Ukraine crisis: participants or observers? East European and Balkan Institute, T.47, №2, 163-191.

Digital Transformation of Education: Current Problems and Ways to Solve Them in Modern Conditions

Irina Ganicheva[1][a], Alexander Morozov[2][b] and Ol'ga Mihaleva[3][c]
[1]*Department of General and Practical Psychology, National Research State University of Nizhny Novgorod named after N. I. Lobachevsky, Arzamas branch, Karl Marx Street, Arzamas, Russia*
[2]*SIC-2, Research Institute of the Federal penitentiary service of Russia, Narvskaya street, Moscow, Russia*
[3]*Department of Foreign Languages of Professional Communication, Vladimir State University named after A. G. and N. G. Stoletov, Gorky Street, Vladimir, Russia*
ganicheva-irin@мail.ru, doc_morozov@mail.ru, denisovaolga@inbox.ru

Keywords: digital transformation, higher education, students, independent work, educational and professional motivation, digital educational technologies, participants in the educational process.

Abstract: The article discusses the current problems of psychological and pedagogical support of students in modern conditions of digital transformation of higher education. The necessity and importance of improving and introducing into the educational process various forms and methods of organizing and directing independent work, taking into account the shortcomings that exist today, is substantiated. Some priority areas of activity are highlighted and analyzed, which contribute to the development of skills in organizing independent work of students with a low level of educational and professional motivation. The data of an empirical study conducted on a sample of undergraduate students of the university are presented in order to identify the level of development of their motivation and analyze the main difficulties in organizing independent work at the university. Some effective ways of working with students are considered and proposed for implementation, taking into account the strengthening of the individual educational component of educational activities in modern conditions of the university.

1 INTRODUCTION

The problem of the comprehensive introduction of digital forms of education into the educational process is due to the need for a qualitative change in its structure and content, which implies significant differences in the main approaches to its organization and management in modern conditions of digital transformation of the education sector. Currently, there is a need to consider the use of digital educational technologies at the modern level, taking into account the situation in higher education.

In these conditions, the issue of applying an individual-personal approach to students becomes very difficult and ambiguous (Lopanova, 2003) due to insufficient direct live contact between participants in the educational process. Since the priorities of digital education are self-discipline, self-control, the ability to volitional regulation, as the main qualities contributing to the effective assimilation of knowledge, skills and abilities, it becomes necessary to provide and use various forms and methods of guiding students' independent work.

In this regard, there is a need to analyze the effectiveness of various forms and methods of teaching from the positions of teachers and students of the university, as well as to identify the problems faced by participants in the educational process in the context of the transformation of the educational space in the digital economy (Morozov, 2019).

2 RESEARCH METHODOLOGY

The essence and process of digital learning as a new educational practice, its main characteristics, the

[a] https://orcid.org/0000-0003-2116-5114
[b] https://orcid.org/0000-0003-0516-0356
[c] https://orcid.org/0000-0002-3917-891X

history of its origin and spread in different countries, are presented in numerous studies by scientists (Dzhemileva, 2010; Kuritsyna, 2016; Polat, et al., 2004; Pyannikov, 2011; Voznesenskaya, 2017, etc.).

The relevance of the identified problem It is also fixed in the interest of the scientific, pedagogical and psychological community in the issues of updating the national higher education, in attention to the processes of formation and development of digital literacy of specialists.

As is known, the primary concepts in relation to the concept of «digital educational environment» are the concepts of «educational environment» and «educational environment of the university», the study of which is devoted to the work of modern domestic authors: A. I. Artyukhina, B. N. Bodenko, V. I. Gorova, T. N. Gushchina, E. B. Laktionova, Y. S. Manuilova, N. M. Petrova, S. V. Tarasov and others.

In the context of digital transformation of education, methods of managing the educational process in the electronic information and educational environment of universities are being developed, which is the subject of the works of P. P. Dyachuk, R. Murphy, G. Hinton, L. Risotto, etc., as well as methods and approaches of digital monitoring, fixation and forecasting of student behavior: A. G. Bermus, I. G. Zakharova, V. A. Kudinov et al.

Over the past twenty years, significant global experience has been accumulated in the field of online learning and the development of e-learning courses and resources: T. Bates, D. Orr, A. Hicken, etc.

In the last decade, digital education has been actively developing, its mechanisms are being improved, and the electronic database is expanding, which contributes to the emergence of new teaching and learning opportunities (Gil', 2020; Gil', Morozov, 2019; Mironova, 2020; Robert, et al., 2022; Seliverstova, 2011; Mukhametzyanova, et al., 2020, etc.). However, digital learning has a number of significant drawbacks associated with the lack of subject-to-subject interaction between the teacher and students. Learning in the context of digital transformation of education is becoming quite algorithmized, reduced to the performance and verification of tasks.

In this regard, it becomes very difficult to fully apply a personality-oriented approach, due to the insufficient implementation of direct active contact between the teacher and the students. In fact, in many ways, the basis of the educational process, in the context of digital transformation, is the purposeful and controlled intensive independent work of the student (Kuritsyna, 2016).

At this stage of the development of this issue in science, various models and methods of building individual educational trajectories in learning environments and electronic educational systems have been developed: R. M. Asadullin, M. V. Litvinenko, T. V. Pogodaeva, K. L. Polupan and others.

In the context of intensive development of e-learning, approaches and methods of personalization of education are developing: D. Bouclei, B. Nilsson, J. Fischer, O. Aiken, etc.

Currently, digital content is an integral part of educational programs in most educational organizations in Russia. The analysis of the main normative documents regulating the educational process in higher education confirms the fact that special attention should be paid to creating optimal conditions for the functioning of the electronic information and educational environment at the university.

Federal Law No. 273-FZ «On Education in the Russian Federation» regulates the provision that «distance learning technologies are understood to be educational technologies implemented mainly using information and telecommunication networks with indirect (at a distance) interaction between students and teaching staff» (Federal Law No. 273-FZ).

Of course, the university should create conditions for the functioning of an electronic information and educational environment, which includes electronic information and educational resources, as well as a set of information and telecommunication technologies that ensure that students master educational programs in full, regardless of the location of the students.

Hence, it is clear how relevant the issue of using modern digital educational technologies in the higher education system and the formation of professional competencies of future specialists is. Obviously, and undoubtedly, in order to be in demand as a professional, it is necessary to be able to build and implement a system of self-realization actions when mastering academic disciplines using various forms, including distance learning – full or mixed (Bashkireva, et al., 2021; Yarullina, et al., 2023).

The main problem that arises when conducting training sessions in conditions of using digital forms of education is the development of individual and personal characteristics of each student; teamwork skills, interpersonal communication and decision-making; development of self-esteem and leadership qualities; increasing the level of educational and professional motivation.

In this regard, it is necessary to create a set of conditions (educational, psychological, organizational, logistical, etc.) to ensure an effective educational process. It is extremely important, in the context of digitalization of the education sector, to create an education system that would include a complex of organizational, telecommunication, pedagogical and scientific resources involved in the creation and practical implementation of educational programs using digital educational technologies. The basis of the educational process in the context of the digital transformation of education is purposeful and controlled intensive independent work.

At the same time, there is a direct link between changes in the organization of the educational process in modern conditions of digital transformation of higher education, which involves an increase in the proportion of independent work of students and planning various effective forms and methods of managing such work.

It is important to emphasize that learning is a systematic, teacher–led independent activity of a student, which becomes a priority and its organization becomes one of the main features of the implementation of various forms of education, including digital. In digital education, students move away from the usual learning system, since they study a significant part of the educational material independently, without a teacher. This requires them to be more independent and to organize their school (work) day clearly.

Thus, we must consider the organization of independent work of students in the information and educational environment not only as providing material and technical conditions, but also as creating psychological conditions for its effective implementation. The psychological component of the support (Morozov, 2016) of students' independent work includes an increase in the educational function in teaching, which involves the organization of direct communication between participants in the educational process. Since the learning process is based on the student's independent cognitive activity, it is of particular importance to guide the educational process, which includes advising students and monitoring the quality of knowledge, especially students with a low level of educational and professional motivation.

3 RESULTS AND DISCUSSION

It is quite obvious that the main purpose of a teacher in organizing and planning independent work of students is to form the need for continuous independent mastery of knowledge, skills and self-education, as well as independent and creative activities (Bashkireva, et al., 2019; Mikhaleva, Morozov, 2021).

In this regard, we conducted a survey among students of the psychological, pedagogical and historical-philological faculties of the National Research Nizhny Novgorod State University (a total of 160 undergraduate students of full-time and part-time forms of study participated in the survey). In order to identify the attitude of students towards the introduction of various forms of education into the educational process, students were asked the following questions:

1. What forms of distance learning do you consider the most effective?
2. What form of training do you consider the most convenient for you?
3. What difficulties do you experience in organizing independent work in the context of the digital transformation of the educational process?
4. What forms of work are of particular interest to you in the process of doing independent work?

Taking into account the attitude of participants in the educational process to various forms of distance learning, the following were identified as the most popular, as a result of a questionnaire survey of students:

- «Portal» as a single information system through which students communicate with the teacher, exchange educational material; electronically-guided courses in SEA Moodle;
- Webinars involving interactive interaction of participants in the educational process;
- A number of third-party electronic resources (social networks, messengers, Google Classroom, etc.).

Special attention should be paid to the fact that most of the surveyed students (88%) note the importance and necessity of direct interaction, the possibility of receiving quick feedback, emotional contact, which provide interactive forms of learning.

In the new conditions of digital transformation of education, the so-called mixed forms of education are actively practiced, providing both traditional and digital forms. In this regard, the subjects were also asked which form of education is most convenient for learning. As a result, 45.9% of students supported the mixed learning format. And the rest – 54.1% would prefer various forms of distance learning.

A number of research questions were devoted to the problems and difficulties that students face within the framework of digital forms of education. The analysis of the presented results allowed us to divide all the problems into three categories:

- technical difficulties;
- difficulties in the organization of the educational and educational process;
- problems of an individual psychological nature.

Special attention should be paid to the problems of an individual psychological nature among students, which are mainly associated with insufficient interpersonal communication and interaction, as well as with an insufficient level of self-organization and self-control. The deprivation of personal contacts and live communication in the context of global digitalization negatively affects students' academic motivation and their performance. These difficulties are especially pronounced among undergraduate students with a low level of educational and professional motivation.

Therefore, from our point of view, it is essential to study the professional motivation of students and their level of self-esteem, which allow us to determine the degree of adequacy of a student's self-esteem in the motives for choosing a profession and, as a result, whether or not they have a predominance of positive motives for a professional position in relation to their future professional activities. Without an in-depth analysis of the features of the professional motivation of a future specialist, it is impossible to increase the activity of his professional activity, as well as the need for it, to determine value orientations.

In this regard, in order to identify the professional motivation of students and their level of self-esteem, we used a technique that allows us to obtain and analyze data from students about objectivity in assessing their positive and negative qualities in the motives for choosing a teaching profession (Simonov, 1995).

As a result of the analysis of the data obtained during the survey of 160 undergraduate students, the results were obtained indicating that future specialists have insufficient manifestation of constant professional interest, positive attitude, understanding and acceptance by students of the goals and motives of professional activity for its effective implementation in the system of tasks put forward.

66.7% of the students who took part in the survey characterize objectivity in assessing their positive qualities (their motives for choosing a teaching profession); at the same time, 33.3% were found to be biased. Special attention should be paid to that category of students, 33.3% of them, whose results show an insufficiently developed level of the motivational component of professional activity.

As the analysis of the assessment level of negative qualities (motives) of the profession shows, the majority of students (87% of the total sample) have an inadequate assessment of the motives for choosing a profession, they underestimate the negative motives for choosing a profession and only 13% assess their motives for choosing a profession adequately.

It is obvious that in the context of the digital transformation of education, there is a need for planning and organizing independent work that will allow undergraduate students not only to increase the level of professionally significant motives, but will also contribute to the acquisition of an incentive, guiding and effective basis for their professional and personal development.

Based on the results of our empirical research, we propose to pay special attention to the development of educational and professional motivation in the context of digitalization of the educational process by improving and introducing more effective and optimal forms of interaction between teachers and students in the process of independent work.

The individual educational component of educational activities at the university should be strengthened. Particular importance should be given to an individual and differentiated approach in the organization and planning of various forms and methods of leadership of independent work of students, taking into account the individual typological characteristics of students, as well as the level of development of their intellectual sphere. A special place and role should be given to the development of multi-level and differentiated tasks for students in the context of using various information forms of education, paying special attention to students with a low level of motivation (Ganicheva, 2016; Morozov, 2023).

Paying special attention to the jointly distributed activities of students when completing tasks in the process of independent work, special attention should also be paid to the creation of microgroups of students aimed at organizing their joint activities in preparation for classes and conducting various types of practice. Collective forms of work not only stimulate and develop students' motivation, but also create the basis for emotional and moral experience, novelty and entertainment, as well as develop students' self-esteem.

The creation of mutual assistance groups can also be an effective direction for guiding independent work, since in the process of mutual assistance, students themselves consult each other, especially when mastering difficult material. Such consultations of students are one of the forms of guiding the work of students and helping them to study the discipline independently.

As part of improving the organization and management of students' independent work in the context of digital learning, it is necessary to pay attention to the time budget allocated for performing various types of tasks, taking into account the different level of dynamic characteristics of students. In our opinion, the criteria for evaluating students' independent work should be clearly defined and brought to the attention of students, taking into account the use of various methods of control and self-control in teaching (Ganicheva, 2021; Ganicheva, Morozov, 2021).

Of particular interest to students in the process of doing independent work are such forms as:

creation of visual aids on the topics under study (memos, booklets, recommendations, clusters, etc.);

- analysis of situations and problem solving;
- creation of thematic web pages;
- writing your own version of the lecture plan or part of it;
- preparation of a fragment of a practical lesson;
- creating and solving various learning situations;
- creating web quests, etc.

4 CONCLUSIONS

It is considered possible to effectively organize group and individual independent work of students, which will help the teacher and the student to realize their strengths and weaknesses.

Thus, the study of the effectiveness of the use of digital learning by various participants in the educational process at the university has revealed data on the basis of which it is assumed that various forms of group and individual independent work of students will be actively introduced into the educational process of the university.

In addition, the restructuring of the communication system of participants in the educational process in the context of digital transformation of education, the improvement of the management system for independent work of students allow them to activate their creative potential, stabilize a favorable psycho-emotional state, develop learning potentials, search activities based on personal involvement, and thereby increase the motivation and self-esteem of students.

REFERENCES

Bashkireva, T.V., Bashkireva, A.V., Morozov, A.V., 2019. Features of the Educational Process Subjects Self-Actualization in the Conditions of Mastering the Profession of a Teacher. Proceedings of the First International Volga Region Conference on Economics, Humanities and Sports (FICEHS 2019). Atlantis press SARL. Advances in Economics, Business and Management Research. vol. 114.

Bashkireva, T.V., Bashkireva, A.V., Morozov, A.V., Kuraev, A.N., Nebrodovskaya-Mazur, E.Yu., 2021. Problems of Professional Self-Development Among Undergraduates in the Digital Space, Identified During the COVID-19 Pandemic. SHS Web of Conferences. 3rd International Scientific Conference on New Industrialization and Digitalization (NID 2020). vol. 93.

Dzhemileva, N.N., 2010. The formation of distance education in the USA and Canada. Bulletin of Vyatka State University. No. 4.

Federal Law No. 273-FZ dated December 29, 2012 «On Education in the Russian Federation» // [Electronic resource] URL: https://base.garant.ru/70291362

Ganicheva, I.A., 2016. Development of professional motivation of bachelors of psychological and pedagogical education in the process of studying at a university. Concept. No. 1.

Ganicheva, I.A., 2021. Independent work of students in new conditions: directions, organization and planning. International scientific and practical Conference «Science, Education, Culture». Comrat: KSU.

Ganicheva, I.A., Morozov A.V., 2021. Organization of independent work of students in the conditions of distance learning. Education and law. No. 12.

Gil', A.V., 2020. Modern trends in the development of informatization – digitalization of education. In the collection: Man in digital reality: technological risks. Materials of the V International Scientific and Practical Conference dedicated to the 75th anniversary of Victory in the Great Patriotic War. Tver': TvSTU.

Gil', A.V., Morozov A.V., 2019. From informatization to digitalization of the educational process. Education and law. No. 12.

Kuritsyna, G.V., 2016. The essential and meaningful characteristics of distance learning at the university. Bulletin of the Buryat State University. Education. Personality. Society. No. 2.

Lopanova, E.V., 2003. Managing personality-oriented learning. Omsk: Heritage. Dialogue Siberia.

Mikhaleva, O.V., Morozov A.V., 2021. Formation of professional competencies for bachelor linguists based on immersive technologies. Education and law. No. 4.

Mironova, E.L., 2020. The developing potential of using modern pedagogical technologies in the context of digital transformation of education. In the collection: Personal development in the context of digitalization of education: from primary to higher school. Materials of the All-Russian scientific conference with international participation. Yelets: I.A. Bunin YSU.

Morozov, A.V., 2016. Psychological support of subjects of educational relations in the conditions of modern communicative space. In the collection: Education and personal development in the modern communicative space. Materials of the All-Russian scientific and practical conference with international participation. Irkutsk.

Morozov, A.V., 2023. The development of professional motivation of students in the context of digital transformation of the educational space. In the collection: The penal enforcement system: pedagogy, psychology and law. Materials of the All-Russian scientific and practical conference. Tomsk: Tomsk IPKR FSIN.

Morozov, A.V., 2019. Transformation of the educational space in the digital economy // In the collection: E-learning in continuing education 2019 // VI International Scientific and Practical Conference dedicated to the memory of A.N. Afanasyev. Ulyanovsk: UlSU.

Mukhametzyanova, F.G., Khayrutdinov, R.R., Aminova, R.R., Morozov, A.V., Fedorchuk, Yu.M., 2020. Modern Development Strategy of Russian Education. International Journal of Higher Education. Vol. 9. No. 8.

Polat, E.S., Bukharkina, M.Yu., Moiseeva, M.V., 2004. Theory and practice of distance learning / Edited by E.S. Polat. Moscow: Academy.

Pyannikov, M.M., 2011. On the question of the history of distance education. Scientific notes of the Trans-Baikal State University. Series: Pedagogical Sciences. 2011. No. 5.

Robert, I.V., Mukhametzyanov, I.Sh., Lopanova, E.V., 2022. Digital transformation of education: theory and practice. Omsk: Omsk Humanitarian Academy.

Seliverstova, E.N., 2011. Modern education focuses on the essential characteristics of a post-industrial society. Bulletin of the Vladimir State University for the Humanities. Series: Pedagogical and psychological sciences. No. 11 (30).

Simonov, V.P., 1995. Diagnostics of the personality and professional skills of the teacher. Moscow: MPA.

Voznesenskaya, E.V., 2017. Distance learning is the history of development and current trends in the educational space. Science and school. No. 1.

Yarullina, A.Sh., Morozov, A.V., Mukhametzyanova, F.G., 2023. The subjective involvement of students – future teachers in the formation of professionally significant personal qualities. Education and law. No. 10.

The Importance of Infocommunication Infrastructure for Sustainable Development, Principles and Methods of its Provision

Tatyana Kuzovkova [a], Olga Sharavova [b] and Maria Sharavova [c]
Moscow Technical University of Communication and Informatics, Moscow, 123423 Moscow, Russia
t.a.kuzovkova@mtuci.ru, o.i.sharavova@mtuci.ru, m.m.sharavova@mtuci.ru

Keywords: Sustainable development, information and communication infrastructure.

Abstract: The transition to a new technological order, digital transformation, and the aggravation of economic, social, and environmental problems have necessitated the development of new principles and methods for ensuring sustainable development at the global, national, and corporate levels. The task is to analyze and systematize successful tools for ensuring the sustainable development of information and communication companies that have system-forming and catalytic importance for the economy and society. Setting the task requires a systematic approach to establishing sustainable development requirements for the infocommunication infrastructure, revealing common goals and components of sustainable development, as well as the formation of tools to achieve these goals. The scientific substantiation of the role and objectives of the development of the infocommunication infrastructure and the proposed system of principles and methods for achieving sustainable development goals, systematically built by an infocommunication company, can be used as a tool by other sectors of the economy and the social sphere.

1 INTRODUCTION

The transition to a new technological order and the transformation of all systems (economic, social, environmental, political and ideological), the increasing role of information and intellectual resources, digital technologies and platforms, the formation of business ecosystems, the aggravation of economic, social and environmental problems of the turbulent state of many countries of the world have actualized the need for a radical revision of all systems and principles of the world order to solve the tasks of creating an information society and an intellectual world.

The digital transformation of business and the network organization of the platform infrastructure of the digital economy determine the convergence of industries, the blurring of business boundaries, the growth of scale and efficiency synergies of digital companies (Kuzovkova et al., 2023). Digital platforms make it possible to form large ecosystems that obey not the theory of intra-company costs by R. Coase, but the laws of network efficiency and information technology, and business models take into account customer demand and the impact of production on humans, ecology and the general planetary state of the Earth (Kuzovkova et al., 2021).

The next decade is characterized by the approach of the intellectual world at an accelerated pace, in which the leading role belongs to the network infrastructure, which will connect billions of people and things and transfer yottabytes of data, with the help of an increase in total computing power by 10 times, and AI by 500 times. So at the Intelligent World 2030 Forum, hosted by Huawei, David Wang noted, “10 years ago, we decided to connect all corners of the world to build a better and more interconnected world in the Internet age. Now our concept and mission is to make digital technologies accessible to any category of consumers in order to create a fully interconnected intellectual world”.

According to ITU, changes in the development of infocommunication infrastructure by 2030 relate to the following main parameters: ultra-dense networks with ultra low latency, decentralized network structure, the impact of the development of artificial

[a] https://orcid.org/0000-0002-0883-0469
[b] https://orcid.org/0000-0002-5910-829X
[c] https://orcid.org/0000-0002-9898-5121

intelligence technologies, quantum computers in related industries (nanosets, nanomachines, molecular networks), which will have a fundamental impact on consumer value and the nature of products: telepresencee, teleportation, personal networks, digital doubles, holographic models (Platunina et al., 2023). The evolution of product transformation consists in preserving the material form of both goods and services with a predominance of the information intellectual component, leading to the fusion of the material form of the product merges with the immaterial service, and ICT, AI make the product intelligent, convenient, safe, comfortable.
The high rates of digital development of society, public administration, economy and regional structure, the interests of ensuring national security and global sustainable development dictate the need for appropriate development of information and communication infrastructure.

2 SUSTAINABLE DEVELOPMENT REQUIREMENTS FOR ICT INFRASTRUCTURE

The high rates of development of the intellectual world, the penetration of digital technologies into the processes of production, management and consumption of goods and services dictate high requirements for the technical capabilities of communication networks in terms of speed, bandwidth and quality (Kuzovkova et al., 2019). The technological solution to most problems of sustainable economic development is possible due to the development of digital networks of fixed, mobile, satellite communications, and the Internet of Things.
Effective development of regional markets and industries in the digital economy is possible only if there are developed platforms, technologies, institutional and infrastructural environment. The development of communication networks that meet the needs of the digital economy and society in the collection, transmission and use of data must meet the technological requirements of digital technologies and the implementation of platform solutions (Sharavova, Sharavova, 2021). The complex of requirements for technological and organizational parameters of the infocommunication infrastructure is presented in Fig. 1.

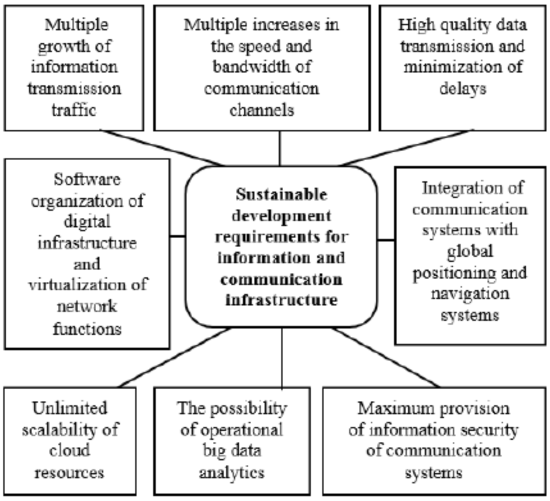


Figure 1: Sustainable development requirements for information and communication infrastructure.

Ensuring the sustainable development of the economy and society is impossible without creating a new generation of communication networks with many times higher bandwidth, speed, reliability and quality of information transmission, with full access to information resources for businesses and the public (Salutina et al., 2021). The importance of creating communication networks of new generations is determined by the essence of the concept of digital transformation, which consists in deep and comprehensive changes in industrial and social processes associated with the total replacement of analog technical systems with digital ones with the widespread use of digital technologies (Kuzovkova et al., 2022).
Scientists name technological innovations in the field of ICT infrastructure and intelligent devices, the latest technologies of mobile, satellite and quantum communications, cloud services, the Internet of Things, etc. as key drivers of digital development, building an intelligent world, platform business models and ecosystems (Cao et al., 2019). Calculations show that the construction of the digital economy is accompanied by a twentyfold increase in the volume of global data transmission – from 9 TB to 180 TB, an increase in the volume of data use in mobile networks by 30 times (up to 2 GB per day) (Kuzovkova et al., 2023).
In Fig. 2 presents the tasks of developing ICT infrastructure in the context of creating a digital economy and information society.
With the digitalization of the economy and society, the introduction of the industrial Internet, the load on the ICT infrastructure increases by several orders of

magnitude, which provides for the digital transformation of the communication systems themselves and the transition to the software implementation of network functions. To create a technological basis for sustainable development, technical solutions are needed for secure high-speed transmission, processing and storage of large amounts of data, as well as organizational solutions to ensure information security and accessibility of all organizations and households.

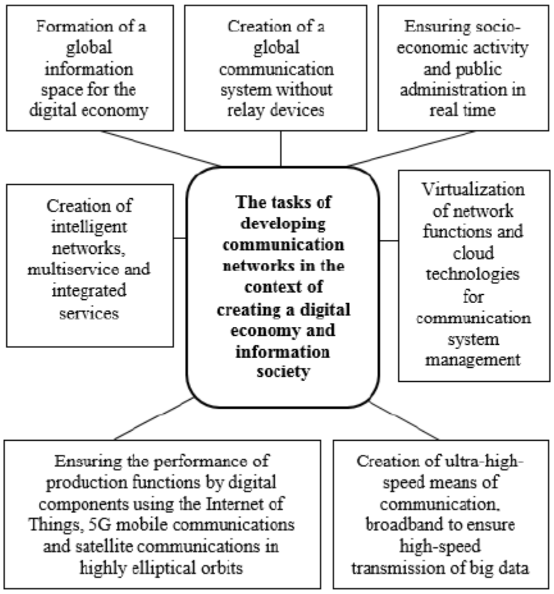


Figure 2: The tasks of developing information and communication infrastructure in the context of creating a digital economy and information society.

Thus, the concept of building and developing narrowband wireless communication networks of the Internet of Things defines not only the needs of the national economy in services provided in 5G/IMT-2020 networks, but also technological solutions, scenarios for building network architecture, requirements for networks, information security and the use of radio frequency bands by operators (Kuzovkova et al., 2023). The potential of the new generation of 5G wireless communications is not only to increase the power and speed of information transmission, but also to integrate businesses by creating new digital products and management models based on the partnership of telecom operators, digital product developers, manufacturers of technological equipment and industry consumers.

In the process of creating an information space, the ICT sector plays a dual role: a transport and network environment (information infrastructure) and an infocommunication resource (factor) for the production of goods and services. Being the most important element of industrial and social infrastructure, the ICT sector serves as a system-forming factor in ensuring sustainable development rates on a national and global scale, with a special catalytic effect on all spheres of the economy and society.

The increasing system-forming and catalytic role of infocommunication infrastructure dictates the need to improve methods and technologies for managing sustainable development, taking into account scientific and technological progress (STP), the impact of many factors and conditions of functioning of economic entities, a sound strategy for harmonious development and improvement of balanced regional production.

3 THE ESSENCE AND COMPONENTS OF SUSTAINABLE DEVELOPMENT

The concept of sustainable development is a new theory of the last decade. More than 100 countries around the world have Councils and national programs for sustainable development. The term "sustainable development" appeared in 1980, when the World Conservation Strategy was adopted, in 1987, the report "Our Common Future" of the World Commission on Environment and Development gave the most popular definition of this term: "development that meets the needs of the current generation without compromising the opportunities of future generations to satisfy their own needs". In 2000, the Millennium Summit was held in New York, at which the UN countries adopted eight development goals by 2015, in 2015, 193 UN countries adopted the resolution "Transforming our world in the field of sustainable development for the period up to 2030", including 17 Sustainable Development Goals (SDGs) (Fig. 3).

The modern understanding of the concept of sustainable development has emerged as a result of combining three points of view: environmental, social and economic. From an ecological point of view, sustainable development should ensure the integrity of biological and physical natural systems, the viability of ecosystems, on which the global stability of the entire biosphere depends. Degradation of natural resources, environmental pollution and loss of biological diversity reduce the ability of ecological systems to regenerate themselves. Hence, the greatest use of the term began to be associated with ecology and environmental problems.

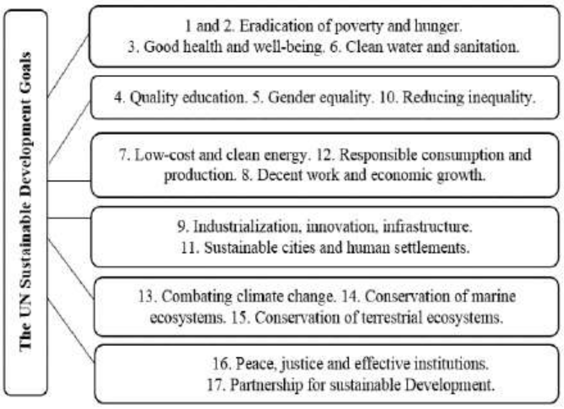


Figure 3: The UN Sustainable Development Goals until 2030.

However, in the literal sense, the phrase “sustainable development” means “constant growth”, without implying a state of balance with nature. In our opinion, it is necessary to pay more attention to the natural environment, it is necessary to strive to ensure stable socio-economic development that does not destroy its natural basis. Improving the quality of life of people should be ensured within the limits of the economic capacity of the biosphere, exceeding which leads to the destruction of the natural biotic mechanism of environmental regulation and its global changes.

In order to achieve the goals of sustainable development, it is necessary to take into account the long-term environmental consequences of economic decisions regarding environmental management and anthropogenic impact on the environment and develop environmental, health and environmental measures. In addition, considering sustainable development, taking into account possible changes in the civilizational attitude, requires regions and countries of the world to preserve their abilities for self-healing and dynamic adaptation to changes. Therefore, “natural” systems and habitats must be considered broadly, taking into account the digital environment created by man, smart cities, and the information society.

The beginning of the XXI century, characterized by an unprecedented growth of cities and settlement systems, the needs of mankind, was accompanied by the application of the principles of sustainable development, especially in the field of urban planning and territorial planning, ensuring safety and favorable living conditions for humans, limiting the negative impact of economic activity on the environment, protection and rational use of natural resources in the interests of present and future generations. At the Russian Forum on Sustainable Development in 2021, it was noted that the three-pronged concept of sustainable development should be complemented by other aspects that take into account the processes of digital development of the economy and society, global relations in economics, politics, and the natural environment.

4 PRACTICAL TOOLS FOR ACHIEVING THE SUSTAINABLE DEVELOPMENT GOALS

Rostelecom is the largest infocommunication company providing digital services and solutions in all market segments. Over the past six years, it has gone from a fixed-line operator to a digital ecosystem with the inclusion of a Tele-2 mobile operator, business expansion in all directions, participation in the implementation of the national Digital Economy program and the implementation of technological and IT projects. Rostelecom Group of Companies includes 65 regional branches and more than 200 subsidiaries. Taking into account the scale of business development and the radical restructuring of the management system, it is advisable to consider the actual practice of implementing the Sustainable Development Goals.

As a participant in the global Sustainable Development Program of the UN SDGs, Rostelecom creates a sustainable digital environment for all spheres of life: the population, business, and the state. According to the independent European rating agency RAEX-Europe, Rostelecom took 41st place in the ESG ranking (out of 160 Russian companies).

The key principles of Rostelecom's sustainable development activities are the integration of sustainable development goals into the company's management and their consideration in the development of projects in the plane of caring for the future of society, openness and honesty to customers, partners, investors and the state, building positive and mutually beneficial relations between the company and employees. Rostelecom focused on 10 main SDGs out of the whole set of UN SDGs and identified two priority levels (Table 1).

Table 1: Priority UN Sustainable Development Goals for Rostelecom.

Sustainable Development Goals	The content of the solution
The first level of priority	
4. Quality education	Ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all
8. Decent work and economic growth	Promoting sustained inclusive and sustainable economic growth, full and productive employment and decent work for all
9. Industrialization, innovation and infrastructure	Building resilient infrastructure, promoting inclusive and sustainable industrialization and innovation
10. Reducing inequality	Reducing inequality within and between countries
11. Sustainable cities and human settlements	Ensuring the openness, safety and environmental sustainability of cities and human settlements
The second level of priority	
12. Responsible consumption and production	Responsible consumption and production
13. Fighting climate change	Fighting climate change
15. Conservation of terrestrial ecosystems	Conservation of terrestrial ecosystems
16. Peace, justice and effective institutions	Promoting a peaceful and open society for sustainable development, ensuring access to justice for all and creating effective accountable and participatory institutions at all levels
17. Partnership for sustainable Development	Strengthening the means of implementation and strengthening the work of the Global Partnership for Sustainable Development

The company's work on sustainable development is characterized by a systematic approach to solving a variety of tasks and using tools:
1) state tasks: participation in projects for building the digital economy of Russia, implementation of the social program “Digital Equality”;
2) production: development of innovative services for customers, maintaining the highest possible level of transparency in conditions of high turbulence;
3) social, human resources: protection of employees and creation of comfortable working conditions, training and career guidance for young people, social and volunteer projects, charity;
4) Environmental: the development of technologies to solve environmental problems.

To measure the factors of assessing sustainability, social responsibility and its position in the ESG rating conducted by the independent European rating agency RAEX-Europe, Rostelecom coordinated its policy according to ESG criteria (Table 2). The ESG factor system includes: Environmental (E) - the impact of the organization on the environment; Social (S) the company's contribution to the welfare and security of society; Governance (G) - management efficiency, transparency of interaction with shareholders, compliance with rules and regulations.

Table 2: Policies and tools for solving accelerated development tasks in priority areas of Rostelecom's activities.

ESG priorities	Policies and tools
Environmental (E)	An effective environmental control and management system. Improving energy efficiency. Waste management. Reducing emissions. Responsible consumption.
Social (S)	Staff training and development. Safe working conditions. Employee support and increased engagement. Charity. Digital services to improve the quality of life.
Governance (G)	High standards of corporate governance. A fair reward. The rights of shareholders.Anti-corruption. High procurement standards.

Shown in the table. 2 The policy and tools for solving ESG tasks in Rostelecom's priority areas of activity confirm the systematic approach and its effectiveness. Thus, the company's environmental policy, in which more than 99% of waste is low-hazard and almost non-hazardous waste (classes IV and V), allowed in 2022 to transfer more than 2 thousand tons of waste for recycling, conduct almost 630 inspections of production facilities to identify and eliminate inconsistencies.
In the field of Social Sphere, Rostelecom not only provides optimal working conditions, but also provides social support to employees based on mechanisms of interaction with staff (collective agreement, corporate pension, housing and voluntary health insurance programs), training and staff development based on the online university platform

with more than 900 courses available. The cost of training employees amounted to 456 million rubles.

Rostelecom PJSC presents an open access report on key indicators, documents and policies in the field of accelerated development "Information ESG". The company invested 175 million rubles in environmental projects and activities over the year. Rostelecom's well-established environmental management system made it possible to undergo an external audit and receive a new certificate of conformity by 2025.

For a number of years, the company has been a key partner of the state in the implementation of the Digital Economy program, data transmission services have been provided for previously connected socially significant facilities and base stations have been installed to eliminate digital inequality.

By implementing social national projects: the integrated social program "Digital Equality", "ABC of the Internet", "GROWTH", "Explore the Internet-manage it", and the international program for the development of social entrepreneurship among young businessmen Social Impact Award (SIA), Rostelecom has a significant impact on the social sphere. The creation of the charter "Digital Ethics of Childhood", conducting a study "Technologies for protecting children on the Internet" with the identification of basic risks for children and the preparation of a manual "A beautiful, dangerous, cybersecurity world" with useful cybersecurity tips for children and parents It promotes the popularization of people's cybersecurity and reduces digital risks.

5 CONCLUSIONS

The disclosure of the general goals and components of sustainable development, the system-forming and catalytic importance of infocommunication infrastructure for the economy and society, the systematization of sustainable development requirements for ICT infrastructure, as well as the analysis of the practical tools of a large infocommunication company to ensure sustainable development goals made it possible to substantiate a package of principles, methods, projects and programs from a systemic perspective, comprehensively ensuring the implementation of the Sustainable Development Goals in the subject-object plan in terms of the scale and depth of impact on economic, social, and environmental problems both within the company and outside at the level of the national economy and society.

Maintaining a balance between environmental, social and corporate components of sustainable development allows you to find the optimal combination of them for a particular business and effectively solve the company's development tasks. Rostelecom's successful experience in implementing practical tools to ensure sustainable business development using clear principles, methods and technologies for training employees and customers, protecting the environment and improving well-being in society can be used in other sectors of the economy and social sphere.

REFERENCES

Kuzovkova, T. A., Kuzovkov, A. D., Sharavova, O. I., Sharavova, M. M., 2023. Methods of Studying the Process and Synergy of the Effectiveness of Digital Business Transformation. *2023 International Conference on Engineering Management of Communication and Technology (EMCTECH), Vienna, Austria, pp. 1-7.*

Kuzovkova, T. A., Saliutina, T. Yu., Sharavova, O.I., 2021. The Impact of Digital Platforms on the Business Management Information System. *2021 Systems of Signal Synchronization, Generating and Processing in Telecommunications, SYNCHROINFO. 2021. Conference Proceedings. P. 9488330.*

Platunina, G. P., Salutina, T. Y., Frank, I. A., 2023. Megatrends of Digital Engineering Technologies: Analysis of the Model of Integral Assessment of the State and Potential of Digital Development in the Conditions of the Fourth Industrial Revolution.*2023 Intelligent Technologies and Electronic Devices in Vehicle and Road Transport Complex (TIRVED), Moscow, Russian Federation, pp. 1-4.*

Kuzovkova, T., Kuzovkov, D., Sharavova, O., 2019. Transformation of criteria and indicators of digital development of economy and information society. *Conference of Open Innovation Association, FRUCT. No 24, pp. 677-681.*

Sharavova, O. I., Sharavova, M. M., 2021. Features of Evaluating and Managing the Resources of Mobile Virtual Network Operators of Digital Ecosystems. *Proceedings of the 2021 IEEE International Conference "Quality Management, Transport and Information Security, Information Technologies. T and QM and IS 2021, 2021, pp. 900-902.*

Salutina, T. Y., Kuzovkova, T. A., Kolotov, Y. O., 2021. Integral Method for Evaluating the Effectiveness of Electronic Interaction between the State and the Population and Business in the Context of Digital Transformation. *2021 International Conference on Quality Management, Transport and Information Security, Information Technologies (IT&QM&IS), pp. 896-899.*

Kuzovkova, T. A., Sharavova, O. I., Tikhvinskiy, V. O., Devyatkin, E. E., 2022. Matching of 6G Network Capabilities to Digital Services Requirements. *Systems of Signal Synchronization, Generating and Processing in Telecommunications, SYNCHROINFO 2022, vol. 5, No 1, pp. 134-138.*

Kuzovkova, T. A., Sharavova, O. I., Tikhvinskiy, V. O., Devyatkin, E. E., 2023. Examining the Impact of Strategic Trends on Radio Frequency Spectrum Requirements in Mobile Communication System. *Conference: 2023 Systems of Signal Synchronization, Generating and Processing in Telecommunications (SYNCHROINFO).*

Cao, B., Zhang, L., Li, Y., Feng, D., Cao, W., 2019. Intelligent offloading in multi-access edge computing: A state-of-the-art review and framework. *IEEE Communications Magazine, vol. 57, No. 3, pp. 56-62.*

Kuzovkova, T. A., Kuzovkov, A. D., Sharavova, O. I., Sharavova, M. M., 2023. Prospects for the Development of Unmanned Transport Based on 5G and 6G Mobile Communication Technologies. *2023 Intelligent Technologies and Electronic Devices in Vehicle and Road Transport Complex (TIRVED).*

Sustainable Development of the World and Russian Metallurgical Industry

Savenkov Leonid Dmitrievich[a]
Institute of Finance, Economics and Management, Togliatti State University, Belorusskaya street, 14, Russia,
Leonidsavenkov89@yandex.ru

Keywords: mineral resources, world iron ore production, metallurgical industry, iron ore, steel, sustainable development.

Abstract: The metallurgical industry has been and remains an important component of the global economy. The importance of metallurgy in the life of mankind is also emphasized by the fact that part of the important stages in the history of mankind was named after the name of the processed metals, namely the Bronze and Iron Ages. A key role in global industrial production lies in the fact that metallurgy provides metals and various alloys to many other industries, including the automotive industry, construction, energy, and mechanical engineering. For example, construction provides up to 6% of Russia's GDP. As for direct employment, it accounts for 9.2% of the total number of people employed in the Russian economy. Thus, metallurgy is a kind of locomotive for the development of the country, pulling other industries along with it. The high level of development of the country's metallurgy makes it possible to provide high-tech raw materials and blanks to such high-tech industries as aircraft manufacturing and the space industry. Also, the production of metals and alloys, taking into account high technologies, is important for the shipbuilding and defense industry of the country. Despite its significant importance, the development of the metallurgical industry is characterized by a number of problems, which are primarily related to the environment, inefficient use of resources, etc. A comprehensive solution to these problems is sustainable development, which allows meeting the needs of society at the current stage, without depriving future generations of the opportunity to meet their future needs. This work is devoted to the issues of sustainable development of the metallurgical industry at the national level.

1 INTRODUCTION

The metallurgical industry has a significant impact on the global economy and the economies of various countries. The main reasons for this are as follows.

Firstly, the metallurgical industry provides the basis for the functioning of other industries. The reason for this is that the metals produced by the metallurgical industry are the basis for many other industries, including automotive, mechanical engineering, production of electronic components, etc. Currently, it is relevant to reuse the products of the metallurgical industry (Pourmehdi, Payda et al, 2020) in order to increase global steel and cast-iron production. The possible negative consequences of problems in the metallurgical industry make the issues of designing the sustainability of logistics supply chains of raw materials and products of the metallurgical industry relevant (Borji, Sayadi, 2023). Modeling processes and simulation make it possible to determine the behavior of the system and decision-making in the process of economic activity of the metallurgical industry (Mohammadi, Sayadi et al., 2022).

Secondly, metallurgy promotes technological innovation. In the course of its activities, the metallurgical industry develops innovative alloys and materials that are used in various innovative industries. Also, in order to reduce costs and ensure the efficiency of metallurgical enterprises, enterprise management must adapt to the best practices in the metallurgical industry (Tizroo, Esmaeili et al., 2017).

Thirdly, the metallurgical industry is one of the largest employers providing millions of people with jobs around the world. Therefore, metallurgical enterprises should take into account environmental and social aspects when forming steel supply chains (Condé, Almeida et al., 2024).

[a] https://orcid.org/0009-0002-4226-5165

Fourth, the metallurgical industry is a key element of the economy of various countries, due to its significant contribution to GDP, for Russia it is about 5%, and export potential, since the export of metallurgical industry products can become an important source of income for the state. At the same time, international competition in the field of steel production and marketing can lead to significant negative consequences. For example, the South African steel industry has suffered as a result of competition, which makes it urgent to form new business models and paradigms to improve the economic activities of the metallurgical industry, including in the field of improving supply chain management strategies (Khoza, Mafini et al., 2022).

Fifth, the development of the metallurgical industry leads to the development of transport infrastructure, such as railways, sea and river ports, and energy infrastructure facilities.

The sixth reason for the significant influence of metallurgy on the production of steel, aluminum, copper, titanium and other materials is of significant importance for the military industry and the production of weapons.

The last seventh reason for the importance of the metallurgical industry is that the effective development of the metallurgical industry will ensure sustainable economic development through the introduction of energy-efficient technologies, reducing emissions of harmful substances and worsening working conditions. Therefore, most of the research related to the metallurgical industry is devoted to improving its efficiency and reducing emissions of harmful substances into the atmosphere. Recovery issues

Hydrogen-based applications in low-carbon sustainable iron and steel production are considered in the work (Sun, M., Pang, K. et al., 2024). The reduction of CO2 emissions in China using hydrogen metallurgy is described in the work (Wan, Li et al., 2024). The work is devoted to the implementation of ESG principles in the global and Russian metallurgical industry (Glushakova & Chernikova, 2023), methods and tools of climate finance, including green bonds, green tariffs are considered in the work (Yashalova & Potravny, 2023). The use of production for clean energy production in order to ensure low-carbon development is being considered (Xu, Zheng et al, 2024). The application of the technology of separation and simultaneous extraction of rare earth elements and fluorine in bastnesite concentrates is described in the work (Cen, Bian et al, 2021).

Considering the metallurgical industry, it is impossible not to consider such a branch of the metallurgical industry as ferrous metallurgy, which provides the production of cast iron and steel.

Global steel production is constantly growing, in 1950 steel production was 189 million tons, and in 2022 1,885 million tons, thus steel production increased 9.97 times over 72 years. China is the leader in steel production, with a production volume of 1,018 million tons and a share in global production of 54% of total steel production. Next in terms of production volumes are India, Japan, the USA and Russia. China's steel production exceeds that of India by 8 times, Japan by 11 times, the United States by 12 times, and Russia by 14 times.

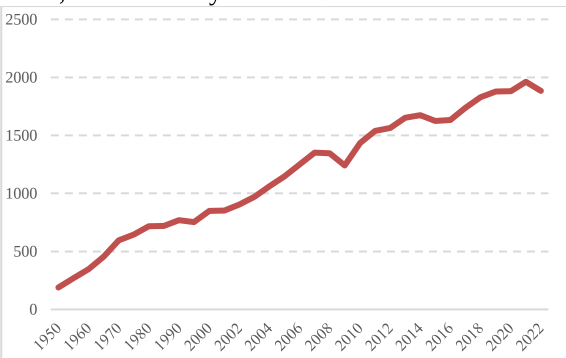


Figure 1: World steel production for the period from 1950-2022, mln tons.

At the same time, China, despite significant volumes of steel production, reserves of the main raw material – iron ore, are not enough for steel production in China, currently the proven reserves of iron ore account for 8.3% of the global total. At the same time, the ores mined in China are characterized by a low iron content in them. Iron ore also contains a large amount of harmful impurities. The yield of the concentrate with an iron content of 65% is very insignificant. For example, 1.5 billion tons of crude Chinese ore yield only about 300-400 million tons of concentrate. Previously, China was considered the leader among iron ore mining countries, overtaking countries such as Australia, Brazil, India and Russia in terms of iron ore production, however, the methodology for estimating iron ore production has changed

If we talk about the proven reserves of iron ore, then according to the US Geological Survey (USGS), its proven reserves as of January 1, 2021 amount to 175.5 billion tons. At the same time, the estimated iron content in these ores is 84 billion tons. Global iron ore reserves are estimated at 800 billion tons with a content of 230 billion tons of iron suitable for processing.

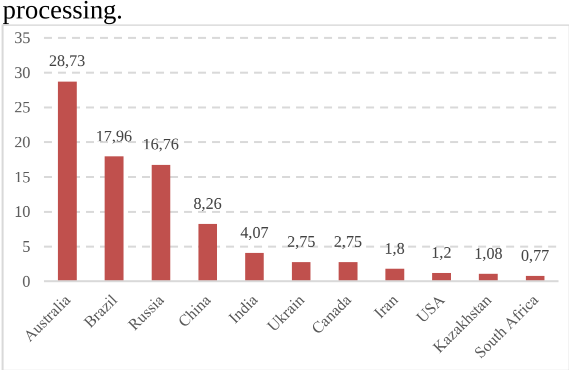


Figure 2: The share of countries in iron ore reserves as of January 1, 2021, in %.

Figure 2 shows that the first place in iron ore reserves is occupied by Australia, which accounts for 28.73% of the world's iron ore reserves. Most of Australia's iron ores have a high iron content of up to 65%. The resulting ore, after the simplest processing methods, which consist in crushing and screening it, is ready for use in metallurgical production. Australia's leading position in iron ore mining makes it the main supplier of this type of raw material to the world market. From Figure 3, it can be seen that 34.62% of the total iron ore is produced in Australia.

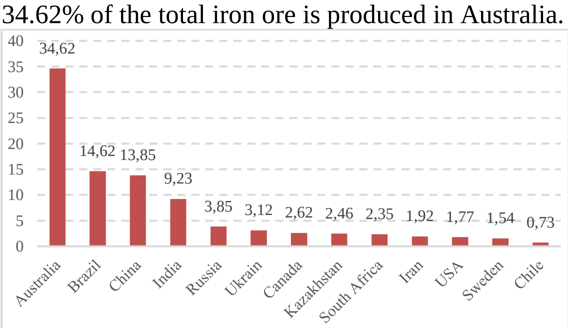


Figure 3: Iron ore production, in %.

At the same time, Australia exports the bulk of the extracted iron ore, more than 90%. The main countries importing iron ore from Australia are China (82.5%), Japan (6.8%), South Korea (6.3%), and India (0.05%).

Brazil is the second country in terms of iron ore reserves and production volumes. Brazil's iron ores are characterized by low levels of harmful impurities such as sulfur, aluminum oxide and silicon dioxide. As for Australia, the main buyer of Brazilian iron ore is China, which consumes 68% of the iron ore supplied by Brazil for export, followed by Malaysia (6.4%), Japan (3.6%), the Netherlands (2%). Unlike Australia, Brazil, in addition to exporting ore, produces steel, occupying a share of 1.8% of global production.

China holds the third place in iron ore production and the fourth place in its reserves. It should be noted that in terms of actual iron ore production, excluding the iron content in it, China is the leader. However, the recalculation of volumes taking into account the iron content, namely to the world standard, implying the presence of 65% iron ore in the extracted rock, gives China only the third place in the world in production. At the same time, it should be noted the poor quality of Chinese iron ores and the presence of a large number of harmful impurities in them. Nevertheless, China ranks first in the world in terms of steel production, see Figure 4.

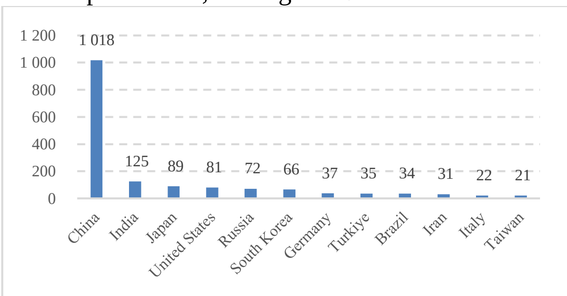


Figure 4: Steel production by the countries of the world million tons.

China is currently implementing a program to reduce the country's dependence on iron ore imports, which includes searching for new deposits in China, expanding the use of scrap metal and buying its own iron ore mining assets.

India ranks fourth in iron ore production with a share of 9.23% in global production. At the same time, India ranks fifth in the world in terms of reserves, and in terms of steel production, the main product of iron ore, second in the world, importing the volume of iron ore necessary for production from countries such as Australia and Brazil. India's iron ore deposits are rich in iron, with a content of 60-68%. At the beginning of the development of the steel industry, most of the extracted iron ore was exported, but after the introduction of protective duties on the export of iron ore, the Indian steel industry began to develop rapidly. If in the 2000s India produced 26.8 million tons of steel, then in 2009 it entered the top four countries in terms of steel production. The Government of India plans to increase the smelting of Indian steel to 300 million tons per year. If India's plan is implemented, it will allow it to maintain its second place in the steel market, and the volume of production will "eat up" part of the market share of other steel producing countries.

Russia ranks fifth in terms of iron ore production, third in terms of its reserves and fifth in steel production. The quality of Russian ores is not high, the iron content in the ore is in the range of 28-34%.

Analyzing the data in Figure 4, it can be concluded that Japan ranks third in the world in the production of cast iron and steel. At the same time, reserves and production of high-quality iron ore with an approximate volume of 228 million tons, for comparison, iron ore reserves in Russia amount to 25 billion tons. The main source of iron ore in Japan is the import of iron ore from other countries. The situation is similar in the United States, which ranks fourth in the world in the production of pig iron and iron ore, while its production is 48 million tons, with a total production of steel and cast iron in the amount of 81 million tons. At the same time, the missing volumes of iron ore are imported from other countries.

To assess the development and prospects of the metallurgical industry, we will group the steel and cast iron producing countries according to the following indicators reflecting production: the country's share in steel production in 2023, in %, the country's share in iron ore production, in%, the increase in steel production over the past thirty-two years, in %, see table 1.

Table 1: A set of indicators for grouping steel and cast-iron producing countries.

Country of manufacture of steel and cast iron	The country's share in steel production in 2023, in %	The country's share in iron ore production, in %	The increase in steel production for the period from 1992 to 2023, in %
…	…	…	…

2 METHODS

The basis for the grouping should be data from the US Geological Survey, as well as the World Steel Association AISBL, which allow us to obtain data on steel production by country of the world million tons, iron ore extraction million tons, these data also allowed us to calculate the indicators indicated in Table 1. The calculation of the increase in steel production will be made for the period from 1992 to 2023 based on data from the US Geological Survey.

The main hypothesis of the study will be that the conducted grouping will allow dividing all steel producing countries into several groups, by analogy with the BCG matrix. These groups will have appropriate characteristics that can be used to determine the directions of sustainable development for each group. To increase the objectivity of grouping, cluster analysis was applied during the study, which is used to group data taking into account their similarities and differences, which are determined by the distance between objects. When conducting cluster analysis, the following methods can be used: k-means, Ward's method, Euclidean distance, k-medians. A review of studies using cluster analysis led to the conclusion that cluster analysis is used in research related to entrepreneurship (Crum, Nelson et al, 2022), retail (Pinto, Salume et al, 2023), marketing research (Punj & Stewart, 1983), the taxonomy of environmental entrepreneurship (Ljungkvist & Andersen, 2021), as well as other studies that allowed the use of cluster analysis in this study.

3 RESULTS

According to the results of the cluster analysis using the k-means method, four groups with clear characteristics were obtained. The first group includes countries with a high share in steel production – at least one percent and with positive growth rates in steel production over the period from 1992 to 2023. This group includes nine steel producing countries, including China, India, Russia, South Korea, Turkey, Brazil, Iran, Taiwan, and Vietnam. At the same time, some countries producing cast iron and steel do not have their own iron ore production, importing the necessary raw materials from other countries. Such countries include South Korea and Taiwan. At the same time, Turkey and Vietnam do not produce enough iron ore to ensure their own steel production, while Brazil produces significant amounts of ore, which are 13 times larger in volume than steel production, sending most of the raw materials for export to other countries. The first group produces 76.18% of the total steel production and 55.48% of the iron ore mined in the world. Characterizing this group, it can be concluded that it and its member countries are a kind of locomotives of the global steel industry, providing the bulk of the increase in global steel production.

The second group of steel producing countries, which includes such countries as Japan, the USA, Germany and Italy, can be described as a group losing its position in the steel production market, but still maintaining its position in the market. The share of these countries in the market is 12.23%. All countries except the United States do not produce iron ore in significant volumes by exporting from other countries. Iron ore mining in the United States also does not provide steel production. Iron ore production is 48 million tons, with a steel production volume of 81 million tons. The dynamics of steel production by the countries of the second group allows us to characterize them as former leading countries in steel production that are gradually losing their positions in the market, mainly under pressure from the countries of the first group. It should be noted that these countries are the most developed countries that are part of the Group of Seven (G7).

The third group consists of countries that do not play a big role in the global steel market, their share in the global market is less than 1% for each specific country. Overall, this group of 25 countries occupies 7.31%. These countries include Mexico, Egypt, Saudi Arabia, Australia, etc. At the same time, in terms of iron ore production, the group accounts for 34.28% of the total iron ore production in the world, mainly due to Australia, Sweden and Mexico with volumes of 880 million tons, 37 million tons and 23 million tons. At the moment, these countries do not play a significant role in the global steel market, but countries such as Australia, Mexico and Sweden can significantly increase steel production due to existing iron ore reserves. Other countries can also significantly increase steel production both by exporting raw materials and by searching for iron ore reserves on their territory. For example, Saudi Arabia has a program for the development of the steel industry based on export raw materials.

The fourth group is characterized by a low market share in the global steel market of 4.27% and a share in global iron ore production of 8.5%. The main feature of this group is a small share in the global market and a decrease in steel output over the period from 1992 to 2023. This group includes France, Canada, Spain, etc. In general, this group, consisting of twelve countries, represents the countries of western and eastern Europe, as well as South Africa and Kazakhstan. Ukraine is the leader in terms of the rate of decline, which has lost significant volumes of steel production compared to 1992. The United Kingdom and France also lost significant volumes of steel production. At the same time, a number of countries in this group produce significant amounts of iron ore. These include Canada, Ukraine, South Africa, and Kazakhstan. The forecast of the activities of this group of countries allows us to conclude that these countries will continue to stagnate in steel production. At the same time, the countries of this group, especially those with significant iron ore reserves, have a potential opportunity to develop steel production and gain their share of the world market.

4 ANALYSES

The conducted grouping of steel producing countries made it possible to identify four groups of producing countries with specific characteristics describing these groups. By evaluating the characteristics of these groups, they can be brought to the BCG matrix, which allows you to divide the company's product portfolio into four groups "Stars", "Cash Cows", "Question Marks" and "Dogs".

Using the terminology and approach of the BCG matrix, the first group of steel producing countries obtained can be defined as a growth group or "Stars", which has positive growth rates and a significant market share.

The second group, with stagnating production volumes and retaining a significant market share, can be defined as "Cash cows". If production volumes remain stagnant, they may lose market share and move to the "Dogs" group, and with an increase in growth rates to the "Stars" group.

The third group, with positive growth volumes and a relatively small market share, can be attributed to the "Question Mark" group, which, in case of a drop in the growth rate of steel production, can move to the "Dogs" group, and in case of successful development and an increase in market share, to the "Stars" group.

The fourth group, "Dogs", is characterized by negative growth rates and low market share. In the future, with the development of their steel industry, these countries may move into the "Question Mark" group, and if stagnation persists, they will completely lose their competence in the field of steel production.

5 DISCUSSIONS

In accordance with the voiced hypothesis of the study, it was assumed that the conducted grouping would allow dividing all steel producing countries into several groups, by analogy with the BCG matrix. It was also assumed that the groups would have appropriate characteristics that could be used to determine the directions of sustainable development for each group. The analysis showed that the grouping made it possible to divide the steel producing countries into groups by analogy with the BCG matrix. Let's define the directions of sustainable development for each of the received groups.

The countries of the first group show significant growth and share of the global steel market. The main direction of development of the countries of the first group should be ecology, improvement of working conditions and improvement of the corporate governance system (ESG).

The environmental direction should include improving the quality of atmospheric air in the steel production area, combating climate change, managing the waste disposal process, as well as protecting water resources.

As for occupational safety and industrial safety, first of all, it is the creation of safe working conditions for the company's employees and employees of companies involved in the steel production process. Another important area is occupational safety and industrial safety in the implementation of steel production, including through the reduction of occupational injuries and other measures.

In order to ensure the implementation of sustainable development directions, it is necessary to ensure the improvement of the corporate governance system of steel companies. Therefore, responsibility at the strategic and operational decision-making levels should be defined at the steel industry level. At the government level, it is necessary to adopt regulations governing the process of sustainable development in metallurgical companies.

The second group of countries represents economically developed countries where steel production rates are declining. These countries are unique pioneers of sustainable development, the first to introduce the concept of sustainable development in their metallurgical enterprises. However, the main problem that these countries need to solve for their metallurgical enterprises is to ensure the sustainability of production volumes. In this regard, various incentive measures are possible, related to the introduction of incentive export and protective import duties, investments in more modern methods of steel production, etc.

The third group represents developing metallurgical countries in which the concept of sustainable development can be implemented together with the development of the metallurgical industry using new technologies for the production of cast iron and steel. With the right balance between production volumes and the sustainable development of the industry, it is possible to create a new type of metallurgical enterprises that have a minimal impact on the environment and have maximum efficiency. An example is the development of the US industry in the 19th century, when the US industry, due to newer equipment and technologies, was able to outpace the UK, which had previously been a leader in industrial production. Among the countries of the third group, it is necessary to single out Australia, which is the largest producer of iron ore in the world – 31.71% of all iron ore in the world is mined by Australia. At the same time, Australia's share in steel production is 0.4%. Potentially, Australia, which in addition to iron ore is the largest producer of coal, including coking coal, can become a leader in the production of steel and cast iron. The main obstacle is Australia's environmental policy, which is aimed at reducing carbon dioxide emissions, which will not allow the development of the metallurgical industry at a significant pace. The countries of this group need to apply sustainable industrial development to increase the competitiveness of their industry,

The fourth group represents countries whose market share is minimal, while the growth rate of steel production is negative. If the current trend continues, these countries may disappear as steel producing countries and lose their competence in this area. Sustainable development is possible in these countries, but strong incentive measures are needed to support the national steel industry.

Summing up the results of the study, it can be concluded that the proposed hypothesis of the study has been confirmed, and the conducted grouping of steel and cast-iron producing countries is objective and gives a fairly clear description of the characteristics of each group.

REFERENCES

Borji, M. K., Sayadi, A. R., Nikbakhsh, E., 2023. A Novel Sustainable Multi-objective Optimization Model for Steel Supply Chain Design Considering Technical and Managerial Issues: a Case Study. Journal of Mining and Environment, 14(1).

Cen, P., Bian, X., Wu, W., Li, B., 2021. A sustainable green technology for separation and simultaneous recovery of rare earth elements and fluorine in bastnaesite concentrates. Separation and Purification Technology, 274.

Condé, B. L., Almeida, J. F. de F., Miranda, D. M., Conceição, S. V., 2024. A country-level multi-objective optimization model for a sustainable steel supply chain. Exacta.

Crum, M., Nelson, T., de Borst, J., Byrnes, P., 2022. The use of cluster analysis in entrepreneurship research: Review of past research and future directions. Journal of Small Business Management, 60(4).

Glushakova, O. v., Chernikova, O. P., 2023. Institutionalization of ESG-principles at the international level and in the Russian Federation, their impact on ferrous metallurgy enterprises. Part 2. Izvestiya Ferrous Metallurgy, 66(4).

Khoza, S., Mafini, C., Okoumba, W. V. L., 2022. Lean practices and supply-chain competitiveness in the steel industry in Gauteng, South Africa. South African Journal of Economic and Management Sciences, 25(1).

Ljungkvist, T., Andersén, J., 2021. A taxonomy of ecopreneurship in small manufacturing firms: A multidimensional cluster analysis. Business Strategy and the Environment, 30(2).

Mohammadi, M. A., Sayadi, A. R., Khoshfarman, M., Husseinzadeh Kashan, A., 2022. A systems dynamics simulation model of a steel supply chain-case study. Resources Policy, 77.

Pinto, M. R., Salume, P. K., Barbosa, M. W., de Sousa, P. R., 2023. The path to digital maturity: A cluster analysis of the retail industry in an emerging economy. Technology in Society, 72.

Pourmehdi, M., Paydar, M. M., Asadi-Gangraj, E., 2020. Scenario-based design of a steel sustainable closed-loop supply chain network considering production technology. Journal of Cleaner Production, 277.

Punj, G., Stewart, D. W., 1983. Cluster Analysis in Marketing Research: Review and Suggestions for Application. Journal of Marketing Research, 20(2).

Sun, M., Pang, K., Barati, M., Meng, X., 2024. Hydrogen-Based Reduction Technologies in Low-Carbon Sustainable Ironmaking and Steelmaking: A Review. Journal of Sustainable Metallurgy, 10(1).

Tizroo, A., Esmaeili, A., Khaksar, E., Šaparauskas, J., Mozaffari, M. M., 2017. Proposing an agile strategy for a steel industry supply chain through the integration of balance scorecard and Interpretive Structural Modeling. In Journal of Business Economics and Management (Vol. 18, Issue 2).

Wan, F., Li, J., Han, Y., Yao, X., 2024. Research of the Impact of Hydrogen Metallurgy Technology on the Reduction of the Chinese Steel Industry's Carbon Dioxide Emissions. Sustainability (Switzerland), 16(5).

Xu, T., Zheng, X., Ji, B., Xu, Z., Bao, S., Zhang, X., Li, G., Mei, J., Li, Z., 2024. Green recovery of rare earth elements under sustainability and low carbon: A review of current challenges and opportunities. In Separation and Purification Technology (Vol. 330).

Yashalova, N. N., Potravny, I. M., 2023. Possibilities of applying ESG-principles and methods of climate financing in the management practice of ferrous metallurgy enterprises. Chernye Metally, 2023(5).

Artificial Intelligence in Preschool Language Education: Are Educators Ready?

Gulnara Sadykova[a] and Albina Kayumova[b]
Institute of Philology and Intercultural Communication, Kazan (Volga Region) Federal University, 18 Kremlyovskaya Street, Kazan, Russian Federation
gsadykov@kpfu.ru, alb1980@yandex.ru

Keywords: artificial intelligence, early childhood education, language education

Abstract: With the proliferation of smart technologies in everyday life, artificial intelligence (AI) tools have started penetrating into universities, schools and even early childhood education centres, raising many questions among educators. AI-powered tools might be used by many on trial-and-test basis; however, to apply them effectively in classrooms, educators should have adequate understating of AI instructional potential and well-developed skills in applying it in the classroom. This study reports on the findings based on the survey that involved 96 early childhood educators who self-assessed their AI literacy skills and expressed their views on the benefits and potential threats of AI technologies on overall and language development of preschool children. The results speak for generally positive attitude to AI as an instructional tool but indicate that educators' understanding of AI potential might be very superficial. The findings suggest the need for educators' AI literacy development and call for further study of effective practices where AI technologies are used for overall and language development of very young learners.

1 INTRODUCTION

Artificial intelligence (AI) technologies have recently become an important driver of educational development. AI in education (AIED) is used to support learners, teachers or educational administration (Baker et al., 2019).

Learner-oriented smart tools such as adaptive learning platforms have been shown to build individual learning trajectories and customize content based on the strengths and weaknesses of a learner, consequently, leading to better memorization and mastery of the learning material (Yilmaz & Yilmaz, 2023; Alam et al., 2023; Cen et al., 2023; Singh et al., 2022). Teacher-focused AI tools are able to provide high-quality and unbiased assessment and help the teacher in lesson planning and content development, thus, reducing teachers' workload and preventing burnout (Dénes, 2023; Hashem et al., 2023). System-focused tools have been successfully used to analyze data from across multiple educational institutions and predict which schools should be prioritized for a full inspection (*Ofsted's Approach*, 2024).

Given the widespread access to AI and its affordances related to text generation, language teachers are among the earliest and most consistent adherents of AI tools. Research indicates a significant potential of AI technologies in developing communicative competencies with different categories of language learners such as university (Keerthiwansha, 2018; Zou et al., 2020; Chen et al., 2022), secondary (Holstein et al., 2018) and primary school students (Ghoneim & Elghotmy, 2021; Underwood, 2017). Studies demonstrate effectiveness of AI technologies in enhancing specific skills: listening (Ghoneim & Elghotmy, 2021; Suryana, 2020), writing (Fitria, 2021; Zhao, 2022), speaking (Li, 2022; Zou et al., 2023) and reading (Johnson et al., 2017; Wijekumar et al., 2017). AI technologies may also assist in corrective language education; for example, during speech therapy sessions for children with speech disorders (Esfandbod et al., 2023) or for improving

[a] https://orcid.org/0000-0003-1868-8336
[b] https://orcid.org/0000-0001-6231-3983

communication skills among autistic children (Ismail et al., 2018).

As with other forms of technologies, the use of AI with very young learners is a controversial issue. However, recent studies have shown its high potential in preschool settings. Researchers' attention is mostly focused on developing AI literacy itself rather than gaining any other knowledge by means of AI technologies (Ng et al., 2021a; Ng et al., 2021b; Kewalramani et al., 2021a). Early AI literacy is taught by specialists in the field of software engineering, intelligent robotics, and digital analytics. It is emphasized that AI literacy has become an important skill that every person should possess, even a preschooler (Kandlhofer et al., 2016; Steinbauer et al., 2021). Empirical research confirms that early childhood is a fruitful period for acquiring knowledge about AI (Lin et al., 2020; Vartiainen et al., 2020; Betelin et al., 2020).

Still, apart from observing improvements in AI literacy, researchers trace other positive changes occurring in presechoolers' development; for example, the development of fine motor skills (Polsley et al., 2022), social and emotional competencies (Kewalramani et al., 2021a; Kewalramani et al., 2021b), mathematical skills (Gulz et al., 2020), creativity and digital skills (Giddings, 2019). Research also reports that smart toys can increase young learners' motivation (Irwin, 2016) and improve exploration skills (Huijnen et al., 2017).

In preschool language education, to a large extent, research interventions have involved the study of child–robot communication. Researchers seem to agree that a social robot can successfully teach new words to children in both their first (Movellan et al., 2009) or second language (Gordon et al., 2016). Social robots are also able to improve children's language production; e.g. by playing a story-telling game (Kori-Westlund & Breazeal, 2019).

Considering the recent introduction of generative AI, we may soon observe new discussions of AI potentials for young and very young learners. However, to date, literature review shows a significant gap in understanding how the new generation of AI can contribute to the speech development of young learners. Little do we know about educators' readiness and willingness to adapt these new developments to their local setting and individual needs of their learners. This study aims to partly address this gap and examine educators' self-assessment of AI competencies and attitudes to the new technologies.

2 MATERIALS AND METHODS

This exploratory mixed-methods study involved a survey that consisted of 13 questions (12 multiple-choice and 1 open-ended questions). The first 6 questions were designed to collect demographic data (participants' educational background, age, gender, teaching experience and the age group of their students). The main body questions were divided into two thematic blocks: 1) the level of competence in AI technologies; 2) integration of AI technologies in early childhood education. The following research questions guided the study:

1) How do early childhood educators self-assess their level of artificial intelligence (AI) competence?

2) What is early childhood educators' attitude to using AI technologies for overall and language development of (very) young learners?

To recruit the participants and collect the data, a link to an anonymous Google Docs questionnaire [https://forms.gle/bfkTXGEVC2xrFHCf9] was sent to educators of private and state-funded kindergartens and preschools in the Republic of Tatarstan (Russia). The questionnaire was completed by 150 people but 54 replies were excluded from the study as the answers indicated that their authors were not educators working on language development of preschool children.

The questionnaires revealed that the survey participants (n=96) were mostly female early childhood educators (99%). The majority had university education (83%) whereas 12.5% had vocational education. Four percent of the respondents did not provide information on their education level. Most respondents were 31-40 and 41-50 years old (40% and 37.5% respectively), followed by respondents aged from 20 to 30 (12.5%) and from 51 to 60 (8%); there was also one respondent aged 61-70 (1%) and one younger than 20 years old (1%).

The educators' work experience ranged between less than one (5%) to over 40 years of service (1%), with the majority of the respondents (22%) having from 4 to 7 years of work experience.

The educators mostly work with children aged 5-7 (38%) and 3-5 (32%); a considerable number work with a wider age range from 3 to 7 (18%) or 0 to 7 (6%). Only 4% work with children younger than 3.

The data analysis involved quantitative and qualitative methods of data processing. Answers to closed-ended questions were counted for frequencies, while open-ended survey answers were theme-coded by two researchers.

3 RESULTS

3.1 How do early childhood educators self-assess their level of artificial intelligence competence?

In the first block of the questionnaire, study respondents were initially asked to self-assess their level of AI competence. None of the participants believe it is very high. A small proportion (11%) finds it to be high. A 69% majority defines their level as average. A fifth of the respondents believe that their level of competence in AI technologies is below average (13%) or low (7%) (Figure 1).

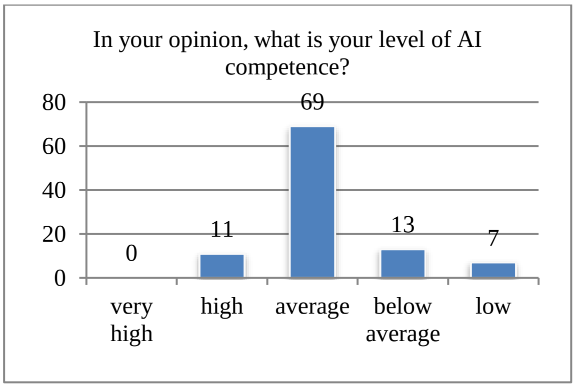


Figure 1: Self-assessment of literacy in AI technologies (%).

The respondents' level of self-assessment in some way contradicts the amount of their interaction with AI. When asked whether they have any experience of using AI technologies for professional purposes, more than a half (51%) of the respondents declared no experience whatsoever. Thirty-five percent have limited experience; only thirteen percent report having a considerable experience of using AI technologies (Figure 2). The contradiction between the self-assessment of AI literacy and the experience might be due to either overestimated AI competencies or misunderstanding of the term. Further study that would involve follow-up interviews might be needed to clarify these findings.

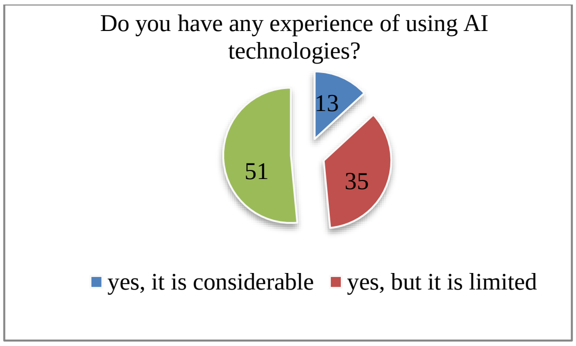


Figure 2: Usage of AI technologies for professional purposes (%).

Analysis of the responses suggests a possible link between the age of the respondents and their competence and experience in the field of AI. As shown in Figure 3, respondents aged 21 to 40 more frequently declare a high level of competence (15%) than those aged from 41 to 60 (7%). One respondent aged 61 rated her level of AI competence as low. This confirms previous research that innovations, including new digital technologies, are better adopted by the young (Roy et al., 2023).

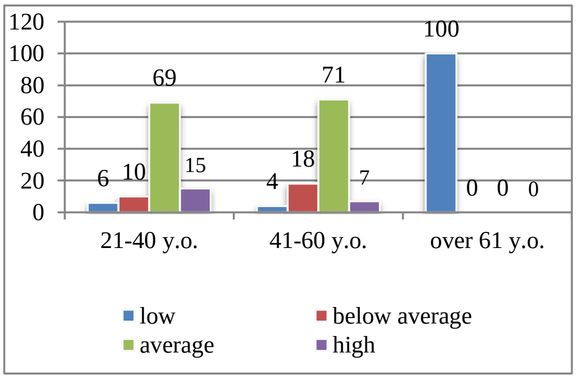


Figure 3: The level of competence in the field of AI by age categories.

However, as can be seen in Figure 4, respondents aged 41 to 60 (44 resp.) have a more considerable experience of exploiting AI technologies for professional purposes (22% vs. 8% of those aged 21 to 40 (51 resp.)), which can probably be explained by their longer work experience. The only respondent who claimed being over 61 years old assessed her experience as limited.

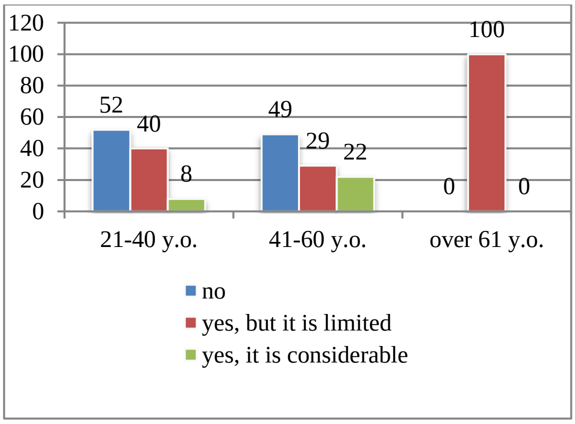


Figure 4: Experience of using AI for professional purposes by age categories.

3.2 What is the educators' attitude to using AI technologies for overall and language development of (very) young learners?

The responses to the questions of the second part of the survey shed light on the educators' attitude towards AI in early childhood development. As shown in Figure 5, a significant number of the respondents disagree or completely disagree with the idea (8% and 44% respectively) that AI technologies threaten the development of preschool children. A lower percentage (22% altogether) believes that AI technologies might pose a potential danger, with 6% showing strong view related to the adverse impact of AI. The proportion of undecided comprises 26%, which speaks for a lack of understanding of these new technologies.

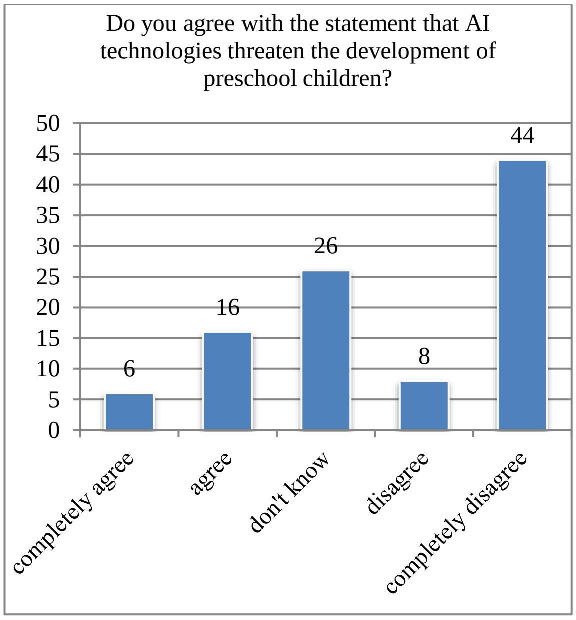


Figure 5: Opinion on AI being a threat to preschool children's development

As regards the respondents' attitude to using AI technologies in early childhood settings, over a half of the respondents (63% in total) either agree (47%) or completely agree (16%) with the idea that AI technologies can be successfully used for the overall development of preschool children. Almost a quarter (21% in total), on the contrary, disagree (15%) or completely disagree (6%) with the statement. As for preschool children's language development, the proportion of AI supporters and opponents is approximately the same. Sixty-six percent of the respondents either agree (55%) or completely agree (11%) with the statement whereas 18% (completely) disagree (see Figure 6).

Thus, the ratio of AI supporters to AI opponents is about 3:1 irrespective of the primary aim of integration. The proportion of undecided on this issue also remains more or less stable.

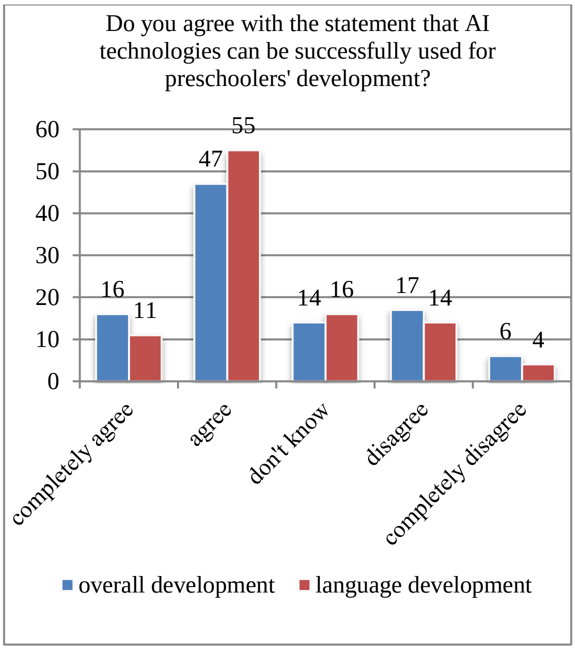


Figure 6: Attitude to using AI in early childhood overall and language development

The next survey question asked the respondents to indicate their opinion on the use of AI technologies in the language development of preschool children. Almost a half of the respondents (44 out of 96) did not respond to this open-ended question. Ten admitted that they could not express their opinion since they do not understand this topic, supporting the idea that many educators have very limited knowledge about the potential of AI technologies as instructional tools.

The other half (42 out of 96) offered their insight into the reasons for being either for or against AI technologies in language development of preschoolers.

The advocates of AI (38 respondents in total) claim that it is *'interesting'*, *'new'* and *'suitable'*. There is a consensus among eight AI supporters that the usage of AI tools can be beneficial in different aspects of preschoolers' language development, such as pronunciation, vocabulary, literacy and reading, etc.:

Using [AI] voice technologies can improve pronunciation. They can find children's pronunciation errors and correct them.

[Thanks to AI] pupils expand knowledge about the world around them, their vocabulary becomes richer.

By using AI technologies in the development of language skills, children learn to speak and memorize the alphabet faster.

Three supporters still argue that AI can only be helpful if *'used in moderation'* or *'as an additional tool'*. The other three say that AI *might* be effective; still, they are not sure.

Four respondents are against the usage of AI in early childhood language development. However, only one of the opponents clarified his/her reasons stating that *'preschool children's main activity should be play and live communication'*.

4 DISCUSSION AND CONCLUSION

The results of the study show two major trends. First of all, educators working with very young children may have rather superficial knowledge about AI technologies. While they may evaluate their AI competencies as average, the majority may lack practical experience using these new instructional tools in professional settings. This could be explained, first, by the novelty of AI and, second, by educators' lack of knowledge and skills necessary for thoughtful and effective integration of AI in early childhood education.

The second trend is related to overall positive attitude to AI among educators that took part in the study. It seems that while many educators have not yet adopted AI technologies and may have none or very limited experience with AI, the overall 'image' of these new technologies (probably built by the media) forms an optimistic view over their educational potential. Still, we see that slightly less than a quarter of respondents believe in potential danger of AI on children's overall and language development, and another quarter have not formed their steady view on this topic.

These mixed views on benefits and dangers of technologies have been previously demonstrated in studies of more traditional computer- and mobile-assisted early childhood learning environments (Sadykova & Kayumova, 2021; Meskill et al., 2020). However, the proliferation of AI in everyday life of technologically advanced societies has raised new questions related to cognitive, physical, psychological and ethical effects of a child-AI interaction (Bukhalenkova et al., 2021; Mustafaoglu et al., 2018; Veraksa et al., 2021). Therefore, issues related to the digitalization of childhood and specifically AI impact on the well-being of young learners should not be overlooked by experts in early childhood development including physiologists and psychologists. However, these are the early childhood educators who should be first to harness the instructional potential of AI technologies and safeguard children's well-being. As such, it is of utmost importance to provide training in AI to in-service and pre-service educators. Further studies should focus on effective instructional practices that may enable the educator to adapt AI technologies for overall and language development of new generations of young learners that grow up side-by-side with robots, AI-powered games and other smart tools.

ACKNOWLEDGEMENTS

The research was funded by Russian Science Foundation grant # 24-28-01129.

REFERENCES

Alam, S., Usama, M., Alam, M. M., Jabeen, I., Farhan, A., 2023. Artificial Intelligence in Global World: A case study of Grammarly as e-Tool on ESL Learners' writing of Darul Uloom Nadwa. *International Journal of Information and Education Technology*, *13*(11), 1741–1747.

Baker, T., Smith, L., Anissa, N., 2019. Educ-AI-tion Rebooted? Exploring the future of artificial intelligence in schools and colleges. *Nesta.*

Betelin, V. B., Kushnirenko, A. G., Leonov, A. G., 2020. Basic Concepts of Programming Expounded for Preschoolers. *Informatika I Ee Primeneniâ*.

Bukhalenkova, D., Chichinina, E., Chursina, A., Veraksa, A., 2021. The relationship between the use of digital devices and cognitive development in preschool children: Evidence from scholarly literature. *Science for Education Today, 11*(3), 7–25.

Cen, C., Luo, G., Li, L., Liang, Y., Li, K., Jiang, T., Xiong, Q., 2023. User-Centered software design: user interface redesign for Blockly–Electron, artificial intelligence educational software for primary and secondary schools. *Sustainability, 15*(6), 5232.

Chen, Y., Hsu, C., Lin, C., Hsu, H., 2022. Robot-Assisted Language Learning: Integrating Artificial Intelligence and Virtual Reality into English Tour Guide Practice. *Education Sciences, 12*(7), 437.

Dénes, G., 2023. A case study of using AI for General Certificate of Secondary Education (GCSE) grade prediction in a selective independent school in England. *Computers & Education: Artificial Intelligence*, *4*, 100129.

Esfandbod, A., Rokhi, Z., Meghdari, A., Taheri, A., Alemi, M., Karimi, M., 2022. Utilizing an Emotional Robot Capable of Lip-Syncing in Robot-Assisted Speech Therapy Sessions for Children with Language Disorders. *International Journal of Social Robotics, 15*(2), 165–183.

Fitria, T. N., 2021. QuillBot as an online tool: Students' alternative in paraphrasing and rewriting of English writing. *Englisia : Journal of Language, Education and Humanities*, *9*(1), 183.

Ghoneim, N. M. M., Elghotmy, H. E. A., 2021. Using an artificial intelligence based program to enhance primary stage pupils' EFL listening skills. *Al-Mağallaẗ Al-tarbawiyyaẗ (Print), 83*(83), 1–324.

Giddings, S., 2019. Toying with the Singularity: AI, Automata and Imagination in Play with Robots and Virtual Pets. In *Springer eBooks* (pp. 67–87).

Gordon, G., Spaulding, S., Westlund, J. K., Lee, J. J., Plummer, L., Martinez, M., Das, M., Breazeal, C., 2016. Affective personalization of a social robot tutor for children's second language skills. *Proceedings of the . . . AAAI Conference on Artificial Intelligence, 30*(1).

Gulz, A., Londos, L., Haake, M., 2020. Preschoolers' Understanding of a Teachable Agent-Based Game in Early Mathematics as Reflected in their Gaze Behaviors – an Experimental Study. *Int J Artif Intell Educ, 30,* 38–73.

Hashem, R., Ali, N., Zein, F. E., Fidalgo, P., Khurma, O. A., 2023. AI to the rescue: Exploring the potential of ChatGPT as a teacher ally for workload relief and burnout prevention. *Research and Practice in Technology Enhanced Learning/Research and Practice in Technology Enchanced Learning, 19*, 023.

Holstein, K., McLaren, B. M., Aleven, V., 2018. Student learning benefits of a Mixed-Reality Teacher Awareness tool in AI-Enhanced classrooms. In *Lecture notes in computer science* (pp. 154–168).

Huijnen, C. A. G. J., Lexis, M. A. S., Jansens, R., de Witte, L. P., 2017. How to implement robots in interventions for children with autism? A co-creation study involving people with Autism, parents and professionals. *Journal of Autism and Developmental Disorders, 47*(10), 3079–3096.

Irwin, J., 2016. Internet-Connected Toys spark a new era of play. *Kill Screen*. https://killscreen.com/articles/internet-connected-toys-spark-anew-era-of-play/

Ismail, M., Azaman, N. I. L., Khalid, N., 2018. Application of Robots to Improve Social and Communication Skills among Autistic Children. *Journal of Advanced Manufacturing Technology (JAMT), 12*, 421–430.

Johnson, A. M., Guerrero, T. A., Tighe, E. L., McNamara, D. S., 2017. iSTART-ALL: Confronting adult low literacy with intelligent tutoring for reading comprehension. In *International Conference on Artificial Intelligence in Education* (pp. 125-136). Springer.

Kandlhofer, M., Steinbauer, G., Hirschmugl-Gaisch, S., Huber, P., 2016. Artificial intelligence and computer science in education: From kindergarten to university. *2016 IEEE Frontiers in Education Conference (FIE)*.

Keerthiwansha, N. W. B. S., 2018. Artificial Intelligence Education (AIEd) in English as a Second Language (ESL) Classroom in Sri Lanka. *International Journal of*

Conceptions on Computing and Information Technology, 18(6), 31-36.
Kewalramani, S., Kidman, G., Palaiologou, I., 2021. Using Artificial Intelligence (AI)-interfaced robotic toys in early childhood settings: a case for children's inquiry literacy. *European Early Childhood Education Research Journal, 29*(5), 652–668.
Kewalramani, S., Palaiologou, I., Dardanou, M., Allen, K., Phillipson, S., 2021. Using robotic toys in early childhood education to support children's social and emotional competencies. *Australasian Journal of Early Childhood, 46*(4), 355–369.
Kory-Westlund, J. M., Breazeal, C., 2019. Exploring the effects of a social robot's speech entrainment and backstory on young children's emotion, rapport, relationship, and learning. *Frontiers in Robotics and AI, 6*.
Li, Y., 2022. Teaching mode of oral English in the age of artificial intelligence. *Frontiers in Psychology, 13*.
Lin, P., Van Brummelen, J., Lukin, G., Williams, R., Breazeal, C., 2020. Zhorai: Designing a conversational agent for children to explore machine learning concepts. *Proceedings of the . . . AAAI Conference on Artificial Intelligence, 34*(09), 13381–13388.
Meskill, C., Sadykova, G., Kayumova, A., 2020. Mediating digital screens with very young emerging bilinguals. *Bilingual Research Journal, 43*(2), 137–156.
Movellan, J. R., Eckhardt, M., Virnes, M., Rodriguez, A. R., 2009. Sociable robot improves toddler vocabulary skills. *Proceedings of the 4th ACM/IEEE International Conference on Human Robot Interaction (HRI '09)*.
Mustafaoğlu, R., Zirek, E., Yasacı, Z., Özdinçler, A. R., 2018. The negative effects of digital technology usage on children's development and health. *Addicta : The Turkish Journal on Addictions/Addicta : The Turkish Journal on Addictions, 5*(2).
Ng, D. T. K., Leung, J. K. L., Chu, K. W. S., Qiao, M. S., 2021. AI Literacy: definition, teaching, evaluation and ethical issues. *Proceedings of the Association for Information Science and Technology, 58*(1), 504–509.
Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., Qiao, M. S., 2021. Conceptualizing AI literacy: An exploratory review. *Computers and Education. Artificial Intelligence, 2*, 100041.
Ofsted's approach to artificial intelligence (AI). (2024, April 24). GOV.UK. https://www.gov.uk/government/publications/ofsteds-approach-to-ai/ofsteds-approach-to-artificial-intelligence-ai
Polsley, S., Powell, L., Kim, H., Thomas, X., Liew, J., Hammond, T., 2021. Detecting Children's Fine Motor Skill Development using Machine Learning. *International Journal of Artificial Intelligence in Education, 32*(4), 991–1024.
Roy, R., Kuo-Hsun, J., Cheng, S., 2023. Digital divide and youth development in the early Twenty-First century. In *Springer eBooks* (pp. 1–20).
Sadykova, G., Kayumova, A., 2021. Digitalization of language teaching of bilingual children: Practices in Russia and abroad. *Kazanskij Pedagogičeskij Žurnal, 145*(2).
Singh, N., Gunjan, V. K., Mishra, A. K., Mishra, R. K., Nawaz, N., 2022. SeisTutor: a Custom-Tailored Intelligent Tutoring System and Sustainable Education. *Sustainability, 14*(7), 4167.
Steinbauer, G., Kandlhofer, M., Chklovski, T., Heintz, F., Koenig, S., 2021. A differentiated discussion about AI Education K-12. *KI. Künstliche Intelligenz/KI - Künstliche Intelligenz, 35*(2), 131–137.
Suryana, I., Asrianto, A., Murwantono, D., 2020. Artificial intelligence to master English listening skills for non-English major students. *Journal of Languages and Language Teaching, 8*(1), 48.
Underwood, J., 2017. Exploring AI language assistants with primary EFL students. In *CALL in a climate of change: adapting to turbulent global conditions – short papers from EUROCALL 2017* (pp. 317–321).
Vartiainen, H., Tedre, M., Valtonen, T., 2020. Learning machine learning with very young children: Who is teaching whom? *Int. J. Child Comput. Interact., 25*, 100182.
Veraksa, A., Bukhalenkova, D., Chichinina, E., Almazova, O. V., 2021. Relationship between the use of digital devices and personal and emotional development in preschool children. *Psihologičeskaâ Nauka I Obrazovanie, 26*(1), 27–40.
Wijekumar, K. K., Meyer, B. J., Lei, P., 2017. Web-based text structure strategy instruction improves seventh graders' content area reading comprehension. *Journal of Educational Psychology, 109*(6), 741-760.
Yılmaz, F. G. K., Yılmaz, R., 2023. The effect of generative artificial intelligence (AI)-based tool use on students' computational thinking skills, programming self-efficacy and motivation. *Computers and Education. Artificial Intelligence, 4*, 100147.
Zhao, X., 2022. Leveraging Artificial intelligence (AI) technology for English Writing: Introducing Wordtune as a Digital writing assistant for EFL writers. *RELC Journal, 54*(3), 890–894.
Zou, B., Guan, X., Shao, Y., Chen, P., 2023. Supporting speaking practice by social Network-Based Interaction in Artificial intelligence (AI)-Assisted language learning. *Sustainability, 15*(4), 2872.
Zou, B., Liviero, S., Hao, M., Wei, C., 2020. Artificial Intelligence Technology for EAP Speaking Skills: Student perceptions of opportunities and challenges. In *Springer eBooks* (pp. 433–463).

Development of an Online Platform for Enhancing Corporate Cyber Literacy

Danil V. Lazarev[1][a], Natalia I. Pikuleva[1][b], Amina Sh. Khafizova[1][c] and Mariya M. Volkova[2][d]
[1]*Institute of Computer Technologies and Information Security, Kazan National Research Technical University named after A. N. Tupolev – KAI, Kazan, Russia*
[2]*Institute of Management, Automation and Information Technologies, Kazan National Research Technological University, Kazan, Russia*
danil.lazarev.90@mail.ru, pikulevan@inbox.ru, aminahafizova@yandex.ru, shadana@mail.ru

Keywords: Cyber Literacy, Phishing Attack, Online Platform Development.

Abstract: In an increasingly digitalized world, the escalation of cyber threats poses significant risks to organizational security. This article focuses on the development of an innovative online platform designed to enhance corporate cyber literacy. Its primary aim is to educate company employees on the fundamentals of cybersecurity, enhancing their awareness of potential cyber threats and fostering a proactive approach to digital safety. The platform integrates interactive training courses that cover various aspects of cybersecurity, including personal data protection, safe internet use, and phishing attack prevention. Through a comprehensive educational framework, the platform ensures that employees not only understand the theoretical underpinnings of cyber threats but also engage in practical, scenario-based learning. This approach significantly improves the overall cyber resilience of organizations by equipping their workforce with the knowledge and skills necessary to mitigate risks and protect critical information assets effectively.

1 INTRODUCTION

In an era where information technology is becoming an integral part of every aspect of our lives, security threats in the digital space continue to grow, posing a serious risk to organizations. Cyberattacks can have catastrophic consequences, including loss of critical information and damage to finances and reputation.
IBM's 2023 report shows that the average cybercrime loss reached $4.45 million, a 15% increase over the previous three years, and more than half of companies plan to increase their cybersecurity budget after data breach incidents. Analytics from Accenture indicates a 31% increase in cyberattacks between 2020 and 2021.

People often become the weak link in the security chain due to social engineering used by attackers to gain access to sensitive information. This can manifest itself in the form of phishing attacks or fraudulent calls. A lack of risk awareness can lead to the creation of weak passwords or the opening of malicious files, which increases the vulnerability of the organization.
In this context, educating employees on cybersecurity becomes critical to protect companies from cyber threats. Possessing a high level of corporate cyber literacy enables organizations to protect their data, preserve their reputation, and avoid financial losses. Therefore, the development of this area is becoming increasingly important for modern companies.

2 OVERVIEW OF THE SUBJECT AREA

Corporate cyber literacy is the ability of an organization's employees to effectively and safely use information technologies in their work. It includes knowledge of the basic principles of information security, the ability to recognize threats and attacks in

[a] https://orcid.org/0009-0004-5986-7239
[b] https://orcid.org/0009-0002-4561-6303
[c] https://orcid.org/0009-0008-3803-3613
[d] https://orcid.org/0009-0001-3436-2961

the network, and the rules of safe behavior in the digital space.

Key aspects of corporate cyber literacy include:

- Employee training. Organizations should conduct regular information security training and education to increase employee awareness and reduce the risk of potential cyberattacks;
- Development of security policies. Companies should develop and implement strict security policies that define rules for the use of information resources, access to data, procedures for responding to security incidents, etc.;
- Threat Monitoring and Analysis. Organizations must continuously monitor and analyze security threats to respond quickly and prevent potential attacks;
- Legal Compliance. Companies must also comply with information security and data protection legislation to avoid potential fines and violations.

Thus, to cover all aspects, a corporate cyberliteracy training system should include the following core functionality:

- Training materials: providing access to online courses, video tutorials, presentations, and other training materials on information security topics;
- Testing and knowledge assessment: conducting tests and quizzes to test employees' knowledge of cybersecurity issues;
- Interactive lessons: using interactive simulations, games, and cases to train staff in practical security skills;
- Progress monitoring: tracking employee training progress, analyzing test results, and evaluating training effectiveness;
- Expert support: the ability to seek help and advice from information security specialists as part of the training system;
- Reports and analytics: generating reports on training progress, test results, statistics on employee participation in training, and other analytical information.

3 DESIGNING

3.1 Search for Actors and Use Cases

Actor – an acting subject who performs actions directed at others. Fig. 1 shows the main candidates for the actors of the system.

The system includes four roles:

- A system administrator is a system user with the right to administer the system as a whole;
- Company administrator – a system user with rights to administer their companies;
- A company employee is a user of the system with rights to take courses, training with a teacher;
- A company trainer is a system user with the right to train employees within the company.

After analyzing the subject area based on the roles of the system, the following functionality can be identified, as presented in Table 1.

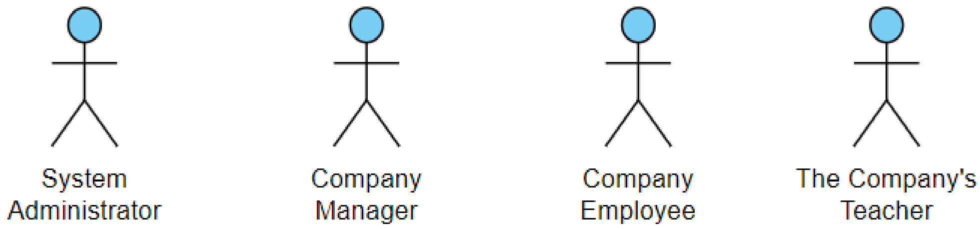


Figure 1: Actors of the system.

Table 1: The functionality of the system.

Actor	Capabilities	Brief description
System administrator	Authentication and authorization	The user can pass authentication and authorization
	Creating, deleting, and editing courses	The user can manage training courses
	Creating, deleting, and editing phishing emails	Users can manage phishing domains, email templates
Company Manager	Registration, authentication, and authorization	The user can pass registration, authentication, and authorization
	Inviting employees	The user can invite their employees to the company
	Reporting and monitoring of course completion	The user can generate reports as well as monitor how workers are being trained
	Creation of study groups	The user can create training groups and add workers and courses to them
	Simulated phishing attacks	Users can create simulated phishing attacks
	Instructor Assignment	The user can assign an instructor to a company
	Creating, deleting, and editing companies	The user can manage their companies
	Scheduling videoconferences	The user can schedule video conferences for their employees
	Adding your slides to the course	Users can supplement courses with their slides
Company employee	Registration, authentication, and authorization	Passing registration, authentication, and authorization
	Course completion	The user can take courses according to the schedule
	Chatting	The user can chat with the group and with the instructor
	Participation in a videoconference	The user can participate in video conferences
The company's teacher	Registration, authentication, and authorization	Passing registration, authentication, and authorization
	Chatting	A user can chat with a group
	Scheduling videoconferences	The user can schedule videoconferences for learners
	Participation in a videoconference	The user can participate in video conferences

All use cases can be represented in the form of a Use case diagram. A use case diagram is the most general representation of the functional purpose of the system. It allows you to understand what actions actors can perform in the system and what functionality the system provides to achieve certain goals. Using a case diagram helps to see the overall picture of user interaction with the system and is the basis for further system design. The diagram is presented in Fig. 2. It shows all roles with their use cases. It should be noted that all actions include authentication and authorization processes.

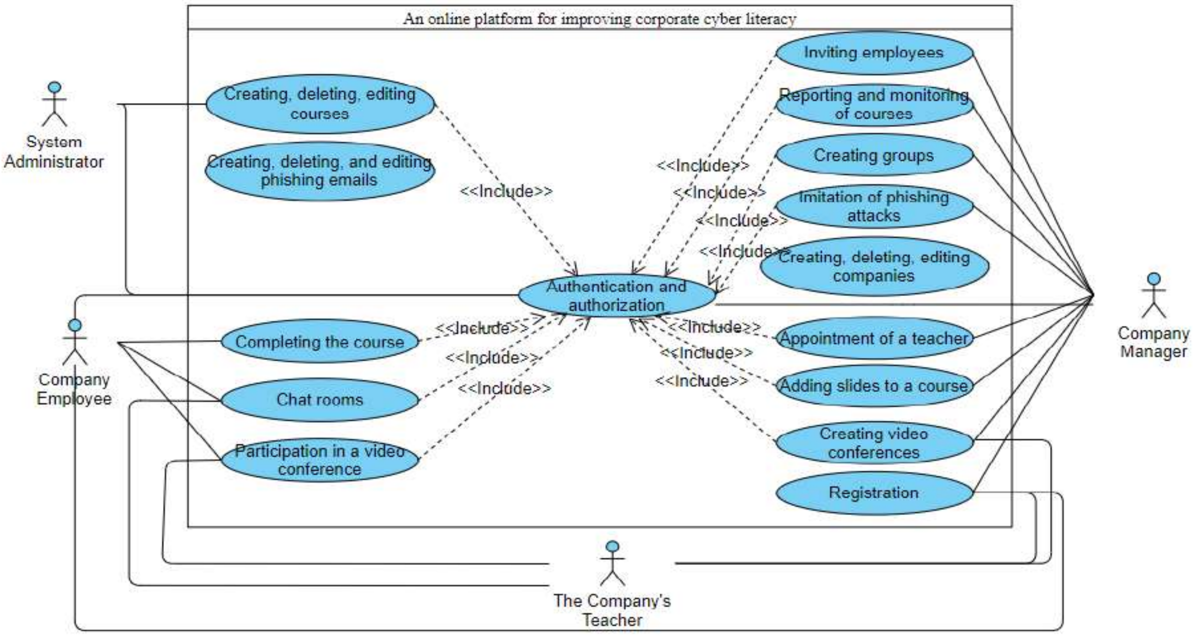


Figure 2: Use case diagram.

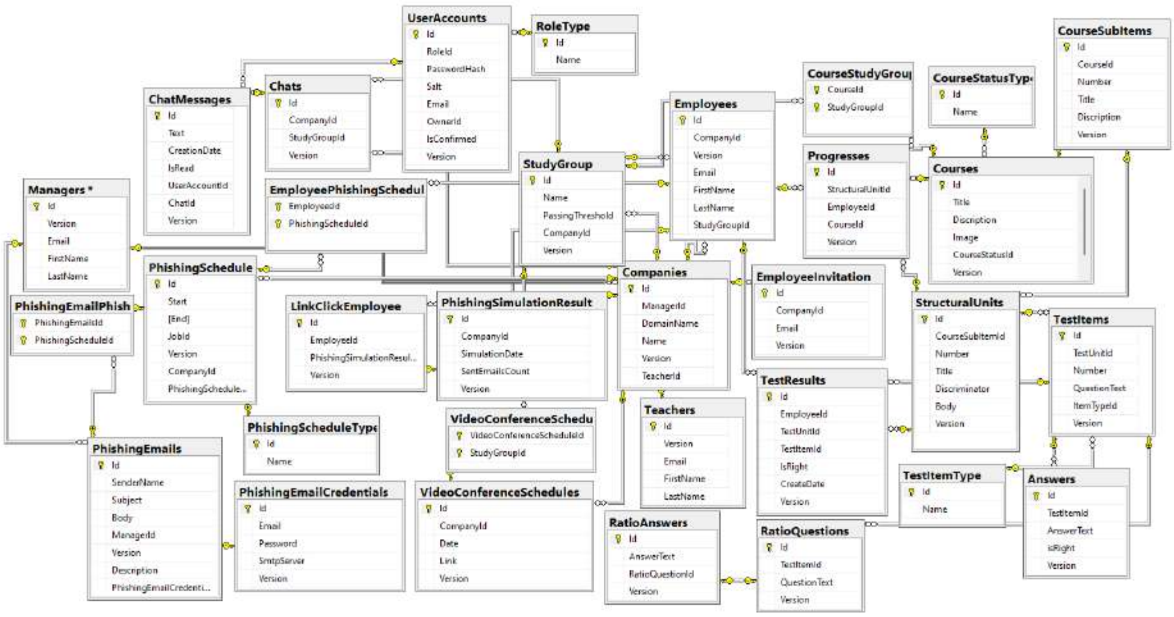


Figure 3: Entity Relationship diagram.

3.2 Conceptual database design

Entity Relationship (ER) diagram is a graphical representation of the database structure that shows entities, their attributes, and the relationships between entities. ER diagram helps to describe the structure of data, define the relationships between different entities, and see how data will be stored and interact in the database. It is an important tool for database design and provides an understanding of the structure of information in the system. Fig. 3 shows the ER diagram of the system.

3.3 Deployment Diagram

A deployment diagram is a diagram designed to describe the placement of components relative to the computing resources involved.

It helps to visualize how the system components are distributed across different nodes and servers and how they are interconnected. The deployment diagram is shown in Fig. 4.

It consists of four nodes:

- The client Device is a node device, which is a personal computer with a browser through which the user can access the online platform;
- A web Server is a device node, which is a server on which an online platform is deployed. The node itself consists of two components: the Backend app and the Frontend app. Both components run on the Windows operating system;
- Blob Server is a device node that is a server for storing files. The node consists of a single component, the S3 server. The component runs in the Windows operating system;
- A Database Server is a device node that represents a database server. The node consists of a single component – MS SQL Server. The component runs in the Windows operating system;

Client Devices can be infinitely many. The "Client Device" and "Web Server" nodes use the HTTP protocol for data transfer. Between "Web Server" and "Database Server" nodes TCP/IP protocol is used for data transfer. Between "Web Server" and "Blob Server" nodes TCP/IP protocol is used for data transfer.

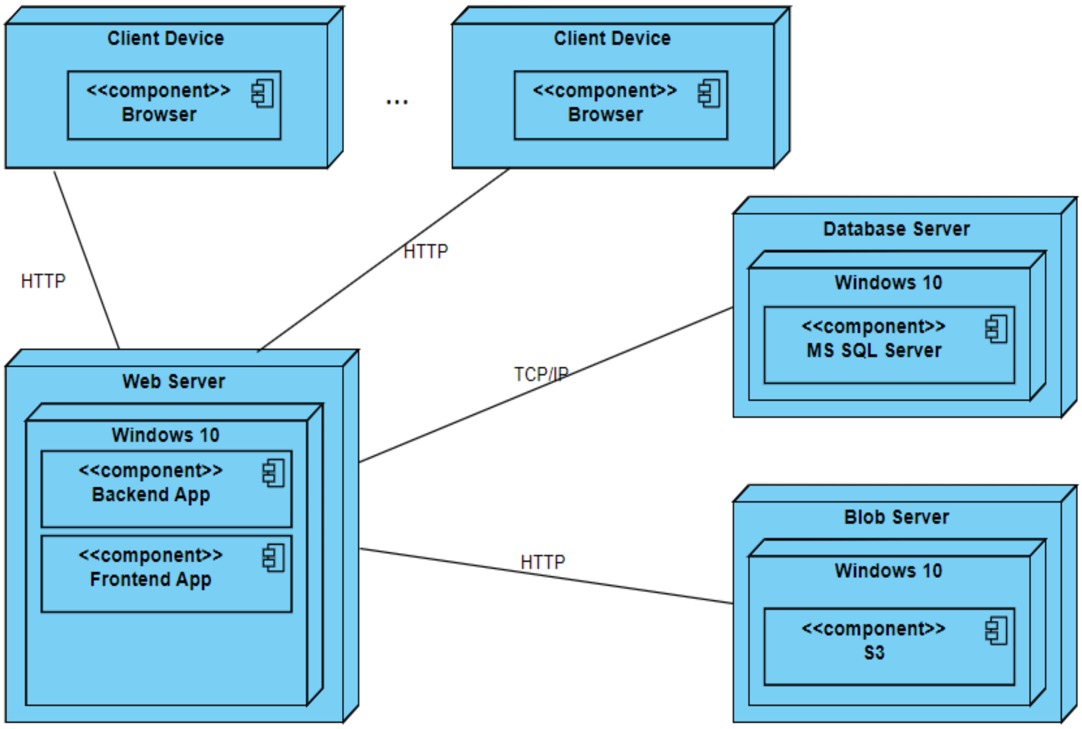


Figure 4: Deployment diagram.

4 TECHNOLOGIES FOR DEVELOPMENT

React will be used to develop the web client. React is a JavaScript library that is used to create the user interface.

MS SQL Server, a relational database management system developed by Microsoft Corporation, will be used as a database. To store files, S3 (Simple Storage Service) will be used – this is a cloud service offered by Amazon Web Services, which allows you to store files of any type and size.

The web server will be written in C# using ASP .NET Core technology and the .NET 8 framework. Key libraries with which the web server will be implemented:

- Hangfire – a multi-threaded and scalable task scheduler;
- MediatR – a simple implementation of the "mediator" pattern;
- AutoMapper is a library that allows you to project one model onto another;
- EF Core is an object-oriented, lightweight, and extensible technology from Microsoft for data access. It is an ORM (object-relational mapping) tool.

5 CONCLUSIONS

In an era marked by the burgeoning complexity and scope of cyber threats, the development and implementation of an online platform dedicated to enhancing corporate cyber literacy is both timely and essential. This platform is presented as a dynamic educational tool designed to equip company employees with the necessary skills and knowledge to effectively navigate and mitigate potential cyber risks. It combines interactive simulations, video tutorials, and real-time assessments into an engaging learning environment that caters to various learning styles.

The platform is adaptive, and regularly updated to include the latest cyber threats and countermeasures, ensuring that the training remains relevant and effective. This continuous evolution is crucial for keeping employees informed about the newest cybersecurity practices and technologies.

Among its core features, the platform integrates interactive lessons and simulations that provide hands-on experience with cyber threats, making the learning process both engaging and practical. It also incorporates continuous assessment tools to track learning progress and ensure knowledge retention and application. The availability of cybersecurity experts who provide advice and feedback enhances the learning experience and offers necessary support. Additionally, comprehensive reporting tools allow organizations to monitor the effectiveness of the training, assess vulnerabilities, and ensure compliance with security protocols.

By adopting this platform, organizations not only strengthen their security posture but also foster a culture of continuous learning and vigilance against cyber threats. This proactive approach is vital for minimizing the risk of data breaches and other security incidents, thereby safeguarding the organization's assets, reputation, and trustworthiness.

In conclusion, the successful deployment of this online platform signifies a strategic advancement in corporate cybersecurity. It furnishes employees with crucial skills and knowledge, thereby fortifying the overall security framework of the organization. As cyber threats grow increasingly complex, such educational initiatives will become ever more critical in ensuring the resilience and security of corporate entities against digital threats.

REFERENCES

Pikuleva, N. I., Khafizova, A. S., Khakov, R. A., 2020. Query processing for heterogeneous data sources in SQL generator. In *2020 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)*, pp. 1-7.

Burris, J. W., 2017. Test-Driven Development for Parallel Applications. In *2017 Second International Conference on Information Systems Engineering (ICISE)*, pp. 27-31.

Pikuleva, N. I., Khafizova, A. S., Gashigullin, D. A., 2021. Event correlation with undefined data. In *2021 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)*, pp. 479-483.

Yogesh, T., Vimala, P., 2020. Test-Driven Development of Automotive Software Functionality. In *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)*, pp. 1162-1165.

Fontela, C., Garrido, A., 2013. Connection between Safe Refactorings and Acceptance Test Driven Development. *IEEE Latin America Transactions* 11(5): 1238-1244.

Gibadullin, R. F., Vershinin, I. S., Minyazev, R. S., 2018. Development of load balancer and parallel database management module. In *2018 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)*, pp. 1-6.

Guerra, E., 2014. Designing a Framework with Test-Driven Development: A Journey. *IEEE Software* 31(1): 9-14.

Amrit, C., Meijberg, Y., 2018. Effectiveness of Test-Driven Development and Continuous Integration: A Case Study. *IT Professional* 20(1): 27-35.
Moe, M. M., Oo, K. K., 2020. Evaluation of Quality, Productivity, and Defect by applying Test-Driven Development to perform Unit Tests. In *2020 IEEE 9th Global Conference on Consumer Electronics (GCCE)*, pp. 435-436.
Dookhun, A. S., Nagowah, L., 2019. Assessing The Effectiveness Of Test-Driven Development and Behavior-Driven Development in an Industry Setting. In *2019 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)*, pp. 365-370.
Viktorov, I., Gibadullin, R., 2023. The principles of building a machine-learning-based service for converting sequential code into parallel code. *E3S Web of Conferences* 431: 05012.
Kozlov, E, Gibadullin, R, 2023. Prerequisites for developing the computer vision system for drowning detection. *E3S Web of Conferences* 474: 02031.
Gorodova, J., Pachina, N., Tkachenko, S., Pachin, G., 2021. Digital Literacy in the Aspect of Continuing Teacher's Education. In *2021 1st International Conference on Technology Enhanced Learning in Higher Education (TELE)*, pp. 220-223.
Yoqubjonov, J., Gibadullin, R., Nuriev, M., 2023. Advanced robotic process automation for enterprise efficiency. *E3S Web of Conferences* 431: 07011.
Kondratiev, V., 2020. Fundamental Changes in Mathematics Education in the Context of Digital Transformation. In *2020 Ivannikov Ispras Open Conference (ISPRAS)*, pp. 75-77.
Shakirzyanov, M., Gibadullin, R., Nuriyev, M., 2023. Prerequisites for the development of the system of automatic comparison of video and audio tracks by the speaker’s articulation. *E3S Web of Conferences* 419: 02029.
Chituc, C. -M., 2022. An Analysis of Technical Challenges for Education 4.0 and Digital Education Ecosystems. In *2022 IEEE German Education Conference (GeCon)*, pp. 1-5.
Gibadullin, R. F., Perukhin, M. Y., Mullayanov, B. I., 2020. Optimization of water supply by the method with model predictive. In *2020 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)*, pp. 1-6.

Consideration of the Method of Borehole Hydraulic Mining in Relation to Gold-Bearing Placer Deposits of Yakutia

V. F. Rochev[1], N. V. Rochev[2]
Technical Institute (branch) North-Eastern Federal University named after M.K. Ammosov in Neryungri, Neryungri, 678960, Russia
viktor-rochev74@mail.ru

Key words: Borehole hydraulic extraction, permafrost, erosion, laboratory, field studies, drilling, experimental installation, indicators.

Abstract: The purpose of the study was a detailed study of the applicability of the use of the method of borehole hydro mining in placer gold deposits, in conditions of the spread of permafrost soils. The main idea of the work was to consider a well-known, little-used, environmentally safe and economically profitable method of developing placer gold deposits. The method is based on the extraction of minerals not by open and underground mining, but with the help of wells. Laboratory studies of the study of this technical solution were carried out on the basis of the Technical Institute (branch) North-Eastern Federal University named after M.K. Ammosov in Neryungri, field experiments on one of the placer deposits of the Iengra River of the Neryungri district. Monitoring of mining operations at each stage is carried out with the help of a software and hardware complex, various measuring instruments and materials, sensors and other materials. Measuring instruments recorded and monitored the frequency of experimental studies according to certain set and obtained parameters, then the data were processed using software. This article presents some results achieved with the help of laboratory and real conditions of experimental reality. Based on the results of the work, the conclusions of the conducted research and the further expediency of further study of the process are made. The methods of conducting the experimental part are described.

1 INTRODUCTION

Mining in Yakutia is mainly carried out by open-cut or underground methods. At the same time, the open-cut or surface method of mining has a negative effect on the environment, while the underground method is very expensive and time-consuming. A replacement for the above methods is the geotechnological method of hydraulic borehole mining, which creates favorable conditions for nature protection and life safety (Arens, Khcheyan, 2001). Using this method of development, we refuse stripping, blasting, and loading operations, avoid dust and gas contamination of the atmosphere, as well as hard work that is harmful to human health.

Based on mining and geological conditions, the most suitable objects for using the method of borehole hydraulic mining (BHM) are gold placer deposits. The sand layer in such deposits consists of sandy-clay-pebble deposits with a small number of boulders. In addition, placers in a thawed state in the warm season are in a watered state, therefore, powerful equipment must be used to lift the pulp. In Yakutia, the placers are mostly in a frozen state, where the top of the gold-bearing formation is quite stable. This makes it possible to extract a large percentage of gold-bearing pulp from the bowels of the earth, which brings this method into the category of inexpensive.

Recently, placers located closer to the surface of the placer are being depleted and buried gold deposits, with a depth of up to 350 m, are becoming more and more in demand. The average gold content in this case is sometimes higher than on the surface and reserves reach several tens of tons. The method of borehole hydraulic mining in these fields will be more acceptable than the others.

[1] https://orcid.org/0000-0001-7429-7263
[2] https://orcid.org/0000-0007-3228-6647

All of the above proves that studying the applicability of the BHM method in conditions is an urgent problem.

In addition, it can be seen from geological materials that there are quite a lot of gold-bearing placer deposits in Yakutia, where the BHM method can be used, but scientific, technical and structural developments of its applicability are necessary.

For the prospect of using borehole hydraulic mining on placers, it is necessary to conduct field experiments, and build mathematical models for various types of deposits in the permafrost zone.

When studying the technology of borehole hydraulic mining, numerous literary sources were studied (Arens, Khcheyan, 2001; Vishnyakov, Khasanov, Khamin, 2017).

The idea of borehole hydraulic mining technology was first put forward in 1936 by research engineer P. M. Tupitsyn. He proved that in some deposits it was more profitable to extract minerals through wells of a certain diameter, without stripping operations (Rukovich, Rochev, 2017).

The rocks located above the pay section are characterized by resistance to collapse and aggregate state. In placers located at great depths, gold is contained in the lower part of alluvial deposits and in any condition the top is unstable. In the frozen state, special conditions are required for the top of the soil, because frozen rocks in the borehole thaw and collapse during mining.

Extensive research experience has been accumulated in the largest institutes of the country on hydromechanized destruction of rocks in open-pit mining using hydraulic monitors. These studies were mainly devoted to finding the relationship between the parameters of the jet from the hydromonitor and the strength characteristics of the soil mass that are being destroyed. In borehole hydraulic mining, it is impossible to obtain a jet with high hydrodynamic characteristics, because the design features of a hydraulic monitoring tool are limited by the diameter of the borehole and the thickness of the formation. To do this, it is necessary to increase the reach of the hydraulic jet during borehole hydraulic mining. The solution to this problem involves adding water-soluble polymer additives to the water, using various types of dampening agents in front of the nozzle, inside it, and (Vishnyakov, Khasanov, Khamin, 2017) installing a mesh with a small mesh size in front of the nozzle. But all this turned out to be not an actual solution.

Theoretically, many scientists and researchers, such as V.Zh. Arens (Arens, Khcheyan, 2001; Arens, Fazlullin, Khrulev, Khcheyan, 2019; Arens, Khcheyan, Khrulev, 2013), A.S. Khrulev (Khrulev, 2002; Khrulev, 2001) and many others (Babichev, Nikolaev, 2000; Britan, 2013; Gevalo, 2019; Ermakov, Burakov, Batugina, 2016; Nicevich, Tsurlo, Yanushenko, 2011; Podoprygorov, 2017; Rochev, 2016; Ashok, 2015; Vishnyakov, Khasanov, Khamin, 2017.) were engaged in mining from boreholes using water pressure. This method is recommended for use in the development of coal and ore deposits (Litvitsev, Alexeev, Kradenykh, 2018; Litvintsev, 2015; Litvintsev, Sas, 2018), amber-containing clays (Malukhin, Mukhin, Vilmis, Shcherbakov, 2013) and other minerals both in thawed and frozen soils, as well as during the construction of underground tanks for storing national products and refrigerators in Arctic conditions.

2 RESEARCH METHODS

2.1 Laboratory tests

Laboratory tests were carried out in the laboratory “Non-traditional technologies” of the Technical Institute (branch) of the North-Eastern Federal University, Neryungri. The test material used was soils brought from various placer gold deposits, which were placed in an experimental installation, which corresponds to the constructed mathematical model (Fig. 1).

The created artificial section of the deposit, which was close to real conditions, consisted of a sand gravel mix with a low content of clay component. The gold in the sands was replaced by magnetite, which corresponded to the geomechanical characteristics.

To create more realistic conditions, sand and peat were frozen to a temperature of -3°C using special heating elements.

A production pipe was built into the borehole using cotter pins and then a supply pipe with a smaller diameter was placed inside. At the top of the supply pipe there were two nozzles: an aqueous solution was supplied into one, and air at a certain pressure into the other. In the lower part there was a hydraulic monitor for washing out frozen rock. The supply pipe was adjustable in depth and rotated 3600. Experiments have shown that when the diameter of the supply pipe nozzles changes from 3.5 and 6.5 mm, the pressure of the aqueous solution is in the range from 0.04 to 0.08 MPa.

If we increase the diameter of the nozzle, the water pressure will automatically increase, the rate of soil destruction will increase, and the percentage of rock uplift will increase (Arens, Khcheyan, 2001). But the extraction of minerals depends on the power of the supply and airlift equipment.

A centrifugal surface pump was used to supply water. The creation of a eddying of the destroyed rock in the borehole and an increase in the speed of water was carried out using a compressor. The mixture was extracted to the surface using a mud pump.

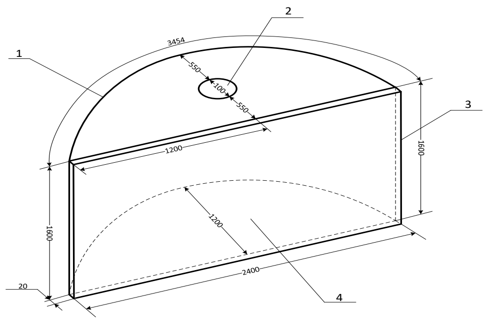


Figure 1: Diagram of a laboratory installation for studying the technology of borehole sand excavation.

where, 1 - removable lid, 2 - borehole, 3 - plexiglass wall for observation, 4 - camera.

A sand-clay-gravel mixture with a moisture content of up to 20% was placed in an experimental installation. Next, the mixture was frozen using columns placed to a certain depth, into which a coolant (freon - 22) was pumped under pressure from the freezing station. The rock was frozen to a temperature of -350C and then thawed to -30C.

2.2 Field studies

Mining is carried out by specialized equipment: drilling, leveling, pipeline, energy, pumping, hydraulic mining, mineral-processing. The main equipment can be purchased and improved, but the rest of the attached and auxiliary equipment must be designed taking into account the mining and technical features of the deposit. Mining by this method consists mainly of an integrated unit, which is manufactured individually for each specific deposit and controlled from the surface.

All mining and control operations for the extraction of a commercial component are carried out from the surface of the site through boreholes using a special ground-based installation. For this purpose, either a drilling rig or a specialized self-propelled or tracked device is used.

The device for extracting pulp in the single-hole version is an assembly of a hydraulic monitor and a pulp lifter made together, or separately, and has a sequential arrangement of pipes. Under complicated conditions, it is sometimes advisable to use the option when commercial components (coal, gold, etc.) should be extracted using two boreholes: production and injection holes. We supply water under pressure into the injection hole through a pumping unit, and air to enhance the destruction effect using a compressor. We suck the pulp out of the production hole and enrich it. We improve the hydraulic monitor device for each field. It is placed on the pay string with the help of hinges and can be moved throughout the borehole in any direction. The hydraulic monitor device consists of a cylindrical pipe, nozzle, barrel, pipe and is located inside the dredger. For each deposit and mineral, its own hydraulic monitors with a length of 0.5; 1.5; 2.5 m are used. To lift the mixture from the borehole, an airlift, a hydraulic elevator, and a dredger are used. When mining from a great depth, this device is made in the form of separately mounted pipes. The lower part, which is directly involved in the destruction, is the hydraulic monitoring device itself, a mechanism for collecting and removing pulp, connected by successive pipes. The upper part is necessary for lifting the pulp to the surface and pumping water and air into the borehole. All necessary resources are supplied through an internal pipeline, and the destroyed component is returned through an additional one.

On the earth's surface, for the hydraulic mining process, a special installation is used that meets the necessary requirements and is used to control the process, move the mining device and pipes, and drill. For these purposes, we can use either a whole complex mounted on a common basis, or stand-alone units working together. As such, it is possible to use a Russian-made drilling rig on tracks or wheels, a soil-suction complex, or a home-made specialized device. These installations must meet the specifics of the field and sometimes work together. The round trip of the mining device in the borehole environment can also be carried out on the basis of the mentioned units.

When developing placer deposits, the main difference between the operation of all units is the large size of the wallrock and valuable rocks and the low density of the transported pulp. When a mineral is located at a great depth, a hydraulic mining tool has several sections: working (lower), intermediate and dispensing (upper).

For Yakutia, it is necessary to use airlift dredgers with a free pulping column for lifting large detrital rocks or with a movable suction tip.

3 RESULTS AND DISCUSSION

3.1 Laboratory tests

At the moment, a wealth of laboratory experimental material has been accumulated. As an example, we present below some obtained averaged dependencies. As a result of experimental studies, it was found that with increasing time, the depth of destruction (Fig. 2) and the radius of destruction (Fig. 3) also increase.

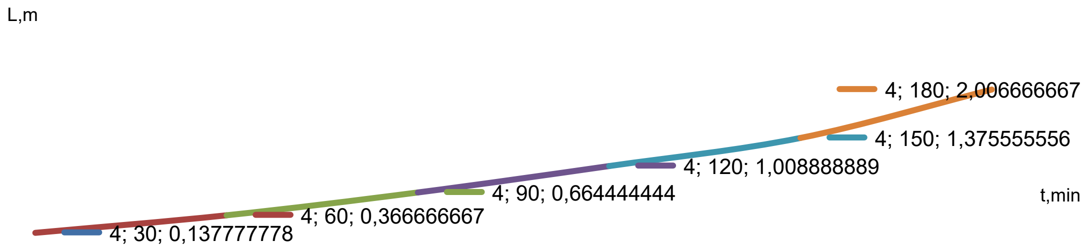


Figure 2: The dependence of the depth of destruction of frozen rocks on time.

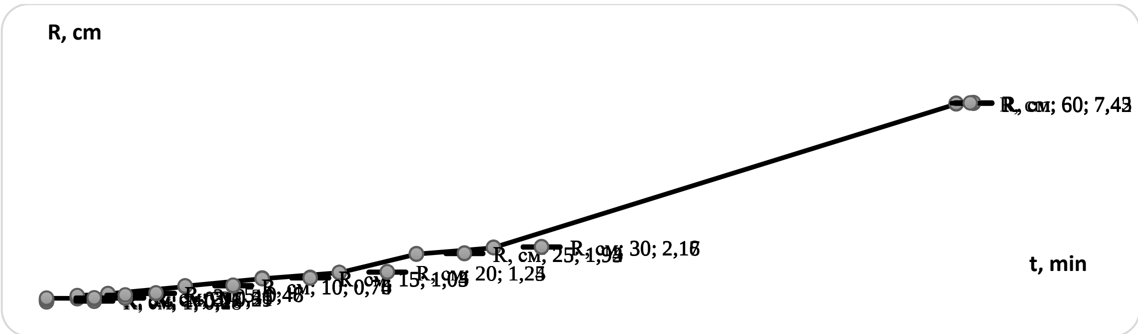


Figure 3: Dependence of the radius of destruction of frozen rocks on time.

3.2 Field studies

The final result of the experimental studies was that a pulp containing gold was raised to the daylight. The hoisting depth was 5-15 meters.

For the soils of some gold-bearing placer deposits in Yakutia, based on field studies, we calculated the main parameters for the application of the borehole mining method.

It is recommended that the drilling of soils be carried out using the rotary-drill rig 2A2 with a distance between boreholes of 40 meters (Fig.4). The upper level in the boreholes was blocked by casing pipes with a diameter of 286 mm, which were held together with couplings.

To lift the pulp, a mining dredger of the SGS-5 type was used, then it was transported through a special pipeline to an industrial device for further enrichment.

The diameter of the lifting pipe is 140 mm, the diameter of the transported pipe is 113 mm. An XAC47 compressor with a capacity of 1.6 to 5 m3/min was used to supply air into the borehole to control the speed of water outflow. A Grundfos CR series delivery pump with a capacity of up to 180 m3/h worked in parallel with the compressor. The water pressure on the hydraulic monitor nozzles with a diameter of 20 mm was 3 MPa, the water pressure on the borehole bottom was 0.6 MPa.

To lift the pulp, an additional suction pump will be used: 8NDv.

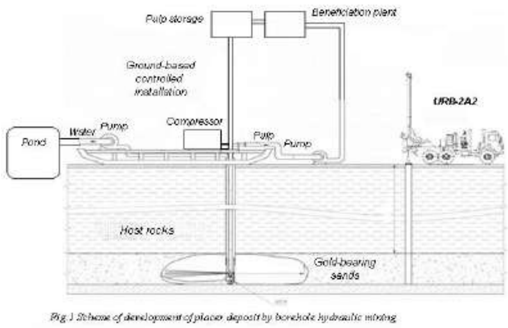


Figure 4: A scheme for the development of a placer deposit using borehole hydraulic extraction.

4 CONCLUSIONS

From the analysis of various sources, it follows that there are many placer deposits containing gold suitable for development of the above method in Yakutia and a sufficient part is unacceptable for development by open-pit and underground methods, which are expensive and not environmentally friendly, and can only be developed using non-traditional methods.

This is shown based on experimental and field studies.

In order to increase reliability and expand the scope of application, the method of borehole hydraulic extraction still requires quite serious scientific work.

REFERENCES

Arens, V. J., Khcheyan, G. H., 2001. Borehole hydro extraction of minerals. M.: Mining book, 293 p.

Arens, V.Zh., Fazlullin, M.I., Khrulev, A.S., Khcheyan, G.H., 2019. Experience of development of buried permafrost placers of gold by borehole hydraulic extraction. *Mining information and analytical bulliten.* No. 1. pp. 26-35.

Arens, V. Zh., Khcheyan, G. Kh., Khrulev, A. S., 2013. Borehole hydraulic extraction of sands with economic use of formed voids in permafrost conditions. *Mining Journal.* No. 10. PP. 79-82.

Rukovich, A.V., Rochev, V.F., 2017. THE USE OF THE METHOD OF BOREHOLE HYDRAULIC EXTRACTION ON PLACER GOLD DEPOSITS OF SOUTHERN YAKUTIA. *Successes of modern natural science.* No. 10. pp. 101-106.

Vishnyakov, A.K., Khasanov, R.R., Khamin, V.A., 2017. Horizontal Wells – the Basis of Innovative Mining. European Association of Geoscientists & Engineers. Horizontal Wells 2017, Volume 2017, p.1 – 5.

Khrulev, A. S., 2002. Technology of borehole hydro extraction of gold from buried permafrost placers: abstract of dis. ... doctor of Technical Sciences. M., 48 p.

Khrulev, A. S., 2001. Features of borehole hydraulic extraction of gold-bearing sands from powerful deep-lying placers. GIAB. No. 9. pp. 142-145.

Litvitsev, V., Alexeev, V., Kradenykh, I., 2018. The technology of development of residue objects of precious metals placer deposits. E3S Web of Conferences. Vol. 56.

Litvintsev, V., 2015. Rational development of noble metal placer mining waste in the east of Russia. *Journal of Mining Science.* No. 51. P. 118–123.

Litvintsev, V., Sas, P., 2018. Current State and Main Directions of Innovative Development of Placer Gold Mining in Far East Federal District. E3S Web of Conferences. Vol. 56.

Malukhin, N.G., Mukhin, Yu.A., Vilmis, A.L., Shcherbakov, Yu.K., 2013. Borehole hydraulic extraction of amber-containing clays of the Palmnikenskoye field beach site. *Gorny information and analytical bulliten.* No. 1. pp. 54-27.

Babichev, N. I., Nikolaev, A. N., 2000. Development of buried placers and deposits of building materials using borehole hydraulic mining. Hydromechanization–2000: Thematic appendix to the GIAB. M.: MGSU, pp. 24-29.

Britan, I. V., 2013. State of borehole hydraulic mining. Crisis or foresight? *Subsurface use of the 21st century.* No. 6. pp. 46-51.

Gevalo, K.V., 2019. Overview of the technology of borehole hydraulic extraction for the development of deep-lying, buried and watered placer deposits. *News of universities. Mining magazine.* No.7. pp. 53-58.

Ermakov, S. A., Burakov, A.M., Batugina, N., 2016. In-line technology of development and enrichment of reserves of buried placer gold deposits in the valley of the Bolshoy Kuranakh River (Yakutia). *Mining Journal.* No. 1. p.

Nicevich, O. A., Tsurlo, E. N., Yanushenko, A. P., 2011. The experience of determining the volume and shape of the production chamber during borehole hydraulic mining. *Mining Journal.* No. 2. pp. 31-35.

Podoprygorov, S.Yu., 2017. Extraction of minerals by means of hydraulic washing of the massif.Topical issues of technical sciences: materials of the IV International Scientific Conference. pp. 67-69

Rochev, V. F., 2016. On the possibility of using borehole hydraulic mining on gold-bearing placers of Southern Yakutia. *Mining Journal.* No. 9. pp. 50-53.

Ashok, A., 2015. Large Hydraulic Direct Drives in Mining Operations. *Engineering and Mining Journal.* P. 52–56.

Vishnyakov, A.K., Khasanov, R.R., Khamin, V.A., 2017. Horizontal Wells – the Basis of Innovative Mining. European Association of Geoscientists & Engineers. Horizontal Wells 2017, Volume 2017, p.1 – 5.

Modern Tools for Strategic Development of the Territory

Kalyugina Svetlana Nikolaevna[1] [1], Mukhoryanova Oksana Anatolyevna[1] [2]
[1]*Department of State, Municipal Administration and Labor Economics, Federal State Autonomous Educational Institution of Higher Education "North Caucasus Federal University", Pushkina str., 1, Stavropol, Russia*
[2]*1Department of State, Municipal Administration and Labor Economics, Federal State Autonomous Educational Institution of Higher Education "North Caucasus Federal University", Pushkina str., 1, Stavropol, Russia*
omukhorianova@ncfu.ru, skaliugina@ncfu.ru

Keywords: strategy, territory development, tools for strategic development of the territory.

Abstract: Over the past 20 years, various mechanisms and tools of territorial development have become a key element in the policy of regional authorities, which has predetermined the need to rank them and select the most effective ones for each territory. However, despite this, there is still a lack of a mature theoretical and practical basis for strategic territorial management, which is primarily due to the abundance of diverse models of spatial management, which are often not coordinated properly and tend to be repeated at different levels. Sometimes regional authorities replace strategic approaches in the management of the territory with more familiar methods, which leads to a deterioration of the management process. In addition, the weak use of strategic methods in regional management hinders the creation of an effective database necessary for scientific analysis and the development of optimal development strategies. To achieve the strategic goals of the development of a certain territory, it is extremely important to classify the tools that are used to regulate it, taking into account the specific objectives and goals of this strategy.

1 INTRODUCTION

In the process of regulating the process of territorial development, the study of external factors influencing this process, as well as strategic guidelines for further transformation, become of key importance. Within the framework of strategic management, this approach becomes fundamental. The selection of effective mechanisms for territorial development contributes to a deep understanding of how local enterprises can penetrate new markets, and includes an assessment of possible dangers associated with the choice of growth directions and certain types of economic activity.

The author's position is that strategic planning is not just a set of tools, but a complex system that integrates procedures for collecting data and using scientifically based methods of analysis to solve problems related to the strategic management of the development of the territory.

2 RESEARCH METHODOLOGY

The purpose of the study is to consider various approaches to the tools of strategic development of the territory used at the present stage of regional development, and to identify the most effective of them in terms of the effectiveness of their use in the strategy of socio-economic development of the regions.

In order to analyze individual tools for the strategic development of the territory, general scientific and specific scientific research methods, methods of logical-methodological, structural-functional and system analysis were used. The following methods of scientific knowledge were also used as part of the study: analogy, induction and deduction, system-situational approach, multiple factor analysis and synthesis, as well as methods of document analysis.

[1] https://orcid.org/0009-0005-6867-4663
[2] https://orcid.org/0000-0002-2997-0110

3 RESULTS OF THE STUDY

In the field of strategic planning, special attention is paid to an individual approach to the development of each individual region, which emphasizes the importance of using tools that take into account the climatic, resource, social and economic characteristics of the territory. Such a policy serves as a leading force coordinating efforts and decisions aimed at achieving the objectives laid down in the strategic plans of a particular region. At the same time, an effectively developed regional policy provides the necessary basis for harmonizing the efforts of all those interested in the development of the region.

In modern Russia, the accumulated experience demonstrates both advantages and certain problems and weaknesses in existing approaches. Thus, in the process of developing regional programs, authorities often face problems such as a lack of clarity in defining goals and objectives, a lack of important metrics for effective monitoring of the achievement of set goals, and ambiguity in the distribution of responsibility for program implementation. To improve this situation, it is reasonable to use strategic approaches to the socio-economic development of the region, taking into account both existing and possible state development mechanisms, based on national projects, federal targeted programs and state initiatives, but at the same time taking into account the potential of each region.

The use of PEST analysis is usually at the center of strategic planning to determine the future of various regions. It provides a unique perspective on how political, economic, social, and technological aspects can influence territorial expansion plans. With the help of PEST analysis, it is possible to develop specific approaches to brand marketing, identify long-term goals and terrain features. In particular, it allows to understand the economic prospects of the industry more deeply, to study market trends and to anticipate potential obstacles to the growth of the industry (Kopylova, 2019).

Information about the current situation of the social and economic sphere, obtained through a detailed study of industry markets in the region, serves as the basis for their subsequent strategic planning. With the help of such data, it is possible to develop strategies to strengthen individual sectors or, conversely, reduce investment in certain areas. The use of Michael Porter's methodology, known as the “five forces of competition,” comparable to PEST analysis in its purpose, makes it possible to assess both the competitive and potential capabilities of a region. A deep understanding of how the five key factors shape the economic structure is critically important to determine how well a region can compete in the market. (Fig. 1).

At the same time, the analysis of the presented model showed its inability to respond quickly to both internal and external influences on the financial well-being and social level of development of the region. The use of SNW analysis can, to some extent, eliminate the problems associated with the "five forces of competition" model, providing an opportunity to assess the strengths and weaknesses of the region according to certain parameters. However, its application also does not allow to fully understand the relationships between the various analyzed aspects or their combined impact on the effectiveness of the strategic development of the region. Consequently, this approach is also insufficient for the formation of a comprehensive assessment of the socio-economic situation in the region and the creation of effective strategies for its further development.

In the context of strategic development, optimizing political approaches to managing the territorial distribution of resources implies the introduction of more precise methods for defining goals and choosing effective means to adjust the economic dynamics of the region in accordance with its long-term interests. There is interest in studying how legislative instruments and institutional mechanisms contribute to the achievement of planned results in the field of spatial development, which is key to improving the quality of territorial planning.

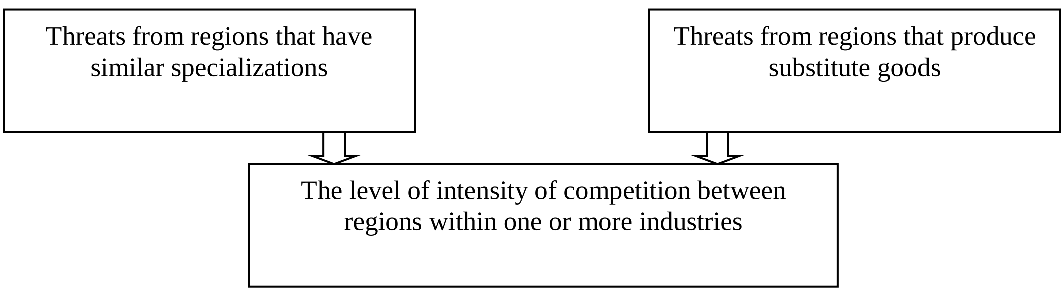


Figure 1: M. Porter's Five Forces of Competition Model from the Perspective of Regional Development (Kopylova, 2019).

Supporting the position of I.N. Domnina regarding the absence of clear criteria in the 2025 Strategy that does not allow building a hierarchy of spatial regulation tools based on the differences in their statuses and target orientations, the authors conclude that it is necessary to revise the institutional foundations for modeling the spatial structure of the economy in the system of strategic planning program documents (Domnina , 2022).

The fundamental tools that set the direction for the state management of economic processes in the spatial aspect are the key regulations. Among them, two Decrees of the President of the Russian Federation stand out, which are of strategic importance: No. 13 dated 16.01.2017 "On Approval of the Fundamentals of the State Policy of Regional Development of the Russian Federation for the period up to 2025" and No. 633 dated 08.11.2021. "On the approval of the Fundamentals of state policy in the field of strategic planning in the Russian Federation."

4 RESULTS AND DISCUSSION

The development of the territorial organization of the Russian economy is based on an innovative approach known as "branches of economic specialization", which recognizes the unique competitive abilities of regions at the international, interregional and local levels. Various methods are used to achieve changes in the geographical distribution of economic activity, including national programs for the development of specialized sectors, as well as investment projects of state corporations and companies with state equity participation. These measures take into account the development strategies of large regions, individual territories of the Russian Federation and local communities.

Strategic plans in national and regional innovation systems play a key role, although they are not deeply rooted in the social structure. These documents actively influence various aspects of the system, including the legal framework, infrastructure, personnel, as well as advisory and financial resources. Among them are various temporary government support measures, such as concessional lending, tax breaks and cost compensation, which are also classified as temporary social institutions in these innovative systems (Strielkowski, Mukhoryanova, Kalnaya, 2022).

Government support tools include a variety of organizations that promote innovation activity. Examples of such institutions include technology parks, business incubators, industrial clusters and engineering centers that combine various industrial enterprises and common use centers. To train and develop specialists in the innovation field, there are higher and secondary specialized educational institutions, resource centers and educational associations. Expert and consulting institutions, which include innovation and consulting centers, subcontracting and technological transformation centers, also play a significant role.

There are a variety of organizations working in the information field, including technology platforms and statistical analysis centers. Investment banks, credit institutions, as well as angel investors and specialized funds that support innovative projects and ventures actively operate in the financial sector.

As part of modern government policy for the development of regions and municipalities, special attention is paid to stimulating private investment in the local economy and building local economic potential. This is emphasized in federal laws, including No. 390-FZ "On Security" dated 28.12.2010 and Law No. 172-FZ "On Strategic Planning in the Russian Federation" dated 28.06.2014, as well as in the Spatial Development Strategy until 2025. The importance of these activities lies in their ability to meet the infrastructure needs of the regions, which is a key aspect of their development. Therefore, the integration of existing and new methods of territorial development with established legal goals and objectives acts as a critically important approach in achieving the designated plans, at least for the period up to 2025.

The main focus in improving the structure of the economic space is aimed at creating fundamental economic nodes within the constituent entities of Russia, while the emphasis is on the development of specialized and future manufacturing industries (Pechkina, 2016).

Within the framework of strategic planning, attention is focused on a key element: the development of the economic field through the architecture of multipolarity, which implies a variety of territories intended for business under unique conditions. It is recommended that management of the economic landscape be approached using extensive tools. These tools include the creation of 12 macro-regions, the identification of economically significant centers, which are classified according to their impact on national GDP (with a contribution range from 1% to 0.2% annually), as well as the development of specialized zones - mineral resources, agro-industrial, scientific and educational centers and investment sites, not to mention the zones with a special "geostrategic" status.

In the context of the formation of an institutional segment aimed at the implementation of spatial development strategies, it is necessary to conduct a detailed analysis of existing approaches to territorial management. When studying traditional and widely used methods of economic organization in a regional context, it is worth highlighting specialized economic regions, such as special economic zones (SEZs) and priority development areas (PDAs). Currently, there are 43 such zones in Russia, including 24 industrial, 7 innovative, 10 focused on tourism and recreation, and 2 port zones (Domnina, 2022).

These zones, which are elements of a regional ecosystem with business privileges, are perceived by government agencies as key tools for stimulating regional development through attracting investments in specialized sectors of the economy in certain territories. In the light of global changes, including international sanctions against Russia, which affect the most important areas of economic activity, including innovative production, investment and exports, special economic zones are adapting to new conditions and can become key players in the process of import substitution and the creation of new production links.

The Russian government has recently made changes aimed at improving conditions for private investment, including simplifying the process of becoming residents of specialized zones. Among other things, the processing of applications for residency has been accelerated - now this process takes only 15 days instead of 40 days, thanks to the signing of a general agreement between the Ministry of Economic Development, management organizations and authorities at the municipal and regional levels. In addition, instead of a detailed business plan, you can now provide an investor's passport. Additionally, it is proposed to reduce the number of special economic zones by combining them from industrial and research into unified industrial and technological ones in order to increase their efficiency.

The main purpose of special economic zones (SEZs) is to stimulate the injection of capital into the infrastructural renewal of certain territories, which differs from the broader foundation associated with geographical planning of economic activity. It is important to note that SEZs do not imply a full-fledged socio-economic transformation within their geographical framework, without focusing on the comprehensive development of the region, which is often not considered as an area of spatial change (Strielkowski, Kalyugina, Astachova, Mukhoryanova, 2023).

Turning to other mechanisms of territorial progress, it is worth mentioning industrial parks and technoparks designed to create conditions that accelerate the launch and implementation of production initiatives, as well as for testing innovative solutions and products.

At the beginning of 2024, 117 technology parks were registered in Russia, 82 of which are operational, 35 are in the process of creation. It is planned to create 7 more technoparks. As for industrial parks, 319 of them are registered now, of which 206 are active, 113 are being created. It is also planned to create 46 industrial parks in the near future.

The formation of Russia's economic space for the long term includes the development of key economic nodes. These nodes may include one or more administrative units that play an important role in promoting the economic progress of both individual regions and the country as a whole. They are expected to contribute to economic growth over a medium- and long-term time interval, as indicated in the document. Nevertheless, the application of this approach to economic structure planning faces certain obstacles.

The 2025 Strategy reflects a new approach to the allocation of public investments, pointing out that a significant number of Russian cities, including regional centers and significant industrial, educational and raw material agglomerations, make a significant contribution to the national economic indicator - GDP. This creates a unique network of economically active zones covering most of the country, and sets the prerequisites for increased competition for federal funds between different regions, stimulating them to fight for development and attract investment.

There are concerns that the current approach to the development of leading economic regions does not fully correspond to the objectives of uniform development of territories and reducing the economic gap between different regions. Unlike other regulatory mechanisms that were described earlier, the key aspect in the identification of these zones is the strategic focus at the national level, the priority of which is not so much investment potential, but rather the maintenance of national security and the unity of the economic space.

Regions recognized as key in the geostrategic context often serve as connecting nodes in the transport network connecting the country's main economic zones with adjacent national borders. These territories play an important role in strengthening economic ties across borders, which contributes to the growth of their economic status. The reality is that federal and regional governments often exercise special management over more than half of the territories of Russia, paying special attention to them. In the context of the development of regional strategies, such geostrategically significant territories often become the basis for the development of primary spatial planning tools.

The element of institutional support, which dynamically adapts to economic fluctuations and is steadily enriched with new components, plays a key role in the organization of spatial development. In particular, testing of innovations in the field of territorial development began in 2019, aimed at enhancing investment activity at the level of federal districts. As part of these efforts, a specialized council was formed in the Central Federal District under the auspices of an investment representative. This initiative is aimed at collecting and implementing best practices in attracting investments from all corners of the district, while preventing any attempts to duplicate projects and inefficient use of resources.

In the regions of Crimea and Sevastopol, a unique mechanism known as special administrative regions (SAR) is used. These zones offer business privileges, ensuring the anonymity of large investors by not including their data in public registers to protect them from sanctions. Thanks to these preferences, large investments are attracted to the regional economy, which makes these tools highly appreciated in the context of regional management and economic development.

In the sphere of regulation of regional initiatives of the state authorities, there is a serious obstacle that puts pressure on the final performance. The problem lies in the simultaneous use of different, but often functionally overlapping, mechanisms in the same territory. Thus, a special economic zone may arise within one industrial park, and a new economically and strategically important project appears on the territory of an existing SEZ. This leads to overlapping of tasks and efforts, which makes it difficult to achieve regional development goals.

5 CONCLUSIONS

Thus, the set of tools for planning the development of regions in the economic sphere should go beyond just developing conditions for priority sectors. It requires a clearer definition, taking into account the tasks facing the general policy of territorial development.

The issue of organizing and managing the economic development of regions through strategic planning is becoming key to the development of modern tools for the strategic development of the territory. In the process of creating strategies, it becomes apparent that aspects of political activity are included in addition to economic aspects, which allows for a more complete understanding of methods for managing territorial development. This expansion of approaches provides a new perspective on spatial development policy.

Defining broad and more specific goals in the field of spatial strategy allows to develop two different regulatory systems that differ in their objectives and methods of achievement. This division is significant from both theoretical and practical points of view, emphasizing the multilevel approaches to managing the development of territories. This approach facilitates the creation of a structured system of economic organizations within a certain territory, preventing repetition. It facilitates the coordination of management mechanisms of various natures and levels, which leads to the successful achievement of predetermined strategic goals in this area.

ACKNOWLEDGEMENTS

The study was supported by a grant from the Russian Science Foundation No. 23-28-10154, https://rscf.ru/project/23-28-10154/.

REFERENCES

Federal'nyj zakon ot 28.06.2014 «O strategicheskom planirovanii v Rossijskoj Federacii» № 172-FZ. URL:https://www.consultant.ru/document/cons_doc_LAW_164841/.

Federal'nyj zakon «O territoriyah operezhayushchego razvitiya v Rossijskoj Federacii» ot 29.12.2014 N 473-FZ. URL:https://www.consultant.ru/document/cons_doc_LAW_172962/.

Rasporyazhenie Pravitel'stva Rossijskoj Federacii ot 13 fevralya 2019 g. № 207-r. Strategiya prostranstvennogo razvitiya Rossijskoj Federacii na period do 2025 g. URL:https://www.consultant.ru/document/cons_doc_LAW_318094/006fb940f95ef67a1a3fa7973b5a39f78dac5681.

Ukaz Prezidenta Rossijskoj Federacii ot 08.11.2021 g. № 633 «Ob utverzhdenii Osnov gosudarstvennoj politiki v sfere strategicheskogo planirovaniya v Rossijskoj Federacii». URL:https://www.consultant.ru/document/cons_doc_LAW_400057/.

Ukaz Prezidenta RF ot 16.01.2017 № 13 «Ob utverzhdenii Osnov gosudarstvennoj politiki regional'nogo razvitiya Rossijskoj Federacii na period do 2025 goda». URL:https://www.consultant.ru/document/cons_doc_LAW_210967/

Domnina, I.N., 2022. Instrumentarij prostranstvennogo strategirovaniya ekonomiki: pravovaya baza i praktika primeneniya. *Ekonomika: vchera, segodnya, zavtra.* Tom 12. № 6A. S. 133-145.

Kopylova, YU.V., 2019. Sistematizaciya instrumentov strategicheskogo planirovaniya social'no-ekonomicheskogo razvitiya regiona. *Fundamental'nye issledovaniya.* № 5. S. 50-56.

Pechkina, E.V., 2016. Metody i instrumenty strategicheskogo planirovaniya regional'nogo razvitiya. *Voprosy ekonomiki i upravleniya.* № 4. S. 78–80.

Semenov, S.S., 2013. Instrumenty strategicheskogo planirovaniya. *Vestnik Krasnoyarskogo gosudarstvennogo agrarnogo universiteta.* №3 . S. 177, 182.

Strielkowski, W., Kalyugina, S., Astachova, E., Mukhoryanova, O., 2023. The role of non-rooted social institutions in the evaluation of the effectiveness of regional innovation systems. *Journal of Institutional Studies.* T. 15. № 3. S. 106-124.

Strielkowski, W., Mukhoryanova, O., Kalnaya, A., 2022. The impact of non-rooted social institutions on the development of national and regional innovation systems. *Journal of Institutional Studies.* T. 14. № 1. S. 70-88.

Sociolinguistic Model of Language Functioning in the Educational Space of a Multiethnic Region (Using the Example of the Republics of Bashkortostan and Tuva)

Salikhova Elvina Akhnafovna[1][a], Kiseleva Larisa Airatovna[2][b], Kuular Elena Mandan-oolovna[3][c], Todosienko Zarrina Vladislavovna[4][d]

[1]*R.G. Kuzeev Institute for Ethnological Research – Subdivision of Federal State Budget Scientific Institution Ufa Federal Research Centre of the Russian Academy of Sciences, 6 K.Marks st., 450077 Ufa, Bashkortostan, Russia*

[2]*Samara National Research University, 34 Moskovskoye shosse, 443086 Samara, Russia*

[3]*State budgetary scientific institution Ministry of Education of the Republic of Tuva "Institute of National School Development", 2 Rabochaya St., 667001 Kyzyl, Republic of Tuva, Russia*

[4]*Foreign Languages, Humanities Faculties, Ufa University of Science and Technology, 32 Zaki Validi St., 450076 Ufa, Russia*

Salelah12@yandex.ru, larisakiseleva2015@yandex.ru, kuular-e-m@mail.ru, venusjupiter@mail.ru

Keywords: indigenous ethnic group; national (ethnic) language; identity; multiethnicity; interethnic communication; bi(poly)linguism; language situation; language policy; multilingual education.

Abstract: The article is devoted to the formation and education of a bi(poly)lingual personality as a social need of modern society. The authors pay special attention to the statistical data of recent years, illustrating the reduction in the number of students studying in their native language in schools in Tuva and Bashkortostan. A sociolinguistic model of the languages functioning in the educational sphere of republics, a characteristic feature of which is multilingualism, is proposed. The authors conclude about the scientific and methodological improvement of language teaching in secondary education: linguodidactic methods and techniques aimed at teaching schoolchildren should help them master the fluency of speech skills in their native language in interaction. One of the effective measures is the organization of multilingual schools, which provide for the creation of a motivating educational environment, the preservation of the national identity, language and residents culture of multi-ethnic regions. Educational institutions of this type need to provide favorable conditions for the multilingual development of creatively developed students who are competitive in various types of activities. As an example, the article describes the experience of a number of multilingual multidisciplinary schools in the Republic of Bashkortostan. In particular, the implementation of this educational model is carried out in two directions: language and information technology. The first direction involves in-depth study of Russian, native and English languages; organization of school subject Olympiads in native and English languages; preparation for international exams in English; organization of language camps. The next direction is based on the study of robotics, programming, 3D modeling, etc. In addition, the authors talk about the need for a well-thought incentive system in teaching the native language, namely a “social order” for a language, according to which a person chooses a means of communication that most contributes to his socialization.

1 INTRODUCTION

In modern conditions of cultural integration, the ever-increasing mobility of people in different countries, active migration flows, expanding employment (in particular, personal and business contacts with foreign partners), tourism development, etc. knowledge of languages becomes a vital necessity.

[a] https://orcid.org/0000-0001-9570-1763
[b] https://orcid.org/0000-0002-4875-6435
[c] https://orcid.org/0000-0002-4351-6547
[d] https://orcid.org/0000-0001-7581-1156

The diversity of bi(poly)lingualism, manifested in different ways in the real conditions of globalization, has a scientific and methodological significance which goes beyond just the structural interaction or functional dispersion of languages. Multilingualism means the language skills of two or more languages or language subsystems and transition from one to another depending on the developing communicative circumstances. In the multilingual conditions of the Republics of Bashkortostan (hereinafter − RB) and Tuva (hereinafter − RT), in which homogeneous and heterogeneous types of bilingualism coexist, we can talk about the formation of a multilingual personality which is a special linguistic configuration, characterized by the interaction of two languages. This is explained by the fact that the cognitive, phatic, emotional and expressive potential of languages provides a bilingual with full access to the information space.

Obtaining a qualitative education increases the need for knowledge of several languages. In this regard, the question naturally arises about the potential capabilities of the multilingual education system in the national entities of the Russian Federation. Thus, based on the available data, N.G. Iskuzhina and Z.F. Shaikhislamova undertook an analysis of the state and prospects for the development of multilingual education in the Republic of Bashkortostan (Iskuzhina, Shaikhislamova, 2023). As for the Republic of Tuva, a number of works by linguists and sociologists have been devoted to the consideration of the characteristics of Tuvan-Russian and Russian-Tuvan bilingualism in recent years (Arefyev, Bakhtikireeva, Sinyachkin 2021; Dongak 2020).

In the general education system in Tuva, mainly two state languages are used − Russian and Tuvan. Foreign languages are studied as a school subject. Decree of the Head of the Republic of Tuva dated August 21, 2023 No. 274 approved the “Strategy for state support and development of the Tuvan language in the period from 2024 to 2033”, within the framework of which one of the main goals in education is the formation and development of the Tuvan-Russian and Russian-Tuvan parity bilingualism as one of the factors ensuring interethnic harmony in society. One of the priority areas of the Strategy in the field of education is the creation of a concept and conditions for the development of a multilingual school by choosing curriculum for primary and basic general education in the native (Tuvan) language and the largest number of hours for studying the native (Tuvan) language and literature. The republic is implementing the state program “Development of state languages of the Republic of Tuva”, approved by Decree of the Government of the Republic of Tuva dated November 8, 2023 No. 815, the purpose of which is to preserve and strengthen balanced Tuvan-Russian bilingualism. According to the above, in this work we would like to focus our attention on considering the main trends and prospects for the use of national (ethnic) languages in the educational sphere of Bashkortostan and Tuva. The relevance of the proposed research is based on the need for an adequate scientific and methodological solution to specific problems related to the education of a multicultural personality. The implementation of this program, according to the authors, will certainly contribute to the activation of integration processes in society.

The purpose of this work is to present, taking into consideration the latest theoretical and empirical data, a sociolinguistic model of the languages functioning in the educational sphere of such multiethnic and multicultural regions of the Russian Federation as Bashkortostan and Tuva. This goal involves solving a number of problems:

1) a general analysis of statistical data that relates to the specifics of education in the Bashkir and Tuvan languages, as well as the study of these languages as native languages in educational institutions of Bashkortostan and Tuva, and the subsequent determination of the role of education in the preservation of the national (ethnic) language;

2) identifying the correlation features of the components of language policy conducted in these regions with the directions of development of national education;

3) establishing trends and prospects in the sphere of multilingual education in the named republics;

4) meaningful synthesis of the obtained data.

2 MANUSCRIPT PREPARATION

The theoretical and methodological basis for the research was a number of works by native scientists, which touch upon a complex of interrelated sociolinguistic problems that have become increasingly relevant in recent years:

– issues of the linguistic situation in the multiethnic regions of the Russian Federation, primarily the functional distribution of the languages of the ethnic groups living in these regions, the sphere and environment of language uses of indigenous ethnic groups, etc. (Ayupova, Iskuzhina, Salikhova, 2021; Turakaev, 2022);

– determination of the characteristic features of bilingualism in multiethnic regions of the Russian Federation in their correlation with the directions of language policy and language construction, carried out both nationwide and within specific administrative-territorial units (Dongak 2020; Borgoyakova 2013; Borgoyakova, Bitkeeva 2020);

– the specificity of the use of languages (primarily national) in the educational sphere of multiethnic regions of the Russian Federation, including the aspect of teaching in native languages and their study as native ones in educational institutions of these regions (Arutyunova, 2018; Bavu-Syuryun 2010).

The object of this study is a sociolinguistic model of the functioning of languages in the educational space of multiethnic regions, in this case, Bashkortostan and Tuva. The subject of the analysis is the structure and qualitative content of this model in its correlation with the directions of language policy implemented in these regions.

The addressing to empirical data relating specifically to these regions is due to a number of reasons:

1) in Bashkortostan and Tuva, an effective language policy is being conducted, aimed at expanding the possibilities of using languages in various spheres of social life and thereby preserving them in a state of communicative suitability;

2) in these entities of the Russian Federation, within the framework of language policy, a set of measures is being taken that are aimed at ensuring the functioning of national (ethnic) languages in the educational space;

3) in the Republic of Bashkortostan, positive experience has been accumulated, which is associated with the implementation of the concept of multilingual education and can be successfully extrapolated to other multiethnic and multicultural regions of the country.

It is in this regard that it seems very interesting and promising to conduct a comparative analysis of the features of the native languages use of indigenous ethnic groups living in Bashkortostan and Tuva in educational institutions of these republics and the subsequent development of a sociolinguistic model that demonstrates the trends in the development of multilingual education in these entities of the Russian Federation.

The research material is a set of documentary sources containing information about the components of the language situation in the named republics and the specifics of the functional relationship of languages in the educational sphere of these regions. These sources include legislative acts, results of sociological surveys and monitoring studies conducted in Bashkiria and Tuva in 2007–2023, etc.

Constructing a model of the functioning of languages in the educational space of Bashkiria and Tuva, the work uses a complex of sociolinguistic methods, such as analysis of written sources, processing of statistical data, correlation analysis, etc.

2.1 The role of education in language preservation

In the multilingual conditions of Bashkiria and Tuva, residents' requests for learning and using a foreign language prevail over the desire and needs to learn and speak the language of their ethnic group. In the historically established multilingual conditions of the named republics, the difference between the Turkic-Russian type of bilingualism is that the Russian language, which has the status of the state language, is the only means of interethnic interaction.

Thus, according to the 1989 census, over 3.5 million people in the RB spoke Russian, i.e. 89% of the total population of the republic, of which up to 1.6 million Russians, about 230 thousand non-Russians who considered it their native language, and about 1 million 700 thousand people for whom it was a second language. Statistical data also show that at that time in Bashkiria, in addition to 99.9% of the Russians themselves, 64% of the Udmurts, 77% of the Mari, 79% of the Bashkirs, 87% of the Chuvash, 93% of the Ukrainians were predisposed to Russian as a native and/or second language , 94% of the Tatars, 95% of the Belarusians, 96% of the Mordovians, 97% of the Germans, 98% of the Jews (Languages of the Peoples of the Republic of Bashkortostan, 2000: 25). According to the 2010 census data, there was an increase in the number of people who speak Russian in Bashkortostan − this is 98.4% of the total population of the region, namely 3 million 938 thousand 63 people, of which 1 million 432 thousand 820 people are representatives of Russian ethnicity. In addition, 45% of people of non-Russian nationality named Russian as their native language.

The vitality of any language is based on its demand in the education system: what is the volume of hours allocated for studying native languages, which languages are the ones of instruction and/or study, etc. The results of sociologists' research convincingly demonstrate the decline in the rating of native languages: for example, 67.08% (340,724) of students chose to study the Bashkir language as the state language of the republic, and this figure, unfortunately, is declining (Salikhova, Kiseleva, 2023).

The reasons for this are both objective and subjective in nature: we can talk, on the one hand, about the incorrect administrative policy of educational institutions when introducing national languages into school curricula, which is also accompanied by poor material equipment of schools (an example of which is the catastrophic shortage of educational resources); on the other hand, about a decrease in students' motivation to master their native literary language.

The fairly high demographic power of the Bashkir and Tuvan languages noted by sociolinguists, a negative language shift is observed among the younger generation of speakers of these languages (Borgoyakova, Bitkeeva, 2020; Salikhova, Kiseleva, 2022). Autochthonous youth often declaratively recognize the language of their nationality as their native language; statistical data regarding ethnolinguistic reality indicate otherwise: young people prefer to choose the Russian language as a means of adaptation to modern demands of society. In other words, there is a shift in language loyalty, expressed in a speech change in the behavior of the Bashkirs, who do not speak their native language fluently, but illustrate "the correct beliefs regarding it".

In Tuva, on the contrary, there is a problem of low level of Russian language proficiency among Tuvan youth: most of the regions of the republic are mononational, they do not have a Russian-speaking environment, which negatively affects the development of communication skills. Hence there are difficulties of social and psychological adaptation among young people who travel outside the republic to study or for military service. Since 2008, teaching the Russian language has become a priority in the educational sphere in Tuva.

The negative dynamics in the functioning of the Tuvan language must be pointed out: almost three quarters of the surveyed native speakers note that its functioning has declined over the past two to three decades. A quarter of respondents believe that the use of the Tuvan language, on the contrary, has expanded. The category of respondents who believe that nothing has changed is 5%. The high symbolic power of the Tuvan language with high linguistic competence was revealed: 83% called the Tuvan language their native language, 10% consider the Russian and Tuvan languages to be their mother tongues, for 7% the Russian language is their native language. 72% of the Tuvans admitted that they were bilingual, 21% chose to answer "more likely yes than no," 4% answered "I don't know," and 3% denied being bilingual. A.N. Bitkeeva (2020) notes that the intergenerational translation of the native language among the Tuvans is preserved, but the emergence of a language shift is observed. Forehanded state support for the Tuvan language, the republican language policy, implemented from 2021, will most likely have a beneficial effect on changing the language shift among the Tuvans.

In Bashkortostan, in comparison with other regions of the Russian Federation, mastery and proficiency of the Russian language has not yet become the reason for the loss of the language of one's ethnic group. Language is recognized by autochthons as a symbol of the linguistic and cultural identity of the individual (Salikhova, Iskuzhina, Nasipov, 2023). At the same time, the loss of motivation in using the native language has led to the fact that it has practically reduced its influence in specific communicative areas. In our opinion, this is quite explainable by the emerging contradiction between the linguistic commitment of the generation of (grand)parents and their actual speech behavior. The fact is that on their part there is no refusal or objection to the transmission of their native language to their children and grandchildren in a family environment, i.e. in natural conditions of language learning. Their choice of interethnic Russian for communication in the family and outside it is because education is conducted on this language. Children acquire their native language – Bashkir or Tuvan – spontaneously (as a rule, in the circle of relatives) with a parallel process of decreasing their level of linguistic competence. Language teaching methodologists note the expediency of reasonable use of the native language at primary schools, based on the actual level of Russian language proficiency of those entering school.

The sociolinguistic model of the languages functioning in the educational space of a multiethnic region should provide reasonable competition between the ethnic languages of autochthons and Russian as the state language at the regional level. It is advisable to take into consideration the real situation of pluralism, which excludes the retrograde position "one language – one people" and pays attention on the importance of the multilingualism of the peoples of the Russian Federation..

2.2 National education and language policy

A regular consequence of the peculiarities of the socio-cultural and economic development of the

Republic of Bashkortostan were significant changes in the education system, also related to the implementation of Decree of the President of the Russian Federation dated May 7, 2021 No. 597 “On measures for the implementation of state social policy”, Decree of the President of the Russian Federation dated 7 May 2021 No. 599 “On measures to implement state policy in the field of education and science”, Decree of the President of the Russian Federation of May 7, 2018 No. 204 “On national goals and strategic objectives of the development of the Russian Federation for the period until 2024”.

By Decree of the Government of the Republic of Bashkortostan No. 690 of November 1, 2022, the Concept for the development of national education in Bashkortostan for 2019–2030 was approved for implementation.

It, according to experts, represents a set of interrelated activities in the field of not only national education, but also language policy in general, since it contains directions for the development of national education in the republic and is designed to satisfy the ethnocultural and linguistic educational needs of students. The project is aimed at updating the potential of national education, while remaining within the regional and Russian educational space.

Taking into consideration the linguistic situation in the RT, then according to the results of the All-Russian Population Census of 2010, representatives of 87 nationalities and nationalities lived in the region, with the most numerous nationalities in the republic being Tuvans (82%) and Russians (16.3%). 98% of the Tuvan population speaks their native Tuvan language (Dongak 2020: 67).

According to the results of the 2020 All-Russian Population Census in Tuva, of the 303 thousand Tuvans living there, 82.35% speak their native language, the same number use this language in everyday life, while 93% of the residents of the republic speak Russian.

From the point of view of teaching the Bashkir language in secondary education, it is regrettable to note a significant reduction in the number of students studying in their native Bashkir language from 52,598 people in the 2007–2008 academic year up to 32,494 in the 2018–2019 academic year (diagram 1). Detailed statistics can also be found in the work of N.G. Iskuzhina and E.A. Salikhova (Iskuzhina, Salikhova, 2021: 327–360).

Diagram 1: Number of students studying in their native Bashkir language in schools in Bashkortostan.

Table 1: Number of students studying mother tongues in schools (2020–2022 academic year).

No.	Studied language	Number of students	%
in the 2020-2022 academic year, 99.4% of students (50,977 people) studied their native languages			
1	Russian	345509	68,2
2	Bashkir	105035	20,63
3	Tatar	46541	9,2
4	Mari	3314	0,65
5	Chuvash	3061	0,59
6	Udmurt	901	0,17
7	Erzya	125	0,024
8	Ukrainian	57	0,011
9	German	416	0,08
10	Belorussian	8	0,0015
11	Latvian	10	0,019

There is a slight increase (+5%) in those who chose to study Bashkir as their native language. The total number of those enrolled in education in their native (non-Russian) language and the study of native languages (non-Russian) is only 31.4%.

For comparison, let us look at the data from the Republic of Tuva Institute for the Development of the language of studying at all levels of general education in the republic is Russian. As for studying in the Tuvan language in general education organizations, there is a negative dynamics of the corresponding student population (Arefyev, Bakhtikireeva, Sinyachkin, 2021: 262) (graph 1).

Graph 1: Proportion of schoolchildren in the RT who studied in the Tuvan language in 1997/1998 – 2018/2019 academic years, in %.

Monitoring results over the past 3 years also indicate a decrease in the number of children studying in their native (Tuvian) language in educational organizations of the RT (Table 2).

Table 2: Number of students studying in their native (Tuvian) language.

No.	academic year	Number (out of 72942 people): 18,764 people – in the field of primary education; 25530 – general education; 3667 – secondary general education	%
1	2021-2022	44349	61,9
2	2022-2023	44384	61,1
3	2023-2024	47961	65,7

The Tuvan language and Tuvan literature are also studied in schools as academic subjects. Thus, in accordance with the requirements of the updated Federal State Educational Standards, Federal work programs have been approved in the following subjects:

– “Native (Tuvan) language” and “Literary reading in the native language” (primary general education);

– “Native language” and “Native literature” (basic general education);

– “Native language” and “Native literature” (secondary general education).

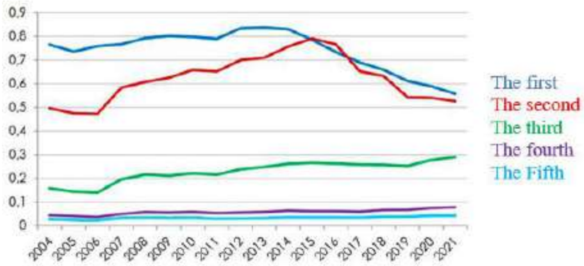
Graph 2: Proportion of schoolchildren in the RT who studied the Tuvan language as native in 1997/1998 – 2020/2021 academic years, in %.

At the same time, the data of a survey conducted through social networks among 2083 people − representatives of the population of the RT (Tovuu, 2022: 1392) are of great interest. The organizers of the survey set out to determine whether the native (Tuvan) language is of value to the interviewees. The information obtained is presented in (Table 3).

Table 3: Attitude of respondents to their native (Tuvan) language.

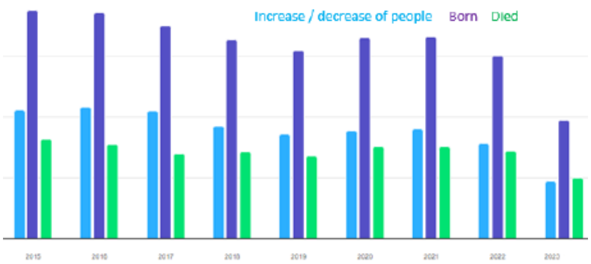
No.	answer	number of respondents	%
1	Tuvan language is a value of the people	1347	64,7
2	Tuvan language is a value in the family	711	34,1
3	often communicate in their native (Tuvian) language in the family	1925	62,2
4	trying to keep communication within the family	769	36,9
5	do not keep communication	19	0,9
6	children learn their native (Tuvian) language	1811	86,9
7	children do not learn	258	12,4
8	do not want to study	14	0,7
9	do not answer	25	1,2
10	wish their children to know their native (Tuvan) language in the future	2053	98,6
11	there is no need to know the native (Tuvan) language	30	1,4
12	the family contributes to the preservation of the native (Tuvan) language	1154	55,4
13	society contributes to the preservation of the native (Tuvan) language	680	32,6
14	educational organization	232	11,1
15	I do not know what contributes to the preservation of the native (Tuvan) language	17	0,9

Undoubtedly, this picture of a decrease in the number of schoolchildren studying in the Tuvan language and studying it as their native language is largely due to objective demographic indicators (graph 3).



Graph 3: Average SKR value for 2019–2021 years by urban districts, 10 municipalities with the lowest and highest rates.

Highly indicative statistical data regarding the dynamics of the population of the RT are presented in (graph. 4).



Graph 4: Natural increase / decrease Tuva population by years.

In this way, in the secondary education level, it seems appropriate to provide scientific and methodological support for language teaching, “improving linguodidactic techniques in order for children to acquire skills in their native language” (Arutyunova, 2018, pp. 28-29). We believe that it is also important to determine the functional directions of national languages development.

2.3 Trends in the development of multilingual education in the Republics of Bashkortostan and Tuva

Taking into consideration the factors discussed above, trends in the field of multilingual education in Bashkortostan and Tuva can be outlined as follows. Thus, the head of the region R.F. Khabirov, at the 1st All-Russian Congress of Teachers of Bashkir Language and Literature, held in 2019, noted the relevance of the emergence of multilingual schools in the republic, associated with their motivating basis for enriching the national identity, language and culture of the peoples of the RB. In this status, from the 2019–2020 academic year in Ufa, “Multilingual Multidisciplinary School No. 44” and “Multilingual Multidisciplinary School No. 162 “SMART” began to function, which later received the status of republican gymnasiums. In addition, “Multilingual Multidisciplinary School No. 23” was opened in Sterlitamak. In the near future, it is planned to open 12 such schools in different regions of Bashkiria. If we keep in mind the specifics of multilingual training in the relevant educational institutions of Bashkortostan, then it includes a number of interrelated components, the implementation of which is carried out at different stages (Table 4).

Educational institutions of this type are faced with difficult tasks related to the preparation of creatively thinking schoolchildren who, in favorable multilingual learning conditions, acquire sustainable skills for self-realization in various types of activities (Arefyev, Bakhtikireeva, Sinyachkin, 2021).

Table 4: Components of a multilingual educational model.

No.	component	stage	description
1	language	preschool	language training in English and native languages
		1-4 grade	English and native languages
		5 grade	+ second foreign language of the student’s choice; subjects of the scientific and mathematical cycle on a bilingual basis − English and Russian according to the Content and Language Integrated Learning methodology
		I-II levels of education	students’ mastery of individual subjects in their native language
			in-depth study of Russian, native and English languages; organization of school subject Olympiads in native and English languages; preparation for international exams in English; organization of specialized, academic shifts and language camps and vacation time
2	information technology	preschool	IT training, study of Lego construction, robotics
		school	robotics, programming, 3D modeling, neural networks

2.4 Discussion

The prospects for multilingual education in Bashkortostan, the linguistic situation of which is characterized by the majority of the population speaking two or three languages, are obvious. Among the primary objectives of the realization of the state program “Preservation and development of the state languages of the Republic of Bashkortostan and the languages of the peoples of the Republic of Bashkortostan” we will designate those aimed at the development of Russian as a state and interethnic language; motivating the younger generation to study their native languages − Bashkir, as well as the languages of ethnic groups living in the region; increasing the level of language literacy of the population .

The status of the state language made it possible for the Bashkir language to expand some of its social and communicative functions. It seems to us that it is important to develop separate standards for school students with a non-native language being studied (Salikhova, Kiseleva, 2023) in order to embody the ideas of multilingualism of a particular individual in real conditions of communicative interaction. Of great importance in this context are the values set in family education and communication, which are closely associated with the participation of (grand)parents in transmitting cultural traditions and knowledge of the language of their people to their children and grandchildren (Arutyunova, 2018: 34).

It should be noted that the choice of language is made on the basis of an parents’ application or legal representatives of the student upon his admission to a preschool educational institution, as well as to the first and fifth grades of general education institutions. Practice shows that parents choose Russian as the language of studying for their children as a state language and a language of interethnic communication.

As for Tuva, the implementation of similar tasks was proposed in the state program “Development of state languages of the Republic of Tuva”. It made possible to create conditions for the preservation of native languages in the educational environment − both Russian and Tuvan. The existing positive dynamics of the proficiency level in the Tuvan language in the republic is associated with the study of the Tuvan as a school subject, which is confirmed by the results of 3 monitoring studies (Tovuu, 2022: 1391). To ensure the opportunity to receive education in their native (Tuvan) language in 2021, by order of the Ministry of Education of the Republic of Tuva (No. 955-d), an experiment was launched in which 440 primary school students (21 classes in total) study the subjects “Mathematics” and “The world around us” in Tuvan language. Federal textbooks on these subjects have been translated into Tuvan.

3 COPYRIGHT FORM

All authors made equivalent contributions to the preparation of the publication. The authors declare no conflict of interest.

4 CONCLUSIONS

In the objectively developing circumstances of the formation of global economic, political, informational, cultural and religious space, the legal status of a language is the determining factor influencing its choice of language. It is known that in the Russian Federation, special attention is paid to the issues of language policy and planning, since they predetermine the functional status of languages in the country and regions, and regulate issues of language construction. The favorable economic situation in the region affects the vitality of the language accordingly. In the presence of conditions on maintaining linguistic competence in the language, there is no need for an ethnic group to migrate. Otherwise, the population is forced to leave the region in search of income. For this reason, the size of the ethnic group is decreasing, resulting in the gradual disappearance of this community, its language and culture. The intergenerational transmission of the native language to children is disrupted, this is especially noticeable in a foreign-ethnic urban environment. In this way, asymmetric bilingualism develops with a consistent transition to the dominant Russian language.

The main goal of the adoption of the Concept for the development of national education in Bashkortostan for 2019–2030, the development of the state program of the Republic of Tuva “Development of state languages of the Republic of Tuva for 2021–2024”, the Strategy for state support and development of the Tuvan language in the period from 2024 to 2033 is to provide favorable and comfortable conditions for the equal development and further functioning of both ethnic (Bashkir and Tuvan) and Russian languages. The authors include the following important features of the linguistic life of both republics:

1) the representation of the Bashkir and Tuvan languages in regional media;

2) the openness of the authorities to solve language problems, as well as their willingness to take into consideration their activities the recommendations of representatives of civil society participating in the discussion of issues related to the preservation and development of languages. This will undoubtedly contribute to the development of balanced bilingualism in the RT and the RB, ensuring the functioning of the native languages of indigenous ethnic groups and maintaining interethnic harmony.

To create conditions for the formation and education of a multilingual (more broadly, multicultural) personality, the project “Multilingual multidisciplinary educational organizations in the Republic of Bashkortostan” was approved. The construction of such environment favorable for learning several languages is based on plans to revive the educational functions of the native languages of the peoples of the republic in particular and the Russian Federation in general, to strengthen the role of the Russian language as an active mediator and catalyst for the dialogue of cultures, to acquire skills in using foreign language speech for the purpose of translation culture of the peoples of the RB into the world community. Similarly, in Tuva, it is provided to create a concept and conditions for the development of multilingual education, within the framework of which it is assumed the choice of curriculum for primary, basic general education with studying in the native (Tuvan) language and the largest number of hours for the native (Tuvan) language and literature.

Support for national languages at the state level should be based on competent, well thought out step-by-step activities, providing stimulating system in the field of teaching the native language. The Bashkir and Tuvan languages are a strategic resource for sustainable ethnocultural development. Taking into account the pragmatic factor that explains a person's choice of means of communication in certain communicative situations will contribute to its successful socialization and adaptation to modern demands of society.

The sociolinguistic model of the functioning of languages in the educational space of a multiethnic region, according to the authors, should be based on the practical implementation of the provisions of language policy, in which minority and majority peoples had the opportunity to receive education in their native languages, while simultaneously mastering the national Russian language, as well as regional and foreign languages..

ACKNOWLEDGEMENTS

The fourth part of this article was prepared within the framework of research work on the state assignment "Historical and cultural heritage of the Southern Urals and the Urals: study, preservation and museumification", No. 122031400062-7 Institute of Ethnological Research named after. R.G. Kuzeev Ufa Federal Centre of the Russian Academy of Sciences for 2022–2024.

REFERENCES

Aref'ev, A.L., Bakhtikireeva, U.M., Siniachkin, V.P., 2021. Problems of bilingualism in the school language education system of the Republic of Tyva. In *New Research of Tuva*. No. 1.

Arutiunova, E.M., 2018. Ethno-linguistic problems and prospects in the educational sphere of the Russian republics (on the example of Bashkortostan). In *Sociological Research*. No. 4.

Aiupova, L.L., Iskuzhina, N.G., Salikhova, E.A., 2021. Language situation as an object of study in sociolinguistics. In *Language mosaic of Ufa*. Ufa, Aeterna, T. 1.

Bavuu-Siuriun, M.V., 2010. Tuvan language at the present stage: educational aspect. In *New Research of Tuva*. No. 3.

Borgoiakova, T.G., 2013. Development of bilingualism in the Republics of Tyva and Khakassia. In *Philological Sciences. Questions of theory and practice.* No. 7 (25): in 2 parts. Part I.

Borgoiakova, T G., Bitkeeva, A. N., 2020. Tuvan language in legal and functional dimensions. In *New Research of Tuva*. No. 1.

Dongak, Ch.B., 2020. Language policy and the problem of contact bilingualism in the national republics of Russia (using the examples of the republics of Tatarstan, Tyva and Sakha (Yakutia). In *Bulletin of Tuva State University*. Vol. 1. Social and human sciences. No. 4 (68).

Iskuzhina, N.G., Salikhova, E.A., 2021. Languages in the field of urban education. In *Language mosaic of Ufa*. Ufa, Aeterna. V.1.

Iskuzhina, N.G., Shaikhislamova, Z.F., 2022. About multilingual education in the Republic of Bashkortostan. In *Sociolinguistics*. No. 1 (9).

Kurtymova, E.A., 2013. Fundamentals of the formation of a bilingual personality in modern society. In *Center for Scientific Cooperation "Interactive Plus"*.

Ochur, N.M., 2015. Development of bilingualism in Tuva schools in the post-Soviet period. In *Tomsk State Pedagogical University Bulletin*. No. 4 (157).

Salikhova, E.A., Kiseleva, L.A., 2022. *Ethnolinguistic space of modern Bashkortostan: a sociolinguistic essay*. Moscow, Flinta.

Sereedar, N.Ch., 2018. Tuvan language as a means of communication among Tuvans: problems and prospects. In *New Research of Tuva*. No. 1.

Tovuu, S.S., 2022. Tuvan language in education: issues of language vitality. In *Oriental Studies*. No. 15 (6).

Turakaev, M.S., 2022. Ethno-linguistic situation as a factor of social well-being of the region in the national republics of Russia (on the example of Tuva, Bashkortostan and Kalmykia). In *New Research of Tuva*. No. 2.

Salikhova, E.A., 2023. Bilingual Polymodal Personality in the Aspect of Intercultural. *Complex Social Systems in Dynamic Environments: Advanced Theories, Innovative Methods and Interdisciplinary Research Results* (book chapter). Cham, Switzerland: Springer Nature, 2023. T. 365.

Building a Framework of Life Safety Concepts

Vera Aksenova[1][a], Sergey Pushenko[2][b] and Lubov Rubizhanskaya[1][c]
[1]*Ural State Law University, Ekaterinburg, Russian Federation*
[2]*Don State Technical University, Rostov-on-Don, Russian Federation*
ver.axenova@yandex.ru, slpushenko@yandex.ru, triazzol@yandex.ru

Keywords: system formation, quality, competences, rating, conceptual framework.

Abstract: The article outlines the peculiarities of concept framework formation of 'Life Safety' in higher education. Moreover, it presents comparative quantitative data on the relationship between the ratings of conceptual framework and the results of mastering the discipline 'Life Safety'. The aim of the current study was to compare the influence of the rating of the conceptual framework on the ratings of mastering the discipline 'Life Safety' according to the pedagogical measurements before and after the introduction of the level scheme of construction of the conceptual framework of the subject. The study found a correlation, its nature and direction, between the rating of the conceptual framework, which was introduced according to the level scheme of conceptualization based on structural-functional, logical and predictive approaches, and the current, credit, and final ratings of mastering the discipline of 'Life Safety'. Pairwise regression equations characterizing the relationship between the independent and dependent variables are given.

1 INTRODUCTION

Any sphere of scientific knowledge is characterized by a set or framework of concepts, which is a system of interrelated and subordinated in various relations to each other meanings, whose cognitive core reflects the belonging to a certain knowledge (Akhmetova 2011).

The processes of integration in science and education generate new thinking strategies corresponding to modern realities, which are becoming increasingly global and multidisciplinary.

'Life Safety' (henceforth, LS) is the science of comfortable and injury-free interaction of a human being with the technosphere. It has been taught to students of all majors of the Ural State Law University (USLU, henceforth), Ekaterinburg, Russia since 2009 and is a compulsory discipline. The subject of study of LS is hazards and their aggregates, acting in the system 'man – source of danger', as well as methods and means of protection from hazards.

LS belongs to the polydisciplinary knowledge, its concepts are based primarily on natural science terms (e.g., '*substance', 'reaction', 'energy', 'mass', 'information'*), general scientific terms (*'system', 'factor', 'phenomenon', 'method', 'means',* to name a few), technical terms (*'technosphere', 'risk', 'hazardous production facility', 'incident', 'accident', 'catastrophe', 'emergency situation'*, etc.), social science concepts (*'human being', 'social group', 'family', 'state'*, etc.). Taking into account the focus of LS, the mandatory concepts include the basic concepts of noxology - the science of hazards of the surrounding world, such as: *'danger', 'source of danger', 'safety', 'protection from danger'*. Noxology, being a section of ecology, studies and systematizes dangerous and harmful factors of the material world, is engaged in the study of the parameters of hazardous zones, qualitative and quantitative assessments of the negative impact on humans and nature. Danger is a negative property of animate and inanimate matter, capable of causing damage to the matter itself: people, natural environment, material values. Hazards always indicate the interaction of two parties: the *subject*, which is the source of danger, and the *object* to which

[a] https://orcid.org/0000-0001-9478-523X
[b] https://orcid.org/0000-0002-3679-7862
[c] https://orcid.org/0000-0002-4345-7962

this negative impact is directed. It is important to emphasize that a person, social group, state and other elements of society are simultaneously the subject and object of social dangers and threats (Kulikovskaya & Bezrukova, 2022; Boyarov & Abramova 2012).

The difficulty in mastering the conceptual framework of LS is the ambiguity of interpretation of the aforementioned concepts both in the scientific community (Bakirov, et al., 2014: Yakupov 2014) and in the current legislation of the Russian Federation.

For instance, in the Criminal Code of the Russian Federation the term ‘danger’ is found in 38 articles of the special part and is used in relation to life and health (dangerous/not dangerous to life and (or) health), property (Art. 168), death (Art. 205, 207), persons (Art. 205.3), environment, plantations (Art. 237, 261), other objects (e.g., a ship - Art. 270, freedom or inviolability - Art. 361). Dangerous, as it follows from the Code, may be actions (e.g. violence, treatment), condition (Art. 125), method (Art. 127.1), disease (128.1), production facilities (Art. 217), objects, substances and other sources (Art. 168, 205.3, 212, 234.1), events, facts, phenomena (Art. 237). Dangers may be serious (Art. 270), potential (Art. 234.1) or increased (Art. 168, 261, 349). Along with the concept of ‘*danger*’ in the Criminal Code of the Russian Federation the terms *‘harm’, ‘threat’, ‘damage’*, etc. are used similar in meaning (Ivanova & Aksenova, 2023).

The wide range of issues that are raised and solved in the process of studying the discipline are closely related to the used conceptual framework. This range comprises such issues as the subject and object of negative impact, the probability of its realization, intensity and time, the degree of completion of negative impact.

When we say *quality of mastering the concepts* of the discipline we mean the assessment of the level of knowledge, skills, abilities, skills and competence on the one hand and the assessment of the quality of the educational process on the other (Kulikovskaya & Bezrukova, 2022; Boyarov & Abramova 2012). We have previously considered the influence of the conceptual framework (CF henceforth) of LS on the quality of education of law students (Aksenova & Pushenko, 2022). We have established that the formation of CF in LS, within the holistic view of the world, allows to succinctly outline the laws of development, which are common to nature, man and society.

The works (Pushenko & Aksenova, 2021: Aksenova & Rubizhanskaya, 2023) provide a comprehensive assessment of the quality of knowledge of law students in the discipline of LS. The assessment was carried out using the educational online portal of the university, the correlation and regression method of analysis was used to assess and predict the educational results of students. It is shown that the CF among other factor attributes, increases the final rating of the student in mastering the discipline of Life Safety. Quantitative indicators of the relationship of the rating of the conceptual apparatus with the current, credit and final ratings of students, given in the paper (Aksenova & Pushenko, 2022), are obtained in the conditions of the requirements for mastering CF within the framework of the basic educational literature and current legislation. The article notes the optimal level of students' performance when performing tasks to reproduce the basic concepts of LS, but the strength of the correlation of this knowledge with the current, credit and final ratings is assessed as ‘weak’.

The problem of the lack of a logically connected CF of LS can be solved using traditional approaches based on the description of genus-species relations (Akhmetova, 2011; Chapaev 2014; Petrov 2021; Titov 2005) and system-structural relations – part-whole (Semenova 2016; Shchekina & Averkina, 2016; Polonskij, 2017). The basic concepts were chosen as the basis for the conceptual and terminological framework of LS. The selection of basic concepts was carried out according to the principles of noxology, system approach and the current legislation of the Russian Federation. We drew students' attention to the essential features of the basic concepts, familiarized them with the rules of formulating the concepts of the second level. Sub concepts are formulated both on the basis of essential features of basic concepts and logical consistency and conciseness. Level III concepts reveal the essential features of the sub concepts, and so on, until the sub concepts begin to overlap or have no distinguishing features from the ‘common’ scientific language reflecting the natural science, technical and legal conceptual systems. An example of the complexity can be seen in Table 1.

Table 1: Levels I-III of the concept ‘Danger’.

I level	№	II level	III level
DANGER negative property of living and non-living	1	natural danger	potential natural danger
			actual natural danger
			realized natural danger
	2	technological danger	potential technological danger
			actual technological danger

matter to cause			realized technological danger
	3	social danger	potential social danger
			actual social danger
			realized social danger
DANGER negative property of causing harm, damage	4	potential danger	potential natural danger
			potential technological danger
			potential social danger
	5	actual danger	actual natural danger
			actual technological danger
			actual social danger
	6	realized danger	realized natural danger
			realized technological danger
			realized social danger

The study was conducted among Bachelor students with the major in ‘Jurisprudence’ who took the mandatory LS course, worth 2 credits or 72 academic hours. The course employed the modular-rating system (MRS). The following indicators were used to do the calculations: benchmark (CF_B), current (CF_C), credit (CF_{CR}) and final ratings (CF_F). The current rating is made up of the ratings of work on seminars (CF_S) and the rating of tests (CF_T). During the seminars, students were engaged in frontal oral questioning on the studied topics, discussion of group research works, performance of tasks using the the online portal. The total assessment of knowledge on these types of work formed the current rating of the seminars (R_S). Of these, the rating of CF_S was formed from the completion of open-type test tasks and "passport of hazards". The rating of tests (R_T) reflected the point value of the student's work on the completion of independent modules, into which all the studied material on LS is divided. The structure of each test included open-ended test questions on the conceptual framework of the module (CF_T).

The credit (R_{Cr}) contained some questions which assessed the knowledge of the conceptual framework of the discipline (CF_{CR}). The final rating of the discipline (R_F) consists of the sum of the current rating (R_C) and the rating of credit (R_{CR}), the final rating of mastering the concepts of LS (CF_F) consists of the sum of the current rating (CF_C) and the rating of the conceptual framework obtained during the credit (CF_{CR}). The distribution of points between these ratings is summarized in Table 2 below.

Table 2: Distribution of point value of task assessment in studying LS by undergraduate students of USLU.

Final rating (R_F) 100 points				
Current rating (Rc) 50 points (CF_C – 11 points)			Credit (R_{CR}) 50 points	
Seminar rating R_S – 16 (CF_C –2)	Test rating R_T – 30 (CF_C –9)	Research works rating R_R– 4	Practice R_{PR} – 30	Theory R_{Th} – 20

To assess the changes in the level of students' CF knowledge before and after the introduction of the level system of building CF LS, a set of data was taken from the academic performance of 675 first-year students studying the Bachelor's programme at the Institutes of Justice (IJ), Institute of Law and Entrepreneurship (IL&E) of V.F. Yakovlev USLU. The experimental group consisted of 339 students, the control group of 336 students.

The requirements to the assessment of CF knowledge within the level scheme of its construction were reduced to the allocation of essential features of basic concepts, logical consistency and conciseness. In the control group, these requirements were reduced to the correspondence of the concept definition to the basic textbook and the current legislation.

2 AIM, MATERIALS AND METHODS

The aim of the current study was to compare the parameters characterising the process of conceptual framework rating formation and its influence on the results of mastering the discipline ‘Life Safety’ according to the pedagogical measurements before (control group) and after (experimental group) the introduction of a systematic approach to the construction of the conceptual framework.

To achieve the goal, the following tasks were set:

1. Assess the indicators of academic performance, quality of knowledge of LS concepts in the experimental and control groups of students;

2. Calculate and compare the strength of correlation of the benchmark rating of the conceptual framework (CF_B) with the ratings of the current, credit and final assessment of knowledge of the conceptual framework (CF_C, CF_{CR} and CF_F) in the experimental and control groups of students.

3.Calculate and compare the strength of correlation of the benchmark rating of the conceptual framework (CF_B) and the ratings of current, credit and final assessment of knowledge in the discipline (R_C, R_{CR} and R_F) in the experimental and control groups of students.

Theoretical methods of the study include the analysis of scientific literature on the problem under study. Empirical methods include the analysis of the impact of CF, taking into account the introduction of a level scheme of its construction and changes in the organisation of the process of current and credit knowledge assessment, on the overall ratings of mastering the discipline. Graphical and correlation-regression methods of analysis are used.

3 RESULTS AND DISCUSSION

3.1 Results

To assess the indicators of academic performance, quality of knowledge and the degree of students' learning of the concepts of LS using the point value of the assessment of tasks during the study of the discipline for each type of tasks were analysed individual ratings of students who scored the number of points in the intervals: [0-39]% with the ‘unsatisfactory’ mark, [40-59] with the ‘satisfactory’, [60-79] with the ‘good’, [80-100] – ‘excellent’ mark. We calculated the absolute performance of students using the formula: (number of [80-100] + number of [60-79] + number of [40-59]) × 100% / total number of students. Qualitative performance of students was calculated using the formula: (number [80-100] + number [60-79]) × 100% / total number of students. The control of CF knowledge in the experimental group was carried out in stages from the benchmark (CF_B) through the current (CF_C) to the credit (CF_{CR}) and final (CF_F) rating. The data of calculations are summarised in Table 3.

Table 3: Indicators of academic performance, quality of knowledge and degree of learning of CF according to the results of pedagogical measurements in the control and experimental groups of students.

	Performance %		Quality of knowledge %	
	Control N=336	Experimental N=339	Control N=336	Experimental N=339
	1	2	3	4
CF_B	78,4	72,0	47,9	35,4
CF_C	82,7	84,0	51,8	38,6
CF_{CR}	93,8	92,3	75,9	55,2
CF_F	92,6	90,3	64,3	36,6

The resulting data show that the indicator of performance in CF mastering in the control group is lower than in the experimental group (columns 1 and 2 of Table 3) at all stages of knowledge assessment. At the stage of the credit, both groups show an optimal level of CF knowledge quality (more than 50%) (columns 3 and 4).

When assessing students' knowledge within the framework of the MRS, it seems reasonable to establish the correlation of independent and dependent variables of the studied ratings. The degrees of strength of the correlation are established by quantitative criteria. These quantitative criteria can be seen in Table 4.

Table 4: The qualitative criteria of strength of correlation.

Value of the correlation coefficient (rs)	Strength of the correlation
more than 0.3	weak
from 0.3 to 0.5	moderate
from 0.5 to 0.7	noticeable
from 0.7 to 0.9	high
more than 0.9	quite high

The correlation coefficient can take values from minus one to one, and at rs=1 there is a direct correlation, and at rs=-1 there is an inverse correlation. If the correlation coefficient is equal to zero, then there is practically no connection between the given values. The closer the absolute value of the correlation coefficient is to one, the stronger the correlation between the variables is (Karaseva, 2016, Knyazeva & Moiseenko, 2019).

We used graphical, correlation and regression methods of analysis to identify the presence of a correlation between dependent (CF_B) and independent variables (CF_C, CF_{CR}, CF_F), its nature and direction. Quantitative criteria for assessing the strength of the correlation between the studied ratings according to the results of assessment are presented in Table 5.

Table 5: Strength of correlation of the ratings according to the results of students' assessment in the control and experimental groups.

	Spearman's rank correlations The correlations are significant at the level p < 0,05 N=675							
	Control group N=336				Experimental group N=339			
	1	2	3	4	5	6	7	8
CF_B	1	0,93	0,22	0,55	1	0,92	0,32	0,68
CF_C	0,93	1	0,29	0,64	0,92	1	0,35	0,74
CF_{CR}	0,22	0,29	1	0,92	0,32	0,35	1	0,90
CF_F	0,55	0,64	0,92	1	0,68	0,74	0,90	1
CF_B	1	0,93	0,22	0,55	1	0,92	0,32	0,68

Using this data, we conclude the following:

1. The influence of the benchmark rating (CF_B) on the current (CF_C) and final (CF_F) in the studied groups does not change, for the former it is rs=0.93 and rs=0.9 – the strength of the correlation **is quite high;** for the latter rs=0.55 and rs=0.68 – the strength of the correlation is **noticeable**.

2. The effect of current rating (CF_C) on the final (CF_F) in the control group (rs=0.64 the strength of the correlation is **notable**) increased compared to the

experimental group (rs=0.74 the strength of the correlation is **strong**). The strength of the correlation of the benchmark (CF_B), current (CF_C) and credit rating (CF_{Cr}) of the conceptual framework increased from **weak** in the control group to **moderate** in the experimental group (see Table 5, columns 1, 2 and 5, 6).

The graphs of the correlation of the final (CF_F) with the current (CF_C) and credit rating (CF_{CR}) in the experimental group are presented in Figure 1.

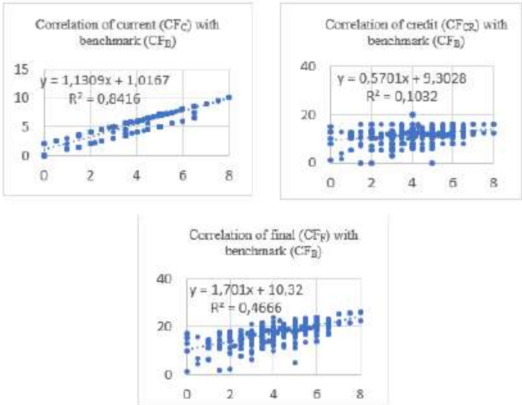


Figure 1: Correlation of current (CF_C), credit (CF_{CR}) and final (CF_F) ratings with the benchmark rating (CF_B) at the end of students' assessment in the experimental group.

The analysis shows close to linear correlation of the indicators, i.e. the higher the scores for CF in the final, current and credit knowledge assessment, the higher the final rating of the conceptual framework. The calculated parameters of regression equations are summarized in Table 6.

Table 6: Parameters of regression equations of the dependent and independent variables in the control and experimental groups.

Variables	Parameters of regression equations			
	Control N=336		Experimental N=339	
	1	2	3	4
	a_0	a_1	a_0	a_1
CF_B&CF_C	1.22	1.05	1.02	1.13
CF_B&CF_{CR}	11.31	0.48	9.30	0.57
CF_B&CF_F	12.53	1.53	10.32	1.70

The results of calculations show that if the CF_B rating is changed by one point in the control group, the values of CF_C, CF_{CR} and CF_F will change on average by 1, 0.5 and 2 points, respectively. When the CF_B rating is changed by one point in the experimental group, the values of CF_C, CF_{CR} and CF_F will change on average by 1, 1 and 2 points respectively (Table 6, columns 1 and 4).

To evaluate the influence of the conceptual framework assimilation on the ratings of the final, current and credit assessment of knowledge in the discipline (R_C, R_{CR} and R_F) we used the correlation-regression method of analysis. We calculated the strength of correlation between the dependent variables (rating of benchmark assessment of knowledge of LS concepts (CF_B)) and independent variables (ratings of current, credit assessment of students' knowledge (R_C, R_{CR}) and the final rating of mastering the entire volume of materials on the discipline (R_F)) in the control and experimental groups. The data are summarized in Table 7.

Table 7: Comparative data of the strength of the correlation of the studied ratings according to the results of students' performance in the control and experimental groups.

№	Variables	Spearman's rank correlations The correlations are significant at the level $p < 0,05$ N=675			
		Control group N=336		Experimental group N=339	
		CF_B	R_F	CF_B	R_F
		1	2	3	4
1	CF_B	1	0,55	1	0,56
2	R_B	0,39	0,79	0,67	0,83
3	R_C	0,31	0,88	0,63	0,92
4	R_{CR}	0,18	0,86	0,36	0,85
5	C_F	0,55	1	0,56	1

From this data we can make the following conclusions:

1. The strength of the correlation between the rating of the conceptual framework (CF_B) and the ratings of the final and current assessment of knowledge in the discipline (R_B, R_C) increased from **moderate** in the control group to **noticeable** in the experimental group (lines 2 and 3: columns 1, 3). The closeness of the relationship of the benchmark rating of conceptual framework (CF_B) and the rating of the credit (R_{CR}) increased from **weak** in the control group to **moderate** in the experimental group (line 3, columns 1 and 3). The strength of the correlation between the benchmark rating of conceptual framework (CF_B) and the final rating (R_F) in the studied groups did not change and remained at the **noticeable** level (line 5, columns 1 and 2).

2. the strength of the correlation between the final rating (R_F) and ratings of the final and credit assessment of knowledge in the discipline (R_B and R_{CR}) in the studied groups has not changed and remained at the **high** level (lines 2 and 3; columns 2 and 4).

3. the strength of the correlation between the final rating (R_F) and the current rating of the discipline (R_C) increased from **strong** in the control

group to **very strong** in the experimental group (line 3, columns 2 and 3).

Graphs of the correlation of final (R_F), benchmark (R_B), and current (R_C) ratings on the benchmark rating of conceptual framework (CF_B) in the experimental group of students are presented in Figure 2.

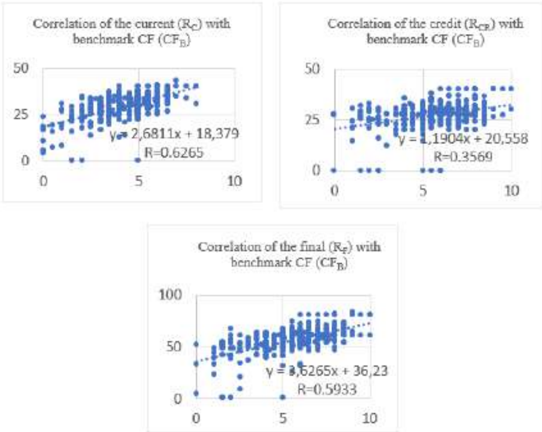


Figure 2: Correlation of current (R_C), credit (R_{CR}) and final (R_F) ratings with the benchmark rating (CF_B) at the end of students' assessment in the experimental group.

The analysis shows the presence of a close to linear correlation of the studied ratings, i.e. the higher the marks for CF in the current knowledge assessment, the higher the values of current (R_C), credit (R_{CR}) and final (R_F) ratings of mastering the discipline as a whole.

The parameters of regression equations of dependent (CF_C) and the independent (R_C), (R_{CR}) and (R_F) assessment of students in the control and experimental groups are summarized in Table 8.

Table 8: Parameters of regression equations at the end of the assessment of the dependent and independent variables in the control and experimental groups.

Variables	Parameters of regression equations			
	Control N=336		Experimental N=339	
	1	2	3	4
	a_0	a_1	a_0	a_1
CF_B&R_C	26,52	1,22	18,37	2,68
CF_B&R_{CR}	28,97	0,65	20,18	1,19
CF_B&R_F	50,11	2,32	36,23	3,62

The results of the calculations show that if the CF_B rating is changed by one point in the control group, the R_C, R_{CR} and R_F values will change on average by 1, 1 and 2 points, respectively. When the CF_B is changed by one point in the experimental group, the R_C, R_{CR} and R_F values will change by 3, 1, and 4 points on average, respectively.

3.2 Discussion

According to the data of pedagogical measurements of individual ratings of students, both in the experimental and control groups, we can observe a **high** level of performance in studying the concepts of LS (92.6% control and 90.3% experimental) groups. The quality of knowledge decreased from **optimal** (64%) in the control group to **acceptable** (37%) in the experimental group. Along with the traditional reasons for the decline in performance such as lack of motivation, low interest in the subject, insufficient amount of time devoted to studying the material (2 credits), it is necessary to pay attention to the increase in the labour intensity of mastering CF after the introduction of a systematic approach. The student should reproduce the basic concepts of LS on the basis of the principles and concepts of noxology, identify the derivatives of the basic concepts on the basis of the essential features of the latter and reproduce them. When solving this task, in addition to the knowledge of principles and concepts of noxology, terminology of natural science and social science, it is necessary to know and apply the laws of logic.

The strengthening of the correlation of the benchmark (CF_B), current (CF_C) and credit assessment rating (CF_{CR}) in the experimental group compared to the control group, indicates that understanding the process of constructing sub-concepts on the basis of a systematic approach, compared to mechanical memorization, allows the student to reproduce the concept more easily in the framework of credit knowledge assessment.

Changing the rating (CF_B) by one point in the control group will change the values of CF_C, CF_{CR} and CF_F on average by 1, 0.5 and 2 points respectively, while in the experimental group, the values of CF_C, CF_{CR} and CF_F on average will change by 1, 1 and 2 points respectively (Table 6, Figure 1).

Changing the rating (CF_B) by one point in the control group, will change the values of R_C, R_{CR} and R_F on average by 1, 1 and 2 points, respectively, while in the experimental group, the values of R_C, R_{CR} and R_F on average will change by 3, 1 and 4 points, respectively (Tab. 8, Fig. 2). With the application of a systematic approach to the construction of concepts, there is an increase in the influence of the rating (CF_B) on the current (R_C) and final (R_F) ratings of mastering the discipline. These results indicate the need to strengthen the connection between (CF_B) and the rating of credit assessment (R_{CR}). To solve the problem, it seems necessary to change the assessment materials base used to test the knowledge of LS concepts in the credit. This will lead to the strengthening of the correlation of the benchmark and final ratings of the conceptual framework and, as a consequence, to the strengthening of the correlation of the benchmark rating of concepts and the rating of the credit.

4 CONCLUSIONS

With the introduction of a systematic approach to mastering the concepts of LS, the strength of the correlation between the ratings of conceptual framework (CF_B), current (CF_C), credit (CF_{CR}) and final (CF_F) ratings of student achievement increased and moved into the categories of **moderate** and **noticeable**.

The calculated parameters of the regression equations show the following values:

– a_0 (1.22; 11.31 and 12.53) allow us to estimate the average effect of factors not selected for the study on the outcome variables;

– a_1 (1.13; 0.57 and 1.70) show that when the rating of the conceptual framework (CF_B) changes by 1.0 point, the values of CF_C, CF_{CR}, CF_F ratings will change by 1, 1 and 2 points on average, taking into account rounding.

With the introduction of a systematic approach to mastering the concepts of LS, the strength of the correlation between the ratings of the conceptual framework (CF_B), current (R_C), intermediate (R_{CR}) and final (R_F) ratings of student achievement increased and moved into the categories of **moderate** and **noticeable**.

The calculated parameters of the regression equations show the following values:

– a_0 (18.37, 20.18 and 17.30) allow us to estimate the average effect of factors not selected for the study on the outcome attributes;

– a_1 (2.68; 1.27 and 3.38) shows that if the rating of the conceptual apparatus (CF_B) is changed by 1.0 point, the values of the ratings of R_C, R_{CR}, R_F taking into account rounding, will change on average by 3, 1 and 3 points.

REFERENCES

Akhmetova, L. V., 2011. Formation of students' conceptual framework in the study of natural science disciplines. *Bulletin of Tomsk State Pedagogical University, 6*, 155–160. (In Russ.)

Aksenova, V.I., Pushenko, S.L., 2022. Influence of the conceptual framework on mastering the competencies of the discipline of LS. In *Collection of scientific articles VII All-Russian meeting of heads of departments in the field of life safety and environmental protection and open session of the Federal Educational and Methodological Association "Technosphere safety and environmental engineering" Kazan September 21-25, 2022*. Kazan: KNITU-KAI Publishing House, 31–37.

Aksenova, V.I., Rubizhanskaya, L.Yu., 2023. Assessment of the results of mastering the discipline "Life Safety" using the capabilities of the educational portal of the university. *Bulletin of Mari State University*, vol 17(2), 149–157.

Bakirov, I. K., Khaliullina, D. X., Kashapova, G. X., 2014. Analyzing the concept of risk, hazard and safety. *General issues of fire safety, vol. 23* (3), 8–10.

Boyarov E. N., Abramova S. V., 2012. Noxological approach in the content of education of Life Safety educators. *Pedagogical education in Russia, 4*, 111–116.

Chapaev, N.K., 2014. Didactics of V.V. Davydov: philosophical and pedagogical prerequisites for the development of the method of ascent from the abstract to the concrete. *Innovative Projects and Programs in Education, 3*, 3–12.

Ivanova, E.V., Aksenova, V.I., 2023 To the question of the concept of danger and ways of its establishment. *Vesnik kriminalistiki* 'SPARK Publishing House', 2, 5–15.

Karaseva, A. E., 2016. Mathematical methods in modeling and diagnostics of students' research activity. *Electronic network polythematical journal "Scientific Works of KubGTU", 5*, 267–281.

Knyazeva, E. V., Moiseenko, V. S., 2019. Mathematical methods as a toolkit for psychological and pedagogical research. *Humanization of Education, (5*), 34–46.

Kulikovskaya, M.A., Bezrukova, N.P., 2022. Noxological competence of bachelors of pedagogical education of natural science profiles and means of assessment of its formation. *Modern problems of science and education, 1*.

Petrov, A.V., 2021. Some methodical aspects of the problem of formation of scientific concepts in school and university students. In *MODERN EDUCATION AND PEDAGOGICAL HERITAGE OF ACADEMICS A.V. USOVA Chelyabinsk*, International Scientific and Practical Conference. Collection of materials. Volume Part 1, 30–36.

Polonskij, V. M., 2017. Concept-terminological apparatus for pedagogy and education. In: *Nauchnyj rezul'tat. Pedagogika i psihologiya obrazovaniya*, 3(2), 54–60.

Pushenko, S., Aksenova, V., 2021. Competence approach in teaching the discipline "Life safety and environmental protection." *E3S Web of Conferences*, 258, 07082.

Semenova, I. N., 2016. Formation of the conceptual framework of the technique and technology of training in the conditions of technologization of educational process. In: *Vestnik TGPU, 4* (169), 86–91.

Shchekina, S. S., Averkina, G. V., 2016. Logical-methodology aspects of studying the conceptual and

terminological system of pedagogy. In: *Ponyatijnyj apparat pedagogiki i obrazovaniya*, *9*, 121–135.
Titov, A.V., 2005. Basis and procedure of selection of basic concepts of technological education. In *Innovative processes in education and problems of improving the quality of specialist training:* Proceedings of the International scientific and methodical conference. Izhevsk: Udmurtian Un-te, 225–229.
Yakupov, A.M., 2014. On the nature of danger and safety, forms of their manifestation and "survivability zones" of systems. *Current problems of the Russian transportation complex, 5*, 67–72.

Solar Energy for Cottage Construction

Oksana Paramonova[a], Natalya Samarskaya[b] and Ekaterina Lysova[c]
Department of Environmental Engineering, Don State Technical University, Rostov-on-Don, Russian Federation
paramonova.o@gs.donstu.ru

Keywords: Solar Energy, Alternative Energy, Cottage Construction, Use of Solar Energy, Energy Supply, Solar Panel, Hybrid Solar Inverter, Photovoltaic System.

Abstract: The article is devoted to the study of the process of solar energy conversion and selection of the optimal design of a photovoltaic solar system for an individual cottage located in the city of Taganrog, Rostov region. The use of renewable energy sources in the private sector is relevant due to the following problems: frequent interruptions in the supply of electricity due to the low category of power supply, losses of electricity due to wear and tear of networks, the use of power consumption restrictions for territories of the private sectors. Thus, a properly selected system for using an alternative energy source in a certain area with its climatic and landscape characteristics can become a solution to the above problems, as well as one of the elements of a regional strategy, which determines relevance of the chosen research topic.

1 INTRODUCTION

In Russia, natural non-renewable resources are actively used to provide electricity to residential buildings, various types of industries and other infrastructure facilities of the country. By 2040, such needs will double due to the development of technology and industry, which could lead to an energy crisis and, as a result, higher prices. An increase in emissions into the atmospheric air, pollution of the hydrosphere and lithosphere when using traditional fossil fuels will lead to health problems among the population and other environmental disasters (Shchinnikov et al., 2020; Saidov and Sadykov, 2020). Therefore, the active development of technologies based on the use of renewable energy sources (hereinafter referred to as RES) such as solar and wind energy, water and earth energy, and the use of low-potential energy sources is obvious (Pilyaeva, 2017; Østergaard et al., 2020; Maradin, 2021).

Despite the fact that "green" energy is not so developed in Russia, the state sets certain goals and strategies for it (Maximov, 2020). Currently, there are a number of power plants operating in Kaliningrad, Orenburg, Belgorod, and Rostov regions and geothermal energy facilities in Kamchatka Territory and Sakhalin Region.

The main problems of active development of this area for large objects are (Sukhoruchkina and Otroshchenko, 2016; Degtyarev and Solovyov, 2022; Dyatlov et al, 2020):

- uncompetitiveness of stations using alternative energy sources;
- lack of a complete regulatory framework;
- low level of investment;
- lack of highly qualified personnel.

The identified problems can be partially solved with the help of state support in the early stages of projects until they pay off.

As for the private sectors, the use of renewable energy sources there is also very important, since there are a number of nuances:

- frequent interruptions in the supply of electricity due to the low category of electricity supply;
- losses of electricity due to wear and tear of networks;
- use of power consumption restrictions for private sector areas.

A properly selected system for the use of alternative energy sources in climate, landscape and

[a] https://orcid.org/ 0000-0002-7854-6703
[b] https://orcid.org/ 0000-0003-2117-4221
[c] https://orcid.org/ 0000-0001-6575-5568

weather conditions can become a solution to the problems discussed above, as well as one of the elements of a regional energy strategy, which proves the relevance of our chosen research topic (Smil, 2012.).

The topic of using renewable energy sources is gaining increasing popularity in the scientific community. This topic was reviewed by the following authors: Tychkov A.Yu., Katkova K.A., Chernyshev N.D., Sidyakina A.Yu., Vissarionov V.I., Deryugina G.V., Kuznetsova V.A., Shchinnikov P.A., Nozdrenko G.V., Borush O.V., Ovchinnikov Yu.V., Pugach L. I., Tomilov V.G., Borodikhin I.V., Elistratov S.L., Lovtsov A.A. and many other researchers.

The purpose of the study is to select the optimal technical solution for energy supply to a cottage located in Rostov region.

2 RESEARCH METHODOLOGY

To achieve the formulated aim, the following tasks were set and solved:

- justification of the relevance of the research topic;
- analysis of energy consumption facilities (cottage) and energy supply (area of cottage location);
- selection of optimal energy supply technology based on comparative analysis;
- justification for choosing a design solution for energy supply technology.

To conduct the research, various scientific methods were used, which were based, first of all, on the analysis and synthesis of natural science knowledge with technical experience. The combination of these methods is adequate to the goals and objectives, subject and object of study of this work.

3 RESEARCH RESULTS

The object considered in the work is located in the city of Taganrog, Rostov region. Consequently, at the first stage of research, an analysis of the climatic characteristics of this area was carried out.

Taganrog is located in the northwestern part of Rostov region and is an industrial city. The city's climate has a transitional character from mild continental to subtropical due to the Taganrog Bay and the Miusskiy Estuary.

The topography of the city is mostly flat, the slope is no more than 0.2% in the eastern and southern directions. There are also erosion forms in the form of hollows and winding beams, as a result of decompaction of the cover loess-like loams.

During the year, the air temperature has a difference of 32.2 ^{0}C. The coldest month is January, the air temperature warms up to -2 ^{0}C. The warmest month is August with air temperatures up to +30.2 ^{0}C. The temperature gradient is discussed in detail at Figure 1 and Table 1.

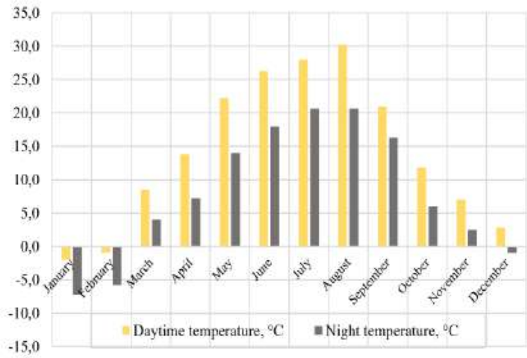


Figure 1: Temperature gradient, °C, Taganrog.

To study the amount of solar radiation and ultraviolet index in the city, data obtained from a weather station installed in the city center was analyzed. The total amount of solar radiation by month is shown in Table 2. The data in Table 2 showed the highest radiation in the summer in June, July and August.

Based on the weather station information, we present the ultraviolet index for each month (Figure 2).

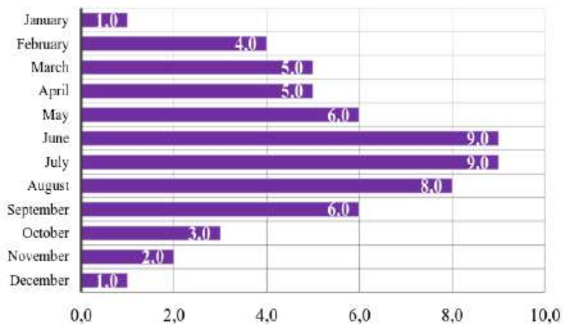


Figure 2: UV Index, Taganrog.

From Figure 2 it can be seen that critical values of the ultraviolet index are reached in June and July.

The results of the study of the number of sunny, cloudy days and the number of days with partly cloudy weather are shown in Figure 3.

Table 1: Average air temperature by month of the year, °C, Taganrog.

The average monthly air temperature, °C	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
During the day	-2.0	-1.0	8.5	13.8	22.2	26.2	28.0	30.2	21.0	11.8	7.0	2.8
During the night	-7.2	-5.8	4.0	7.2	14. 0	18.0	20.6	20.6	16.3	6.0	2.5	-1.0

Table 2: Average solar radiation intensity, W/m^2, Taganrog.

Solar radiation intensity, W/m^2	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
	2108	4872	8618	11220	15345	21180	22785	20212	13050	9951	5370	3968

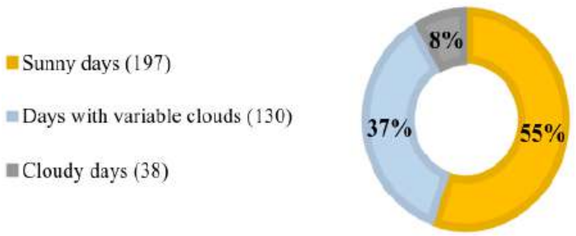


Figure 3: The number of sunny, cloudy days and the number of days with variable clouds, Taganrog.

The following are the results of assessing the amount of precipitation during the year (Figure 4).

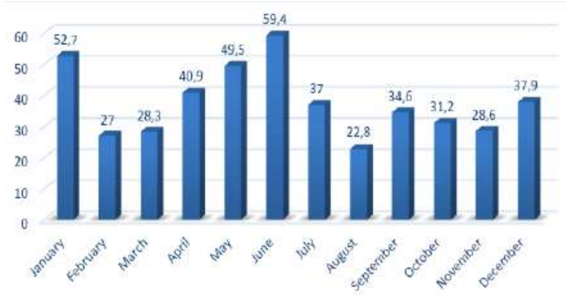


Figure 4: The amount of precipitation by month of the year, mm, Taganrog.

From Figure 4 it can be seen that the maximum monthly precipitation falls in June and is 59.4 mm.

The wind regime as a percentage of the average speed for the winter period is presented in Table 3.

The wind regime as a percentage of the average speed for the summer period is presented in Table 4.

The constructed wind rose for the winter and summer periods (Figure 5, 6).

The analysis of the energy supply facility, that is, the territory under study, allowed us to conclude that this territory is promising for the use of solar energy.

Table 3: Wind regime for the winter period, Taganrog.

Wind mode parameters	The rhumb							
	North	Northeast	East	South-East	South	Southwest	West	Northwest
Repeatability of wind directions, %	4	14	33	10	4	12	17	6
Average wind speed, m/s	3.4	5.8	8.8	4.8	3.3	4.0	4.1	3.1

Table 4: Wind regime for the summer period, Taganrog.

Wind mode parameters	The rhumb							
	North	Northeast	East	South-East	South	Southwest	West	Northwest
Repeatability of wind directions, %	13	13	20	5	3	12	23	11
Average wind speed, m/s	3.4	4.0	4.4	3.2	2.3	3.5	3.8	8.3

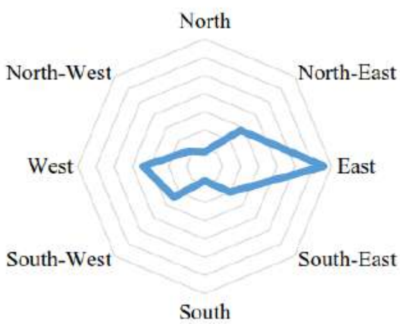


Figure 5: The wind rose for the winter period, Taganrog.

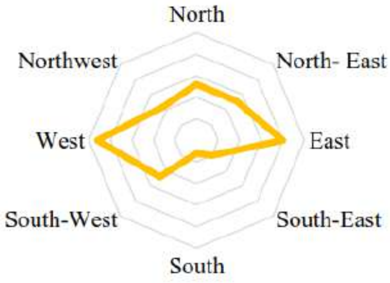


Figure 6: The wind rose for the summer period, Taganrog.

The object of energy consumption is a residential individual cottage. Category of land where the object is located: land of settlements (land of settlements) for the placement of individual housing construction projects. Specified land area: 413 m^2. In the northern direction at a distance of 2.5 m there is a one-story residential building, in the southern direction at a distance of 6.2 m there is a roadway, in the western direction at a distance of 2.1 m there is a single-story residential building, in the eastern direction at a distance of 1.7 m residential one-story house. The development of the territory under consideration is quite dense.

The total building area of the house is 286.44 m^2. On the ground floor there are 4 rooms, a garage and a veranda, on the second attic floor there are 4 rooms and a storage room. The house is designed for a number of residents of four or more. The electricity consumption of an individual cottage directly depends on its size and the number of people living in it. So, for example, one person can consume from 800 kW·h to 1600 kW·h, and a family of four or more from 1400 kW·h to 4700 kW·h. This range is explained by the method of electricity consumption and the energy consumption of available household appliances.

We calculated the electricity consumption consumed by each household appliance in the house and the average time of its use (Table 5).

The total monthly electricity consumption when using an air conditioner in the warm season will be 1635.45 kW·h. During the heating season, when using an electric boiler, consumption will be 2529.45 kW·h.

Table 5: Energy consumption of household appliances in an individual cottage.

Name of the device	Number of devices, pcs.	Power, kW	Working hours per day, h	Consumption per day, kWh	Consumption per month, kWh
Refrigerator	1	0.20	24	4.8	144
Microwave	1	1.00	2	2.0	60
Electric kettle	1	0.70	1	0.7	21
Dishwasher	1	1.20	1	1.2	36
Multicooker	1	1.00	2	2.0	60
Food Processor	1	2.00	0.5	1.0	30
Electric stove	1	2.50	4	10	300
Coffee Maker	1	0.75	0.25	0.2	6
Vacuum cleaner	1	0.60	0.5	0.3	9
TV	1	0.30	5	1.5	45
Iron	1	1.10	0.25	0.275	8.25
Conditioner	2	2.60	7	18.2	546
Computer	1	0.20	5	1	30
Lighting (lamps of 60 watts each)	27	1.62	7	11.3 4	340.20
Electric boiler	1	4.00	12	48	1440

The total electricity consumption for the year, $\sum E_{total}$, kWh/year, can be found using the following expression:

$$\sum E_{total} = E_{summer\ period} \cdot n_i + E_{winter\ period} \cdot n_j + E_{stable} \cdot n_k, \quad (1)$$

where $E_{summer\ period}$ – the amount of electricity consumed in the summer using an air conditioner, kW·h;

n_i – number of months in summer using air conditioning;

$E_{winter\ period}$ – the amount of electricity consumed during the heating period, kW·h;

n_j – number of months in the heating period;

E_{stable} – stable electricity consumption per month without the use of air conditioning and an electric boiler, kW·h;

n_k – number of months with stable electricity consumption.

Let's calculate the total electricity consumption for the year:

$\sum E_{total} = 1635.45 \cdot 3 + 2529.45 \cdot 6 + 1089.45 \cdot 3 = 23351.4$ kW·h

Based on the obtained values, we can conclude that the annual energy costs for maintaining an individual two-story cottage are quite large, so its maintenance will be expensive, especially during the heating season.

At the next stage of the study, to select the optimal energy supply technology, we analyzed the alternative sources available on the territory of the location of the residential individual cottage. The following types of alternative energy were accepted for consideration: solar, wind, bio-, hydro- and geothermal energy.

The sun is an inexhaustible source of energy that can be converted into electricity or used as a source of thermal energy. Electricity can be generated directly using photovoltaic cells or indirectly using concentrated solar power technology (Hayat, 2019).

Solar energy has wide applications in various industries: in agriculture, primarily for water purification and irrigation, used for charging electric vehicles and for domestic purposes such as heating rooms or providing electricity for appliances used in everyday life (Hayat, 2019).

However, the biggest challenge facing the future of solar energy is its unavailability year-round, coupled with high capital costs and shortages of solar cell materials. These problems can be solved by developing an efficient energy storage system and developing cheap and efficient photovoltaic solar cells.

Assessing the practice of using solar energy-based technologies, the following advantages can be highlighted:

- long service life;
- no noise;
- no negative impact on the environment;
- availability.
- Among the shortcomings, the most significant are:
- long payback period;
- in some cases, insufficient efficiency;
- dependence of work on weather conditions.

For residential properties, solar energy can reduce appliance costs by reducing the load on electrical grids. Technological equipment using solar energy will not occupy large areas in a densely built-up city and will not disturb residents in the neighborhood with high noise levels. For an individual cottage, this is the best option for using alternative energy sources.

Wind energy is considered the most developed area compared to other areas. Wind energy technology is based on the ability to capture energy contained in air movement. The power of the wind determines the rate at which this kinetic energy is extracted. The efficiency of wind energy extraction is a balance of slowing the wind while maintaining sufficient flow (Samarskaya et al., 2023).

The advantages of using wind power plants include (Samarskaya et al., 2023):

- no polluting emissions into the atmosphere;
- location of the working elements of the installation at a high altitude;
- ability to use in isolated areas;
- minimal maintenance.
- Disadvantages of using wind power plants:
- dependence on weather conditions;
- high costs for start-up capital;
- distortion of natural landscapes;
- presence of aerodynamic noise.

For our energy consumption facility, the location of a wind power plant within the city is not practical due to its scale and noise during operation. Wind systems can be used for larger objects, but for an individual cottage such construction will not be economically viable.

Hydropower is based on a simple process that uses the kinetic energy released by falling water. In practice, this process is applied in many different ways depending on the required electrical energy production and the specific conditions of the construction site using dams, hydraulic turbines, hydro generators (Egré and Milewski, 2002). Such systems can provide electricity to large areas and have a huge, cost-intensive scale.

Advantages of hydropower:

- independence from fuel suppliers;
- cheap electricity;
- ability to regulate the power of hydroelectric power plants.

Disadvantages of using hydropower:

- possibility of land flooding;
- unnatural changes in river channels;
- water vapor emissions;
- large scale;
- Possibility of use only in certain hydrological conditions of the regions.

Our study examines the possibility of using alternative energy sources within one residential private household. Hydropower is used for larger scale research. Therefore, this type of renewable energy source is not suitable for us.

Bioenergy plays a large and growing role in the global energy system, but is resource intensive and only scales up when using vast areas of land. Because of limited land resources, initially low energy output per unit land area, and rapid technological advances in competing technologies, bioenergy makes most sense as a transition element in the global energy mix, playing an important role over the next few decades (Reid et al., 2020).

Advantages of bioenergy:

- continuity of biofuel production;
- possibility of efficient use of waste;
- great potential in agro-industrial areas;
- less emissions into the air than when using traditional energy sources (gas, oil, coal).

Disadvantages of bioenergy:

- use of large scale land areas, which may affect the ecological balance;
- when biofuel is burned, sulfur oxides enter the atmospheric air;
- difficulties in transporting and storing solid biomass.

Bioenergy is limited in its use. Suitable for agriculture and industry, where relevant production waste is generated to create fuel (agricultural waste, crop production waste, food industry waste, wood waste), and the free space allows for placement of biogas plants, processing equipment, pyrolysis plants (Reid et al., 2020). As a consequence of this, this method of energy generation is inappropriate for the energy consumption object we have chosen.

Geothermal energy involves the use of heat from the bowels of the Earth and sources of geothermal waters that are accessible to humans (geysers). Most often, geothermal stations are located in seismically active areas; it is necessary to monitor the awakening of volcanoes, earthquakes and soil movement. Many countries are developing geothermal energy, for example, New Zealand, Kenya, Iceland, and Russia.

Advantages of use:

- large reserves and production of electrical energy;
- significant savings on fuel;
- cost-effectiveness in maintenance.

Disadvantages of use:

- use only in certain conditions;
- coolant temperature is not less than 150 °C;
- difficulties at all stages of design (obtaining a construction permit, searching for areas suitable for the conditions);
- stopping work at any time.

Taganrog is a seismically inactive city; there are no volcanoes or geothermal waters at a temperature suitable for generating energy. Geothermal energy is also aimed at application on a large scale, for example, a city or town. It is impossible to take it for further research.

Based on the results of the analysis, we can conclude that for an individual cottage located within dense buildings, solar energy technologies are most suitable. Based on the results of a study of an energy supply facility, it was found that sunny days predominate in the city of Taganrog (55%), and solar radiation ranges from 2108 W/m^2 to 22785 W/m^2 per month. Consequently, according to all placement conditions, we can use photovoltaic solar panels to provide electrical energy to the selected energy consumption facility.

Currently, there are several design solutions for solar panels. We will choose three of them and conduct a comparative analysis of their designs for the purpose of further application at the energy consumption facility under study.

Among the wide variety of elements from which photovoltaic panels are made, silicon elements are the most widespread:

- monocrystalline (efficiency – 21.5%);
- polycrystalline (efficiency – 17%);
- amorphous (efficiency – 8%).

A feature of monocrystalline panels produced using silicon (monocrystalline) is the uniform color of the surface of the working plate.

This appearance is due to the peculiarities of production, as a result of which all the constituent elements become identical in appearance.

The main advantages of such designs of photovoltaic panels are:

- high efficiency (modern modules have an efficiency of up to 22%);
- take up minimal space compared to other types of solar panels;
- durability guaranteed by manufacturers from 25;
- work in low light, the quality of which depends on the manufacturer.

The disadvantage of such designs is the cost. Monocrystalline modules are the most expensive on the market of similar designs.

The next type of design solutions is polycrystalline silicon elements. Solar cells produced from polycrystalline silicon cells are made by melting and pouring into ready-made molds to cast the raw materials. Next, the cooled blocks are divided into plates of standard sizes, having the correct square shape. The result is low-cost, easy-to-use polycrystalline modules.

The most important advantages of such structures are:

- production cost, because the process of growing polysilicon is much simpler and less energy-intensive;
- less affected by temperature than monocrystalline modules.

In addition to the advantages of the structures under consideration, the following disadvantages have been identified:

- low efficiency due to the low purity of silicon in the polycrystal. Modern polycrystalline modules have an efficiency of 15-18%.

- large required area to accommodate the structure.

In addition to classic monocrystalline and polycrystalline panels, amorphous silicon solar cells began to become very popular several years ago. With the beginning of the transition to thin-film manufacturing technology, the productivity of amorphous solar panels has increased significantly. Currently, their use is quite widespread.

Amorphous solar panels are a flexible film surface made of amorphous silicon. Such designs are excellent for use in areas with frost. The production of flexible panels is based on spraying technology. Hydrogen silica is sprayed in a very thin layer onto a special substrate. The substrate material is most often stainless steel, but glass, ceramics, and polymers can also be used. The sprayed layer is covered with protection.

Taking into account the above features, we can highlight the following advantages of such design solutions:

- high efficiency;
- affordable price;
- slight heating in hot weather;
- minimal risk of manufacturing defects;
- easy installation.

Among the main disadvantages are:

- low efficiency;
- unreliable top coating;
- large panel size.

In addition to the considered designs of solar panels, film batteries based on cadmium telluride, copper-indium selenide and polymers are also known, but they still cause controversy regarding toxicity and disposal without harming the environment.

The variety of design solutions for solar panels poses a question of choice to the consumer. Therefore, the next stage of the study was the selection of the optimal design solution for energy supply technology based on a patent search for Russian inventions.

The best, in our opinion, design solution, the basis of which is the use of photovoltaic panels, is the autonomous kit Energovolt A5.21-230V.

It is designed for autonomous power supply of equipment with a power of up to 5 kW, including in remote and hard-to-reach areas. The energy stored in batteries and replenished during the day from the sun is enough to power lighting, a refrigerator and freezer, a TV, a washing machine, heating pumps, water supply pumps, an electric kettle, a microwave oven and other electrical appliances. A carbon battery is not afraid of deep discharge and can be charged at higher currents than a helium battery, which means faster. 3760 cycles at 70% depth of discharge. In the future, it is possible to add solar panels, increasing the charging power and adding batteries. Lithium batteries can be used. Remote monitoring from a computer or smartphone of the state of charging and energy generation is carried out using the Wi-Fi/LAN module through the SOLARMAN Smart mobile application.

Scope of application: for home, cottage, remote settlement in the taiga, in the mountains, in the forest, on an island, in the absence of power supply, it will significantly save fuel when using a generator. The kit of such a system will include eight solar panels 550W Half-Cut NEOSUNTM Ultra M6 9BB 144. This is a series of solar panels with power up to 550W, manufactured using the latest technologies available on the market: 9BB Half-Cut cells with PERC technology.

Thanks to the use of the latest HalfCut technology, the internal cell resistance is reduced, which provides an additional increase in module power even in conditions of partial shading, cloudy weather or low light conditions. Solar cells with an efficiency of up to 23.4% are used, providing a final module efficiency of up to 21.5%.

Half-Cut Cell technology consists of dividing the panel into two parts using an infrared laser, as a result of which the operating current is divided in two. Thanks to this technology, the panel power increases by 2%, since the percentage of heat losses is significantly reduced. In addition, when dividing the panel, its reliability also increases.

During operation, the Vektor Energy VPbC 12-200 carbon fiber battery does not emit any substances harmful to health due to its sealed housing. Therefore, it does not require a separate room or additional ventilation, and can be used in residential areas. The battery is suitable for operation in both cyclic and buffer modes.

The power supply system also includes a hybrid solar inverter EB-5K-HYB-48V.

This inverter has the ability to sell electricity to the network, as well as the function of mixing the missing energy from the network with solar energy. First of all, the equipment is powered from solar panels, secondly from batteries or from the network, and lastly, the loads are powered and the batteries are charged from a generator (diesel, gasoline). If the owner does not use a generator, then an additional electric boiler can be connected to this separate input to heat water, or a grid-tied solar inverter or microgrid inverter can be connected to add power.

Also, to operate the system one will need a cable for solar panels with a cross section of 4 mm2 with an MC4 connector, a set of cable with a cross section of 35 mm2 with bolt ends, 1.5 meters (from the inverter to the battery), 1 set, a surge protection device ZBeny BUD-40/2R DC, 2-pole DC circuit breaker 16A (20A) ABB S201 (C) 6kA 16 A, fuse 250A "IEK ППНИ-37 with holder – 2 pieces.

4 DISCUSSION OF THE RESULTS

For the energy consuming object considered in the work, located in certain climatic and natural conditions, an optimal technological solution has been determined that makes it possible to obtain electricity in an alternative way through photovoltaic panels. Let's consider our solutions from the point of view of environmental safety and the possibility of recycling structural elements of the system.

The process of recycling silicon-based photovoltaic panels begins with disassembling the product itself to separate the aluminum and glass parts. Almost all glass (about 95%) can be reused, and all external metal parts are used to re-mould the cell frames. The remaining materials can be processed thermally. When exposed to high temperatures, the encapsulating plastic evaporates, leaving the silicon cells ready for further processing.

After heat treatment, 80% of what is separated can be easily reused, while the remaining 20% is further purified. Silicon particles in the connecting layer of the wafers are etched away by acid. Warped and spent wafers are melted down for reuse in the production of new silicon modules, resulting in 85% silicon reuse.

Carbon batteries Vektor VPbC 12-200 belong to the second hazard class waste according to Russian standards; they are prohibited from being taken to landfills or used for indirect purposes. Disposing of batteries at a specialized facility is the only correct way for a used power source. Recycling batteries mechanically assumes that the device will first be divided into its component fractions, and then each group of components will undergo individual recycling at a special enterprise.

Today, there are three methods for recycling cables for solar panels. The first, most primitive, is annealing the cable over fire. The essence of this method is to simply burn polymer insulation to obtain pure metal cores. This is an extremely harmful technology both for the environment and for the processors themselves. The second recycling method is to manually separate the cable from its insulation. This process is labor-intensive and time-consuming. Only small amounts of cable can be recycled in this way. The third method is mechanical processing of the cable in a high-performance, specialized installation. As a rule, such processing consists of shredding the cable, after which polymers and metals are separated by various methods, including electromagnetic methods. The third method is more rational.

The surge protection device ZBeny BUD-40/2R DC after the end of its service life is subject to transfer to organizations that process ferrous and non-ferrous metals. The design does not contain substances and metals that are hazardous to human health and the environment.

Thus, we can conclude that the use of a photovoltaic system, if properly disposed of, does not pose a hazard to the environment, and recycled system elements can be reused.

When choosing the optimal technical solution for cottage construction, not only the environmental safety of the design solution is important, but also the service life.

Elevated temperatures lead to degradation of solar modules and shorten the service life of the entire system. Therefore, to solve this problem, it is important to effectively protect the work surface from overheating.

The following factors can influence the increase in panel surface temperature: wind speed, ambient temperature, relative humidity, accumulated dust and solar radiation. High ambient temperatures and high operating surface temperatures of PV modules cause them to overheat, which affects the current-voltage characteristic and radically reduces the efficiency of the device. Each increase in the surface temperature of a solar module by 1 °C compared to the standard temperature of 25 0 C leads to a decrease in its efficiency by 0.5%. The preferred operating temperature of solar modules is in the range from 0 °C to 75 °C (Kirpichnikova et al., 2019).

The effect of temperature on the electrical efficiency of solar panels can be analyzed using the following equation:

$$\eta_{PV} = \eta_{TR} \cdot [1 - \beta_R \cdot (T_C - T_R), \quad (2)$$

where η_{PV} – the efficiency of the photovoltaic module measured at ambient temperature;

η_{TR} – module efficiency at the reference cell temperature;

T_R– reference cell temperature, °C (T_R=25 °C);

β_R – temperature coefficient for cell efficiency, °C;

T_C – surface temperature of the photovoltaic module, °C (Kirpichnikova et al., 2019).

It follows from the formula that the higher the surface temperature of the module, the lower its efficiency (Kirpichnikova and Makhsumov, 2020). Thus, for solar energy technology to be viable, various ways to solve this temperature problem (such as the use of holographic film) must be found, which should lead to improved overall conversion efficiency.

5 CONCLUSIONS

In most cases, the use of solar energy to power individual cottages is a promising alternative to traditional energy supply.

The technical solutions proposed in the work for the implementation of a solar system can be applied to objects with similar characteristics and climatic conditions of the region.

To obtain maximum operating efficiency of solar modules, it is necessary to comply with climatic and operating conditions. An increase in air temperature during operation of solar modules reduces the generation of electrical energy and leads to premature degradation of the modules.

REFERENCES

Shchinnikov, P.A., Nozdrenko, G.V., Borush, O.V., 2020. *Comprehensive studies of power units of power plants and power plants*, Novosibirsk State Technical University. Novosibirsk.

Saidov, K.U., Sadykov, M.A., 2020. Problems of energy development in modern conditions, *Science and Innovative Technologies*, 16, 111-117.

Pilyaeva, O.V., 2017. Renewable energy sources and development prospects, *The Age of Science*, 11, 120-122.

Østergaard, P.A., Duic, N., Noorollahi, Y., Mikulcic, H., Kalogirou, S., 2020. Sustainable development using renewable energy technology, *Renewable energy*, *146*, 2430-2437.

Maradin, D., 2021. Advantages and disadvantages of renewable energy sources utilization, *International Journal of Energy Economics and Policy*, *11* (3), 176-183.

Maximov, A.G., 2020. Renewable energy 2.0: A new program for the development of "green" energy in Russia, *Energy policy*, 11 (153), 22-27.

Sukhoruchkina, T.Yu., Otroshchenko, O.S., 2016. Problems of development of renewable energy sources in Russia, *Energy and Resource Conservation: Industry and Transport*, 2, 40-43.

Smil, V., 2012. A skeptic looks at alternative energy., *IEEE Spectrum*, 49 (7), 46-52.

Degtyarev, K., Solovyov, D., 2022. Problems and prospects for the development of renewable energy in Russia in new conditions, *Energy policy*, 6 (172), 55-69.

Dyatlov, S.A., Didenko, N.I., Ivanova, E.A., Soshneva, E.B., Kulik, S.V., 2020. Prospects for alternative energy sources in global energy sector. In *IOP conference series: Earth and environmental science*. IOP Publishing.

Hayat, M.B., Ali, D., Monyake, K.C., Alagha, L., Ahmed, N., 2019. Solar energy – A look into power generation, challenges, and a solar-powered future. *International Journal of Energy Research*, 43(3), 1049-1067.

Samarskaya, N., Lysova, E., Kotlyarova, E., 2023. A Scientifically Based Choice of the Most Appropriate Design Features of a Wind Power Plant to Improve the Environmental Safety of the Region. In *2023 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)*. IEEE.

Egré, D., Milewski, J.C., 2002. The diversity of hydropower projects. *Energy policy*, 30(14), 1225-1230.

Reid, W.V., Ali, M.K., Field, C.B., 2020. The future of bioenergy. *Global change biology*, 26(1), 274-286.

Kirpichnikova, I., Makhsumov, I., Madiyar, Z., Abdulloev, I., Boboev, K., Shohnazarov, P., 2019. Study of the operation of solar modules using holographic thermal protection. In *E3S Web of Conferences*. EDP Sciences.

Kirpichnikova, I.M., Makhsumov, I.B., 2020. Increasing the energy efficiency of solar modules by reducing the surface temperature. *Proceedings of Tula State University. Technical Sciences*, 2, 489-499.

Green Economy – Startup of Environmental Saving Technologies of the Eurasian Economic Union

Oksana Gavrilova[1][a], Olga Maksimova[1][b], Lyudmila Medvedeva[1,2][c], Gennady Lukyanov[1][d] and Julia Onoprienko[1][e]

[1]Volgograd state technical University, Volgograd, Russian Federation

[2]All-Russian Research Institute for Hydraulic Engineering and Land Reclamation them A.N. Kostyakov, Volgograd, Russian Federation

smile427@mail.ru, maxsima@list.ru, milena.medvedeva2012@ya.ru, lukianov@post.volpi.ru, sttask@mail.ru

Keywords: Green economy, environmentally friendly technologies, Eurasian Economic Union, renewable energy sources, irrigation, reservoirs, green spaces

Abstract: The article presents materials that reveal the prospects for the development of a green economy in the Eurasian Economic Union (EAEU), the use of environmentally friendly and monitoring technologies in agriculture and land irrigation. Arguments have been put forward in favor of promoting the concept of a green economy and the use of technologies that reduce the effects of climate change. The use of natural and human capital, the reduction of climate and social risks, the use of renewable energy sources and the development of land irrigation to improve the efficiency of agriculture are justified. Engineering, technical and economic calculations are proposed for the placement of renewable energy sources in irrigation systems and natural reservoirs. The areas of use of the public-private partnership mechanism to stimulate organic farming and comprehensive land reclamation in arid regions of the world are shown.

1 INTRODUCTION

One of the dynamically developing economic unions is the Eurasian Economic Union (EAEU) with a population of 182.7 million people, a territory of 20.3 million km^2 (Eurasian Economic Commission, 2024). The Union includes the republics: Armenia, Belarus, Kazakhstan, Kyrgyzstan, and Russian Federation. The main factors determining the development of the EAEU include: the expansion of regional markets, a changing climate, growth in the size and well-being of the population, and the promotion of environmentally friendly technologies. The UNEP report presents the "green" economy as resource-efficient and socially inclusive, as opposed to the "brown" economy, which was driven by industrialization and the use of minerals (UNEP, 2011). The authors of the green economy concept focused on the use of natural and human capital, reducing climate and social risks, and the use of renewable energy sources (RES) (Ahman, 2017).

Some governments and civil society groups believe that the adoption of this concept is premature and that it does not affect the global social and economic foundations of humanity. Some researchers argue that "green economy" is an inappropriate term, but a scientific and philosophical error with the help of which they are trying to form a "utopian" paradigm of the world economy (Barbier, 2013, Zvarych, 2022). We believe that further exploration of the concept of a green economy and how it will be promoted economically, environmentally and socially will require some effort on the part of the UN Department of Economic and Social Affairs (UNDESA), the Global Green Growth Institute (GGGI), the Partnership for Action on Green Economy (PAGE), the Green Growth Knowledge

[a] https://orcid.org/0009-0000-6173-2609
[b] https://orcid.org/0000-0001-8147-2875
[c] https://orcid.org/0000-0002-3650-2083
[d] https://orcid.org/0000-0002-8901-8463
[e] https://orcid.org/0009-0001-6510-8691

Platform (GGKP) the Green Economy Coalition. Already today, the development of a green economy entails a transformation of relationships between states and business communities, increases added value in international sales chains, and changes the usual way of life of many peoples (Selishcheva, 2018, Dissanayake, 2021, Johnson, 2021, Liu, 2024) (Table 1).

Table 1: Argument for the transition to a green economy.

For promoting a green economy	Against the promotion of a green economy
The transition to a green economy will reduce the risks of climate change, mineral depletion, and water shortages. Increasing green investments and the use of environmentally friendly technologies will stimulate the use of RES and the environment.	The consequence of the growth of green investments will be an increase in production costs and a decrease in the competitiveness. It will lead to government intervention in the economy and an increase in protectionist decisions.

For EAEU countries, the transition to a green economy model is further complicated by the fact that the main contribution to their development is made by extractive and manufacturing industries, which in turn are the “pillar” of the brown economy, which the UN commissions oppose (Barbier, 2013 Bailey, 2014) . The adopted EAEU Development Strategy until 2030 lays down certain areas of the green economy model: the use of environmentally friendly and digital technologies, the expansion of organic farming, and the generation of new types of energy (EAEU, 2024). For example, EAEU countries have signed Agreements on the implementation of digital navigation seals to ensure the unhindered movement of goods, and on investing in a digital platform for accounting for greenhouse gas emissions. The main focus of the Euro-Asian Economic Commission is the optimization and harmonization of processes within the EAEU through the creation of a single integrated platform (Selishcheva, 2018, EAEU, 2024) (Table 2).

Table 2: Strategic directions for the development of the EAEU until 2030, taking into account the promotion of environmentally friendly technologies.

Introduction of innovations	Stimulating scientific and technical progress	Digitalization of management
Cross - industry digital ecosystems. Green technologies in energy, transport, agriculture.	Using EDB tools. Development of a circular economy. Formation of international R&D bases.	Removing barriers to the movement of goods and services. Harmonization of cross-border trade. Formation of an integrated platform.

The purpose of the study was to study the development of the green economy in the Eurasian Economic Community, the promotion of environmentally friendly technologies, renewable energy sources in agriculture and land irrigation.

2 MATERIALS AND METHODS

In preparing the article, analytical and statistical materials from the EAEU on promoting a green economy, agricultural development, and land reclamation (EAEU, 2024) from Volgograd Technical University on the application of environmentally friendly technologies and renewable energy sources were used. With the help of cyber-economic and computational design modeling, solutions are proposed in the fields of land reclamation and renewable energy sources, conservation of water resources, and countering foreign economic risks. When constructing forecast values for the development of land reclamation, the relational databases of the VNIIOZ Institute for agrometeorology, ecology, water and biological resources, and investments were used. Materials characterizing the development of agriculture and the EAEU infrastructure complex are grouped in tables 3, 4 and 5 (Eurasian Economic Commission, 2024).

Table 3: Share of agriculture, forestry and fisheries in the gross value added of the EAEU economy, %.

Countries	By year		
	2015	*2020*	*2022*
Armenia	17,2	4,8	11,6
Belarus	6,3	12,7	8,6
Kazakhstan	4,7	8,1	5,6
Kyrgyzstan	14,1	5,7	12,8
Russia	3,9	4,4	4,3
Total	*4,2*	*4,8*	*4,6*

Source: EAEU bulletins.

Table 4: Agricultural production EAEU, $ million.

Countries	By year		
	2018	*2020*	*2022*
Armenia	1 928	1 774	2 489
Belarus	9 506	9 606	12 062
Kazakhstan	13 048	15 411	20 676
Kyrgyzstan	2 977	3 226	4 260

Russia	85 526	104 181	126 941
Total	112 985	137 972	166 428

Source: EAEU bulletins.

Important in EAEU policy is the conservation of water resources, including transboundary rivers that are the subject of disputes between users (Danilov-Danilyan, 2010, Garud, 2022). These are the Syrdarya, Chu, and Talas rivers, flowing through the territory of Kazakhstan and Kyrgyzstan; the rivers Ural, Ishim, Irtysh, and Tobol, belonging to Russia and Kazakhstan; and the Dnieper, Usha, Polota and Sinaya rivers, which are within the jurisdiction of Belarus and Russia (Table 5).

Table 5: State of EAEU water resources, 2019.

Name River flow	River flow km^3/year	Underground flow km^3/year	Specific water availability, m^3/person
Russia	4258,6	787	29944
Belarus	57,9	15,8	5800
Kazakhstan	26,06	16,4	5041
Kyrgyzstan	44,1	13,0	8480
Armenia	7,7	4,0	2945

Source: EAEU bulletins.

In the green economy, priority is given to RES, The EAEU has significant potential in the generation of solar and wind energy, the construction of hydroelectric power stations, and biogas production complexes (Ahman, 2017; Egorova, 2022). As of January 1, 2022, the total installed capacity of RES was: Armenia - 528 MW, Belarus - 495 MW, Kazakhstan - 57.1 MW, Kyrgyzstan - 57.1 MW and the Russian Federation - 3 GW. To develop the EAEU economic development model until 2030, forecasts for agricultural development for each country and balances of food supply and demand were studied. According to the forecast, the number of people employed in agriculture in the EAEU by 2030 will decrease by 21.9% compared to the reporting year 2020(Figure 1).

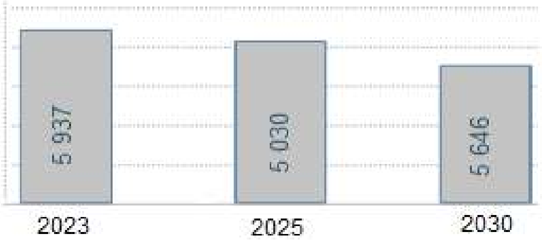


Figure 1: Forecast of the number of people employed in agriculture in the EAEU, thousand people.

Replenishment of labor resources will be ensured through technological modernization, the introduction of robotic systems, and digital technologies (Pestel, 2019, Emirov, 2019, Abualfaraa, 2020).

In the forecast period, the growth of gross agricultural production should increase by 31.3%, or $155.0 billion (Figure 2).

Figure 2: Forecast of agricultural production in farms of all categories (A), per person employed (B) in the EAEU, $ billion.

Mutual trade in food products and agricultural raw materials should grow by 24.2% or $12 billion (Figure 3).

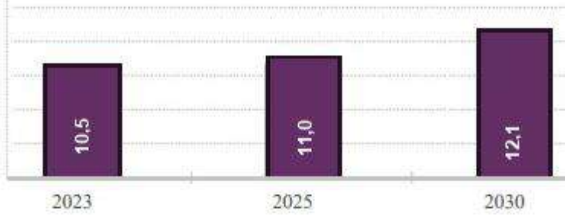


Figure 3: Forecast of EAEU mutual trade in food products and agricultural raw materials, $ billion.

By 2030, the market for EAEU goods and services will be provided in the following ratio: Belarus - 47.1%, Russia: 40.0%, Kazakhstan - 6.4%, Armenia - 4.5%, and Kyrgyzstan - 2.1% (EAEU, 2024).

3 RESEARCH RESULTS

For EAEU agriculture, the transition to environmentally friendly technologies will ensure the development of organic farming and integrated land reclamation. The area under organic farming will increase to 1.8 million ha by 2030 (EAEU, Agriculture, 2022). The development of land reclamation will be ensured, which will be a response to a changing climate (Shchedrin, 2018). The Eurasian Economic Commission, together with the Russian Association of Water Supply and Sanitation, will continue to develop an integrated digital platform that provides year-round biosphere monitoring of the state of water and biological resources in the EAEU (Danilov-Danilyan, 2010 Siebrecht, 2020) (Figure 4).

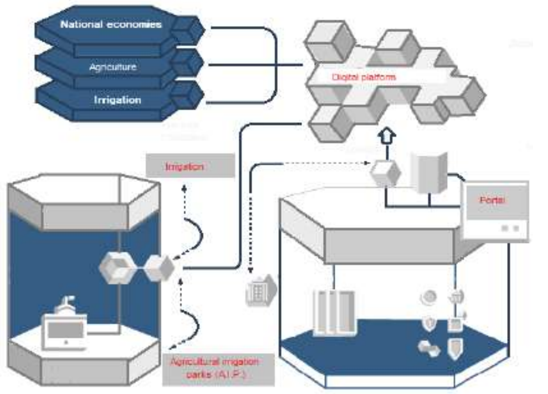


Figure 4: Block diagram of the integrated platform for agriculture and water management in the EAEU.

Irrigation lands is a very expensive resource and energy-intensive activity that ensures the supply (discharge) of water to agricultural fields and populated areas. The development of land reclamation on the green economy platform should be supported by improving the material and technical base, the use of digital virtual technologies, the construction of new generation irrigation canals, and a Public-Private partnership mechanism. Increasing the sustainability of irrigated agricultural landscapes should be ensured adaptively - landscape technologies, growth of human capital (Shchedrin, 2018, Tahat, 2020, Roiss, 2022, Liu, 2024). Table 6 presents the forecast for the increase in reclaimed land in the EAEU until 2030 (Table 6).

Table 6: Irrigated lands in EAEU countries, thousand ha.

Countries	By year		
	1991	2016	2030
Russia	11000,9	9000,1	10100,5
Belarus	3423,6	3442,5	3631,5
Kazakhstan	2000,3	1600,0	3010,0
Armenia	286,3	208,1	228,6
Kyrgyzstan	836,6	896,9	1064,0

According to calculated data, the introduction of new irrigated lands by 2030 will allow increasing the area sown with oilseeds - 14.1%, vegetables and melons - 6.6%, sugar beets - 5.0%, orchards - 4.8%. For the development of irrigated lands in arid regions, an organizational and economic structure can be used – Agricultural Irrigation Parks («A.I.P.») with a Public-Private partnership mechanism (Shchedrin, 2018, Abualfaraa, 2020, Roiss, 2022). «A.I.P.» – local agricultural clusters aimed at optimizing natural and human resources, increasing agricultural production on irrigated lands. A feature of the functioning of «A.I.P.» is the concentration of agricultural resources and the attraction of private and public investment. Management company «A.I.P.» on behalf of farmers, it designs, builds and maintains distribution, irrigation and drainage systems, develops renewable energy sources and ensures the sale of agricultural products in markets (Figure 5).

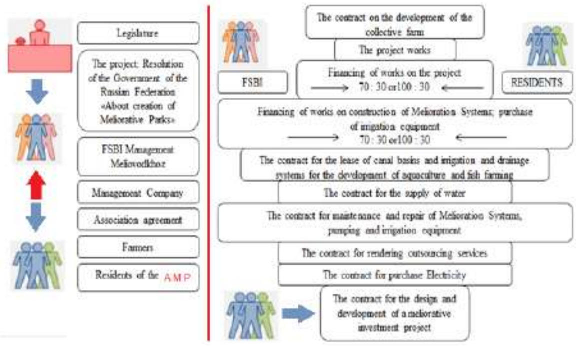
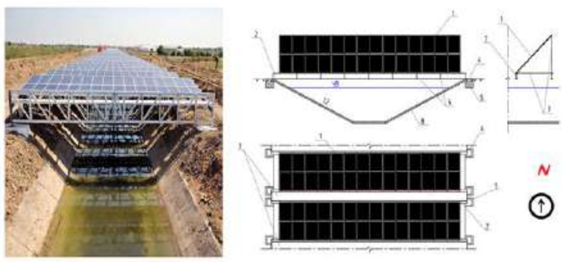


Figure 5: The algorithm for management of the «A.I.P.».

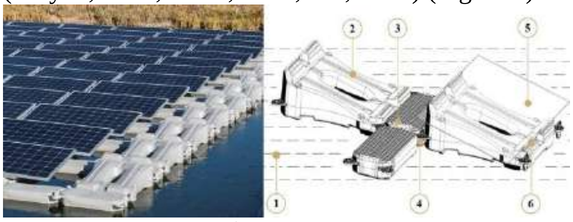
Using res in «A.I.P.» will reduce costs and increase the profitability of farms (Heshmati, 2016, Tahat, 2020, Garud, 2022, Yin, 2022,). The study developed options for using res in irrigation systems. The first option for using res on irrigation canals. The cost and efficiency of placing solar panels on the suburban irrigation system in the Krasnodar region of Russia was calculated. The total irrigation area is 23,940 hectares, the annual electricity consumption of the main pumping station is 5,754,910 kw hour, the cost of electricity for water supply is 31,313.3 thousand rubles. In year. The payback period of the project is 7 years (Belykh, 2018, Roiss, 2022). An example of placing solar panels on the main canal is shown in figure 6.



1 – solar panel (south direction, angle 45º), 2 – dvutuvr 35B1, 3 – panel mounting (Sigma profile), 4 – embedded part MI1-22, 5 – concrete foundation, 6 – transverse edge of dvutuvr, 7 – technological transition (wooden bridge), 8 – concrete facing of the canal.

Figure 6: The construction of solar panels on the main canal of suburban irrigation system.

The second option is represented by solar panels placed on the water surface of the Krasnodar reservoir in Russia. The waters of the reservoir are used to irrigate rice fields and placing solar panels on the water surface will solve the following problems: reduce evaporation from the surface of the reservoir, obtain energy for pumping water to rice paddies (Belykh, 2018, Roiss, 2022, Liu, 2024) (Figure 7).



1 – reservoir, 2 – primary float to support the solar panel module, 3 – secondary float for maintenance and buoyancy, 4 – connection module, 5 – module platform for mounting a solar panel, 6 – mount for fixing the solar panel and the primary float.

Figure 7: Project for placing solar panels on the water surface of the Krasnodar reservoir, Russia.

4 CONCLUSIONS

The study shows that one of the dynamically developing state associations is the Eurasian Economic Union. The economic union's agenda includes the use of green technologies in economic sectors. The main factors determining the direction of the EAEU activities were the increasing turbulence of the global economy, the expansion of regional markets for goods and services, a changing climate, rising living standards, and the environment. The EAEU Strategy until 2030 presents solutions in the field of application of environmentally friendly and digital technologies in agriculture and land reclamation. Presented solutions for creating «A.I.P.» and the use of renewable energy sources at land reclamation sites are aimed at strengthening the economic potential of the EAEU and presence in global food markets. The concept of a green economy affects the global social fabric of society, which requires further study and understanding on the part of governments and the world's population.

REFERENCES

Eurasian Economic Commission [Electronic resource]. – URL: http:// eaeunion.org.

United Nations Environment Program (UNEP). [Electronic resource] – URL: http://web.unep.org/emissionsgap.

Green Economy Coalition [Электронный ресурс]. – URL: https://www.greeneconomycoalition.org.

Ahman M., Nilsson L. & Johansson B., 2017. Global climate policy and deep decarbonization of energy-intensive industries. Climp. Vol.2. pp.634-649.

Barbier E., 2013. The green economy post Rio+20. Science Institute on Climate Change and the Environment. pp. 887-898.

Zvarych R., Masna O. & Rivilis I., 2022. Methodological principles of the formation the concept of green economy. Herald of Economics. 4. 131-144.

Selishcheva T.A., 2018. Green economy as a model for sustainable development of the EAEU countries. Problems of modern economics. Vol. 3. pp. 6-12.

Agriculture of the EAEU [Electronic resource]. – URL: https://agro.eaeunion.org/Pages/default.aspx.

Agro-industrial complex, 2023. Statistics of the Eurasian Economic Union. Moscow. 137.

Dissanayake, N., Withanawasam, A., Sarjoon, A., 2021. Conceptual nexuses between sustainable development and blue-green economy: An analysis of the importance of adopting blue-green economic principles in achieving sustainable development goals. Civilization. Vol. 12. pp. 102-110.

Johnson, A. E., Smith B. L., 2021. The role of technology innovation in digital economy under thegreen economy framework. Journal of Economic and Environmental Studies. 45(2). 211-229.

Liu, Y, Yang, Y, Zhang, X., Yang, Y., 2024. The impact of technological innovation on the green digital economy and development strategies. PLoS ONE 19(4): e0301051.

Bailey, I., Caprotti, F., 2014 The green economy: functionaland Governance 23 209.20 domains and theoretical directions of enquiry Environment.

Egorova, N. E., Nekrasov, S. A., 2022. Renewable energy and small business: Synergies and sustainability strategies. Economics of Contemporary Russia. Vol. 4. pp 89-103

Pestel, N., 2019. Employment effects of green energy policies. Vol. 76. pp.1-11.

Emirov, N.D., Saltykova, A.S., 2019. Features of the implementation of the green economy concept in the EAEU countries. Current problems of international relations. pp. 407-412.

Abualfaraa, W., Salonitis, K., Al-Ashaab, A., Ala'raj, M., 2020. Lean-green manufacturing practices and their link with sustainability: A critical review. Sustainability. Vol. 12. pp. 981-1011.

Shchedrin, V., 2018. Meliorative institutional environment: The area of state interests. Espacios. Vol. 39. pp. 28 - 32.

Danilov-Danilyan, V., Khranovich, I., 2010. Water resources management. Coordination of water use strategies. M.: Scientific world. 232.

Siebrecht, N., 2020. Sustainable agriculture and its implementation gap-Overcoming obstacles to implementation. Sustainability.12. 3853.

Tahat, M. M., Alananbeh, K. A., Othman, Y. A., Leskovar, D. I., 2020. Soil health and sustainable agriculture. Sustainability. 12 (12). 4859.

Roiss O., Medvedeva L., 2022. Innovation in agriculture - An actor in the development of a green economy. AIP Conference Proceedings. 2650. 030019.

Roiss O., Medvedeva L., 2022. Rising agriculture on a convergent green economy platform. AIP Conference Proceedings. 2650. 030031.

Shchedrin V., 2017. Creation of «Reclamation agricultural Park» on the basis of resource-saving technologies, alternative energy sources, the mechanism of public-private partnership. The Novosibirsk scientific centre of RAS. Vol.2. pp.163- 165.

Belykh D., Ryzhakov A., 2018. The Use of solar energy on the land-reclamation facilities (for example, Suburban sprinklertion system of the Krasnodar territory). Ways of improving the efficiency of irrigated agriculture. Vol.2. pp. 168-181.

Garud R., Kumaraswamy A., Roberts A., Xu L. 2022. Liminal movement by digital platform-basedsharing economy ventures: The case of Uber Technologies. Strategic Management Journal. 43(3).447- 475.

Yin S., Wang Y., Xu J., 2022. Developing a conceptual partner matching framework for digital green innovation of agricultural high-end equipment manufacturing system toward agriculture 5.0: Anovel niche field model combined with fuzzy VIKOR. Frontiers in Psychology. 13. 924109.

Heshmati A., 2016. An empirical review of the implications of the green economy. Int J Green Econ. Chang technology forecast. 2016. 104:102 -21.33.

In the Field of Digitalization of Agriculture in Russia

Marinchenko T. E. [a]
Russian Research Institute of Information and Feasibility Study on Engineering Support of Agribusiness, the Federal State Budgetary Scientific Institution (Rosinformagrotekh FSBSI), 60, Lesnaya Str., Pravdinsky Township, 141261 Moscow Region, the Russian Federation
9419428@mail.ru

Keywords: digitalization, agriculture, regions, stimulation, experience, activity.

Abstract: Digitalization is becoming a factor that determines the prospects for the growth of agricultural enterprises and competitiveness in the Russian and global markets. The government is making significant efforts to activate the process of production digitalization, and regions are implementing projects and organizing infrastructural elements in order to launch and stimulate the process of digitalization of agricultural production facilities. The purpose of the study is to analyze and identify those regions that are leaders in Russia in the field of digitalization of the agricultural sector. The objectives of the study are to analyze regional strategies and experience in organizing infrastructure elements that directly affect the digitalization process, determination of the effectiveness of these activities, as well as to identify factors that positively affect the dynamics of digitalization of enterprises in the agricultural sector. The material for the study was the Digital Agriculture departmental program, scientific publications on the problems of digitalization of the agricultural sector and data on Russian projects in the field of digitalization of agriculture obtained from analytical agencies and authoritative sources in the field, as well as from researchers. The monographic, comparative and systems analysis, idealization and mental modeling methods, as well as a logical approach, were used. Those regions are identified that are leaders in the field of digitalization of agricultural production and pay great attention to this process. The experience of these regions can provide investment in the development of other regions, as well as the development and upgrading of agricultural enterprises. Therefore, information on successful practices in the application of information technology should be popularized to ensure the possibility of replication in other regions of Russia.

1 INTRODUCTION

A decade of science and technology is being implemented in Russia. Activity in critical areas for the development of the country is intensifying, including that in the field of agriculture. The priority for agriculture is the task of "transitioning to highly productive and environmentally friendly agriculture and aquaculture, developing and implementing systems for the rational use of chemical and biological protection of agricultural plants and animals, storing and efficient processing of agricultural products, creating safe and high-quality food products, including functional ones" (Decree No. 642). An important role is played by the digitalization of agricultural production, which has great potential for increasing efficiency. According to the McKinsey Global Institute, the Internet of Things alone will bring from USD 4 to USD 11 trillion annually to the world economy by 2025. The potential economic effect of the digitalization of the Russian economy is expected to increase the country's GDP by 4.1-8.9 trillion rubles by 2025 (in 2015 prices), which will amount to 19% to 34% of total GDP growth (Digital Russia: a new reality).

At the same time, digitalization is becoming a factor determining the growth prospects of companies and industries, and therefore the economy as a whole (Orlova, 2022). Modern agriculture is becoming a platform for testing modern Industry 4.0 technologies, such as digital platforms, in-depth analytics of big data, the Internet of things, etc. (Klerkx, 2020).

The degree of efficiency of modern agricultural production is increasingly determined by the degree of its intellectualization (Khabarov, V., 2019). Digital platforms and ecosystems, in-depth analytics of big

[a] https://orcid.org/0000-0003-3721-112X

data, robotization, technologies such as 3D printing, the Internet of Things and other elements of Industry 4.0, are gradually becoming elements of agricultural production (Marinchenko, 2021, Digital technology). The implementation practices are widely discussed within appropriate business events. Domestic developers of hardware and software produce competitive products in comparison with foreign projects, which are leaders in some areas (Krupina, 2019, Shafieva, 2020).

The papers of domestic researchers discuss various aspects of the agricultural sector digitalization, including theoretical approaches to the interpretation of the "digitalization" term, substantiation of the relevance of digitalization of the industry and the process of managing the industry at the federal and regional levels (Marinchenko, 2022) as well as problems and prospects of digitalization of the agricultural sector in Russia and other countries (Boev, 2020, Kuchnarenko, 2020.). Much attention is paid to the analysis of the legal framework for the agriculture digitalization (Kovaleva, I., 2021, Serova, 2022, Utrendeeva, 2021).

An analysis of literary sources has showed that all researchers come to the conclusion that the introduction of digital technology in the agricultural sector at the present stage of development is a determining factor in the competitiveness of the industry.

Since the degree of intellectualization is becoming a necessary component of the competitiveness of agricultural production in the domestic and foreign markets, in order to activate the digitalization process, the Digital Agriculture departmental project is being implemented, which should provide a technological breakthrough using such replicated end-to-end intelligent systems as Country, Region, Agricultural Enterprise and Field (Farm) based on domestic methods, algorithms, IT technologies, systems and devices. The total economic effect from digitalization could amount to more than 4.8 trillion rubles in annual terms with 3-5-time increase in labor productivity (Lyubanova, 2021, Marinchenko, 2023).

Despite the fact that a large number of research papers have been devoted to the analysis of the digitalization process at the regional level (Gordeev, 2019, Reshetnikova, 2022), no interregional comparisons and any analysis and identification of the most effective regional digitalization strategies have been made. Due to the fact that the digitalization of the agricultural sector in the regions is actively developing, and the dynamics of the digitalization process is influenced by events and incentives at the regional level, further research on the most effective practices is relevant and of an applied nature. Therefore, an analysis of regional activity in the field of agricultural sector digitalization was carried out, and the regional experience in organizing infrastructure for the agricultural sector digitalization and regional strategies was studied.

The scientific novelty of the study lies in the comparison of regional practices and strategies for the agricultural sector digitalization and the identification of factors and infrastructure elements, the presence of which contributes to the intensification of the digitalization process. The results of this study can serve as a methodological basis for further research on regional strategies and practices in the field of the agricultural sector digitalization.

2 MATERIALS AND METHODS

The purpose of the study is to analyze them and determine their sufficiency to ensure the sustainable development of agriculture. The subject of the study is the support measures implemented within the framework of state programs and projects that stimulate innovation activities in the agricultural sector.

The purpose of the study is to analyze and identify the regions that are leaders in Russia in the field of digitalization of the agricultural sector. The objectives of the study are to analyze regional strategies and experience in organizing infrastructure components that directly affect the digitalization process, determine the effectiveness of these activities and identify factors that positively affect the dynamics of digitalization of agribusiness enterprises. The departmental project entitled "Digital Agriculture" (Gordeev, 2019.) and data obtained from analytical agencies served as materials for determining the prospects for digitalization of the agricultural sector. The leaders in the rate of implementation of digital components were determined using the methods of comparative and system analysis of information obtained from authoritative sources in this area, such as Ministry of Agriculture of Russia, Sberbank, Russian Agricultural Bank, Center for Forecasting and Monitoring the Scientific and Technological Development of the Agribusiness on Precision Agriculture Technology, including automation and robotization of the Kuban State Agrarian University (that performs monitoring in this area in accordance with the state assignment of the Ministry of Agriculture of Russia), other Russian universities conducting research and development in this area, as well as Russian and foreign experts in the field of digitalization of the agricultural sector. At the same time, regional digitalization strategies and initiatives in the field of organizing infrastructure components and factors that determine the dynamics of the digitalization process were determined using the methods of monographic, comparative and system analysis, idealization and mental modeling, as well as the logical approach method. The use of this methodological apparatus in the study of the sources described above made it possible to limit the geography of the study to leaders and to identify success factors in more detail. Their formation in regions with low rates of digitalization will create conditions in the latter to speed up the digitalization process.

3 RESULTS AND DISCUSSION

The IT market in agriculture in Russia reached 360 billion rubles in 2019. It is expected to increase more than 5 times by 2026. The Ministry of Agriculture of Russia has prepared a draft strategy for the digitalization of agricultural production with a budget of 50 billion rubles, which proposes to introduce technologies of digital twins, artificial intelligence (AI), the Internet of things, drones, robotics, predictive analytics and remote sensing of the Earth, as well as develop an online platform to promote Russian agricultural products and launch modeling and forecasting systems (Digital Russia, The economy goes).

The potential for digitalization is estimated very high (Bunin, 2020, Marinchenko, 2023). According to Sberbank's estimates, the agricultural sector is in the TOP-3 sectors of the economy that will actively undergo digital transformation in 2023-2025. According to the Russian Agricultural Bank, farm management technologies allow automating manual labor and reducing costs, as well as optimizing the use of fertilizers and plant protection products, which will reduce the cost of production (by 25%-40%) and increase yields (by 10%-15%) (Kovaleva, 2021 Orlova, 2022).

Andreev DV, Makarova ME note that the introduction of digital technologies makes it possible to eliminate inequality caused by higher production costs compared to other regions and territories and to produce goods and services that compete on the open market (Andreev, 2021). The paper (Krupina, 2019) has concluded, as a result of the SWOT analysis, that the introduction of information technologies in the production process will reduce the cost of production, as digital technology will allow optimally and cost-effectively organize business processes at enterprises, which in turn will increase their competitiveness in the market of agricultural goods. The investment effect from the digitalization begins to decrease in the future, but on average a positive result is observed almost 15 more years (Akmarov2021).

A digital service information system has been created, which will make it possible to transfer the provision of state support to the agricultural sector completely into electronic form and to exclude the human factor from it (Marinchenko, 2023). The project should start functioning in nine pilot regions during 2021, and the transfer of all the powers of the Ministry of Agriculture public services in electronic form will take place by the end of 2024. In the near future, a monitoring system for the reclamation sector will become available in all regions, and it is planned to transfer the management of all irrigation and reclamation facilities based on the state digital platform by 2024 (Gordeev, 2019).The introduction of information technologies in the production process will reduce the cost of production, as digital technology will allow optimally and cost-effectively organize business processes at enterprises, which in turn will increase their competitiveness in the market of agricultural goods (Krupina, 2019).

The Ministry of Agriculture of Russia monitors the activity of the regions in organizing conditions for the digitalization of agriculture, including such parameters as legal regulation, the effectiveness of e-government, the availability of connectivity to existing IT systems, the availability of tested IT technologies and the level of their replication, etc. Among the leaders are Altai and Krasnodar Krais, Kursk, Lipetsk and Samara Regions and other regions. Rosselkhozbank has assessed the level of readiness of the regions for the agricultural sector digitalization when analyzing the prospects for introducing the precision and smart farming techniques (Kovaleva, 2021, Krupina, 2019, Marinchenko, 2023).

Rosselkhozbank has assessed the level of readiness of the regions for the introduction of digital technology in agricultural production based on an analysis of the prospects for the introduction of two groups of technologies, such as precision farming and smart animal husbandry. Indicators such as technological, personnel, innovation and government components have been taken into account. According to the results, the regions have been divided into four groups. The first group has included regions with a high degree of readiness to implement the technologies.

Krasnodar Krai, Novosibirsk Region, Bashkiria, Voronezh, Tambov, Chelyabinsk, Nizhny Novgorod, Belgorod Regions, as well as Omsk and Arkhangelsk Regions (Russia), which have a good technological base, including coverage with the Narrow Band

Internet of Things (NBIoT) networks for the Internet of Things and a large share of agricultural enterprises using technologies for digital agriculture and a high level of training of specialists in agriculture, have been included in the top 10 entities in terms of readiness for the implementation of digital technologies in the agricultural sector. These regions are implementing regional programs to support the introduction of new technologies. The second group includes regions with a good level of readiness of basic infrastructure and personnel training, but inferior to the leaders in terms of the availability of support programs or the number of enterprises working with digital technologies. This group includes the Omsk, Arkhangelsk, Lipetsk, Volgograd, Leningrad, Sverdlovsk, Moscow, Vologda, Tyumen, Tomsk, Rostov regions, the Udmurt Republic, the Republic of Tatarstan and the Altai Krai (Russia). The third and fourth groups include the rest of the regions in which work is underway to create conditions for the introduction of digital agriculture technologies (Akmarov, et al., 2021, Marinchenko, 2021, Digital Transformations).

The regions are implementing projects and organizing infrastructure elements to facilitate the digitalization of agricultural production. The Altai Krai, for example, has been operating an information system since 2015 in order to automate the processes of preparing documents for manufacturers to receive state support. Since 2017, the use of arable land has been monitored on the Rostelecom Rus GIS platform, which takes into account more than 94% of the arable land of the Altai Krai or about 140,000 plots with information about crops and users. The system is used by more than 2,500 agricultural enterprises of the Krai (Marinchenko, 2021, Digital Transformations). In addition, the Altai State Agrarian University (Barnaul, Russia) has created a Competence Center for the Digitalization of Agriculture, which solves the tasks of training highly qualified personnel, developing algorithms for digital platform services, advising agricultural producers, improving the qualifications of agricultural workers in the field of geoinformatics and processing remote sensing data.

The program of digitalization of the agricultural sector is being actively implemented in the Tambov region (Russia). Here, the Competence Center for Digitalization of the Agricultural Sector was created in 2018, within the framework of which it was planned to receive grant support from the Skolkovo Foundation (Moscow, Russia). The Center, together with the regional Development Corporation, is implementing a project to create a digital platform for the agricultural sector.

Five projects have been selected among the participants in the Skolkovo Foundation projects (residents). For example, the Supply Chain Management System service, where buyers and sellers can sell and buy products and act as a communicative provider of 5PL (network logistics), contributes to the implementation of the modern concept of distribution logistics, the so-called demand-oriented supply chains (Marinchenko, 2023). It is planned to create one of the first business accelerators in the country in the field of digitalization of the agricultural sector jointly by the ASB agricultural holding and Competence Center for the digitalization of the agricultural sector (Moscow, Russia), which is enshrined in an agreement signed at the Open Innovations-2019 international forum. The business accelerator will become part of the Michurin Valley Innovation Science and Technology Center (Tambov, Russia).

Mielta (Tambov, Russia), the first technology park in the Tambov region in the field of information technologies was opened in 2018, including technologies of the Internet of things, electronic instrumentation, information and telecommunication technologies, as well as Global Navigation Satellite System / Global Positioning System (GLONASS / GP technology). More than 80% of the area of the Mielta technology park is already occupied by residents, over 51.8 million rubles of investment have been raised. The total area of the technology park exceeds 10,000 square meters. The first residents were Mielta Technology, TN-Group, SmartAgro, and TSK.

At the Tambov State Technical University (Tambov, Russia), a Digital Mechanical Engineering collective use center has been opened, which studies advanced technologies in the field of mechanical engineering, metalworking and digital design. In addition, the Center for GIS Technologies and Precision Agriculture has been opened at the Derzhavin Tambov State University (Tambov, Russia), which is an interregional platform for the training and retraining of specialists in the field of precision farming and geographic information systems (The economy goes).

About 70% of farms located in the Republic of Tatarstan have already implemented certain elements of digitalization. Automatic systems for dispensing fuel are popular. Fuel is dispensed using cards in accordance with the established limits, and the flow of fuel into the tank is controlled by the dispatcher of the Global Navigation Satellite System (GLONASS). A good example is the Sabinsky District, which has equipped almost all farms with card-based fuel dispensing systems and GLONASS systems. The

Zilanseeding control system is also popular, which controls not only probable drill malfunctions and clogging of the openers, but also the work of the operator. Revealing a single clogged opener gives a system payback of 200–300 ha. Animal husbandry needs for systems that control the process of preparing animal feed, as well as for robotization of farms. As part of the digitalization of the agricultural sector, the introduction of a unified animal identification began in 2020. In a pilot mode, a system of unified digital identification of animals on farms has been implemented in the farms of the Arsky and Baltasinsky districts (Republic of Tatarstan, Russia) (Akmarov, 2021, Lyubanova, 2021).

The Center for Forecasting and Monitoring at the Kuban State Agrarian University (Krasnodar, Russia) conducted a survey on the prospects for digitalization of agriculture. According to the survey, experts attribute to the areas of high importance for the digitalization implementation in 2021-2030 the introduction of elements of precision farming, as well as monitoring the health of the herd, quality of livestock products and identification in animal husbandry (Truflyak, 2020). Experts have identified the positive effects of the introduction of digital technologies, as well as additional costs associated with the implementation (Table 1).

Table 1: Effect of the use of precision farming techniques taking into account the estimated costs.

Technique	Additional cost	Effect
Parallel driving	Automatic control system; executive card; software; personnel training costs	Saving time; fuel economy; the driver can perform other tasks; improving overall productivity and quality of work
Differentiated sowing	Soil maps; differentiated seeding drill, changes in depth and density; OSP8 / KTK systems	Increased productivity due to better seed density and distribution; reduction in seed costs
Differentiated fertilization	Differentiated fertilization system; built-in GIS system; aerial photographs; yield mapping; soil samples; soil map, staff training costs	Increased productivity; saving time; saving fertilizers
Differentiated spraying according to the weed map	Integrated injection sprayer; soil samples (soil map); personnel training costs; Weed Mapping using Autonomous Weed Display Systems	Saving herbicides; saving time; increase in productivity
Differentiated irrigation	Water use management software; drip irrigation system irrigation pipeline; sensors	Saving water; saving nutrients
Differentiated tillage according to soil maps	Soil maps; sensors for determining the soil composition; working bodies	Increased productivity; energy saving; saving time; improving the efficiency of the machine
Measurement of chlorophyll content in crops before harvest	Sensors for mapping chlorophyll content in plants; yield mapping	Improving product quality; optimal period for starting harvesting; improving grain quality with optimal moisture content
Harvesting logistics	Unified vehicle management system; new vehicle system; yield maps; logistics optimization system; harvest time scheduling software	Increased productivity; optimization of harvesting; fuel economy; decrease in moisture content in cereals; saving time during transportation
Information management	Field map processing software	Reducing the time and cost of searching for labor; improving the quality of the data received

Source: Truflyak, 2020

To unite efforts in overcoming problems in the digitalization of the agricultural sector, Russian agricultural producers have established the SmartFarmingClub (SFC), a platform for the exchange of best practices for the formation of global trends. Sixty-five agricultural holdings and development companies in the field of automation and digitalization of the agricultural sector have become its residents, the total number of the club has more than 1,000 members from different countries. It is assumed that the SFC will take part in the development of standards, a legal framework for regulation in this area and advising participants on digitalization issues, which will accelerate the large-scale implementation of IT solutions in agribusiness (Marinchenko, 2021. Digital Transformations).

The papers (Andreev, 2021, Boev, V. U., et al., 2020, Bunin, 2020) underline that digital technologies of agricultural production are becoming a factor of strategic competitive advantage and the determining factor in the competitiveness of the industry at the present stage of development, as papers in this area agree. The author completely agrees with the above conclusion. Akmarov PB et al note thatthe investment effect from the digitalization begins to decrease in the future, but on average a positive result is observed almost 15 more years (Akmarov, 2021), therefore, it is especially important to perform systematic work at the regional level to improve the conditions for the introduction of digital technology by enterprises, while improving legal regulation, developing digital public administration and services and integrating them on common platforms when providing financial and non-financial support measures. Scientific publications of researchers are devoted to various aspects of the development of the digitalization process, including the prospects for digitalization (Akmarov, 2021, Reshetnikova, 2022, Troshin, 2018), legal regulation (Serova, 2022, Utrendeeva, 2021) and the results of the implementation of specific platforms and projects (Kondratieva, 2021, Sakharov, 2020). The results obtained are consistent with the conclusions presented in (Akmarov, 2021, Krupina, 2019), which show that the implemented regional policies and the applied measures to support agricultural producers in the process of introducing digital technology also play a big role. The experience of implementing regional policies in the field of digitalization of agriculture, as noted in (Akmarov, 2021, Andreev, 2021), should be used as widely as possible, while replicating them in less active regions. Some papers devoted to the experience in the field of digitalization of the agricultural sector, to the regional policy and measures in order to support agricultural producers in the process of introducing digital technology have been analyzed. The papers (Bessonova, 2021, Krupina, 2019, Kuchnarenko, T., 2020, Reshetnikova, N., 2022) have showed that the pace of digitalization depends on the initiative of governments in the regions, and the author agrees with the authors of these studies too. They confirm that the presence of digital elements in other industries stimulates the introduction of digital technology in agricultural production.

No interregional comparisons of the pace of digitalization, effectiveness of regional policies and support measures have been found when analyzing the papers (Khudyakova, 2019, Kovaleva, 2021, Kuchnarenko, 2020) devoted to the experience of digitalization of the agricultural sector in the regions. Such papers as (Andreev, 2021, Bessonova, 2021., Krupina, 2019) have made it possible to identify effective practices of regional policies, whilea comparison of regional practices and strategies for the digitalization of the agricultural sector has been carried out, as well as factors and infrastructure elements that contribute to the intensification of the digitalization process have been identified. Thus, more active processes of digitalization of agricultural production are observed where the process of digitalization covers more areas of economic activity, e-government services are more developed, regional programs are implemented, widely unified and centralized solutions are applied, as well as regional infrastructure elements of the system with a high level of development of IT technologies are functioning. The number of agricultural enterprises using technologies in crop and livestock production is growing, and the situation is monitored annually. All this determines the prospects for digitalization feasible within the framework of the tasks set by the government.

The Digitalization of Agriculture departmental program developed by the Ministry of Agriculture of Russia and the results of its implementation have been analyzed in a number of papers (Boev, 2020, Marinchenko, 2020, Truflyak, 2020). The digitalization process in the agricultural sector is proceeding according to the program plan, however, the study has showed that leaders and outsiders have been identified extremely unevenly in different regions. The study of the causes of slow digitalization in outsiders is the basis for continuing research in this area.

The formation of such associations as SFC speaks of the interest of agribusiness in cooperation to resolve digitalization issues, which is a transition to a qualitatively new level of production. Involvement of organizations interested in digitalization in this kind of association will contribute to the formation of a unified digital environment.

4 CONCLUSIONS

Digital technologies of agricultural production are becoming a factor of strategic competitive advantage. The level of regional digitalization is more intensively observed where the digitalization process covers more areas of economic activity, e-government services are more developed, regional programs are implemented, widely unified and centralized solutions are applied, as well as regional infrastructure elements of the system with a high level of IT technology development are functioning. The number of agricultural enterprises using technologies in crop and livestock production is growing, and the situation is monitored annually. All this determines the prospects for digitalization that are feasible within the framework of the tasks set by the government.

Among the leading regions in the field of digitalization of agricultural production are the Altai and Krasnodar Territories, Kursk, Lipetsk and Samara Regions, and the Republics of Bashkortostan and Tatarstan, which pay great attention to the development of digitalization. An analysis of regional activity in the field of digitalization of the agricultural sector and the experience of organizing regional infrastructural elements to speed up the process shows their high efficiency and a high degree of regional interest in accelerating the digitalization process. The experience of the Altai Krai, in which the Center of Competence for the Digitalization of Agriculture has been established, the Tambov Region (the Digital Engineering collective use center), the Republic of Tatarstan and other regions should be studied in more detail to determine the effectiveness of their strategies and disseminated in regions where the pace of digitalization of agricultural production is slow and degree of readiness for the process is inferior.

The dynamics of digitalization is influenced by regional events and measures to stimulate digitalization. Since the policy of the regions in this area is constantly being improved, further studies of the most effective strategies, measures and activities are relevant and will be of an applied nature. The results of this study results will be helpfulfor further research on regional strategies and practices in the field of agricultural sector digitalization, including identifying the main problems in the field of digitalization in regions, which lag behind in the pace of this process.

ACKNOWLEDGMENTS

The author would like to thank the anonymous reviewers for all their constructive comments. Any errors or opinions expressed in this article are solely the responsibility of the authors. The opinions expressed in this article are those of the authors and do not necessarily reflect the position or policies of their institution.

REFERENCES

Akmarov, P. B., 2021. Assessing the potential of the digital economy in agriculture. In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 666, p. 042036. -1

Andreev, D. V., Makarova M. E., 2021. Implementation of digital technologies in agriculture on the example of the Republic of Sakha (Yakutia). In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 839, p. 032052. -2

Bessonova, E. A., 2021. Digitalization of the agro-industrial complex as the main factor of regional economic development. In *LNNS*, vol. 205, pp. 289-296.-3

Boev, V. U., 2020. Digitalization of agro-industrial complex as a basis for building organizational-economic mechanism of sustainable development: foreign experience and perspectives in Russia. In *LNNS*, vol. 87, pp. 960-968. -

Bunin, M. S., 2020. Information support of digital agriculture. An analytical review. Central Scientific Agricultural Library, Moscow, 21 p.

Decree No. 642 of the President of the Russian Federation entitled “On the Strategy for the Scientific and Technological Development of the Russian Federation” dated December 1, 2016 (as amended by Decree No. 143 of the President of the Russian Federation dated March 15, 2021. Retrieved from http://government.ru/docs/all/109256/ (accessed on 21.01.2024).

Digital Russia: a new reality. 2017. McKinsey Report. Retrieved from https://www.mckinsey.com/~/media/mckinsey/locations/europe%20and%20middle%20east/russia/our%20insights/digital%20russia/digital-russia-report.ashx (accessed on 20.10.2023).

Gordeev, A. V., 2019. Digital Agriculture Departmental project. Rosinformagrotekh, Moscow, 48 p.

Khabarov, V., Volegzhanina I., 2019. Knowledge management system of an industry-specific research and education complex. In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 403(1), p. 012197.

Khudyakova, E. V., 2019. Improving the efficiency of agro-industrial complex management based on digitalization and system approach. In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 274, p. 012079.

Klerkx, L., Rose D., 2020. Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways? *Global Food Security*, vol. 24(3), p. 100347.

Kondratieva, O. V., 2021. Using digital technologies in horticulture. In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 723, p. 032033.

Kovaleva, I., 2021. The development of digital economic in the agricultural sector of region. In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 677, p. 22004.

Krupina, G. D., 2019. Analysis of the efficiency of digitalization of the agricultural sector of the Republic of Tatarstan In: Agriculture and food security: technologies, innovations, markets, personnel. Proceedings of the international scientific-practical conference dedicated to the 100th anniversary of agricultural science, education and enlightenment in the Middle Volga region. Kazan State Agrarian University, Kazan. pp 700-710

Kuchnarenko, T., Pudeiyan L., 2020. Mechanisms for the modernization of regions having agricultural specialization in the imperatives of the digital economy. In *E3S Web of Conf.*, vol. 13, p. 13021.

Lyubanova, T., 2021. Existentialism of engineering marketing and technological entrepreneurship in large agricultural enterprises. In *E3S Web of Conf.*, vol. 273, p. 8030.

Marinchenko, T., 2023. Improving the infrastructure for the transfer of innovations in the agribusiness. In *E3S Web of Conf.*, vol. 371, pp. 03001.

Marinchenko, T. E., 2021. Digital technology in agricultural sector. In *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 666(3), p. 032024.

Marinchenko, T. E., 2021. Digital Transformations in Agriculture. In *SSDC*, vol. 283, pp. 409–41.

Marinchenko, T. E., 2022. Regional Activity in Agriculture. In *IOP Conf. Ser.*: Earth Environ. Sci., vol. 988, p. 032025.

Marinchenko, T. E., et al. 2024. Innovative activity of Russia: Dynamics and position in international comparisons. In *AIP Conf. Proc.*, vol. 2969, is.1, p. 030019.

Orlova, N. V., Nikolaev D. V., 2022. Russian agricultural innovations prospects in the context of global challenges: Agriculture 4.0. In *Russian Journal of Economics*, vol. 8(1), pp. 29-48.

Reshetnikova, N., 2022. Digital technologies adoption in the agro-industrial complex as a priority of regional development in the conditions of global macroeconomic changes. In *LNNS*, vol. 246, pp. 3-12.

Sakharov, D. A., 2020. Creation of a digital platform for scientific and technical interaction between education and production. In *Interexpo Geo-Siberia*, vol. 7(1), pp. 26-30.

Economic Design of Integration of Small Forms of Management into the Digital Ecosystem of Agricultural Economy

Larisa Popova[a], Mariya Lata[b] and Petr Melikhov[c]
Volgograd State Agrarian University, 26, Universitetskiy Ave., Volgograd, 400002, Russian Federation
lvpopova@bk.ru, mariya-lata@yandex.ru, mpad@mail.ru.

Keywords: Ecosystem of the digital economy, digital agriculture, digital potential of small agricultural formations, digital transformation of the agro-industrial complex, geoinformation systems, precision agriculture, ERP systems, milking robots, small agribusiness.

Abstract: The purpose of this study is a theoretical, methodological and scientific-practical analysis of the specifics of digital ecosystems introduced into agricultural production, their adequate assessment in the context of economic efficiency, prospects for sustainable development and the development of practical recommendations for the introduction of modern digital technologies in small agricultural production. In achieving this purpose, a combination of methods of both general scientific and highly specialized economic research was used, including observation, survey, questionnaire, numerical-analytical and statistical methods, the method of expert assessments, as well as the method of comprehensive assessment of economic activity. The result of the study is the development of an information and economic concept of "digital economy ecosystems", as well as an analysis of existing and promising digital ecosystems, the introduction of which into real agricultural production can be illustrated by the example of small agricultural formations. The results of the analysis can be used in the development and implementation of state agrarian policy in the context of digitalization of agricultural production, and are also useful in the practical implementation of smart digital farm projects.

1 INTRODUCTION

An important component of the development of modern civilization is a fundamentally different type of communication, which has become a consequence of the introduction of global information and digital technologies into all aspects of human life, society and the state without exception. This fact explains the rapid growth of the world economy, the increase in social standards of living and the level of global consumption. Information and telecommunication systems have begun to play a crucial role not only in the mass production of tangible and intangible goods, but also create conditions for sustainable development and ensuring the economic security of the state, part of which is food security. At the same time, achieving food security without the systematic introduction of agricultural innovations, mass digitalization and informatization of agricultural production in the context of the new technological mode of agro-industrial complex 4.0 seems unlikely, and most likely, simply impossible.

Within the framework of the fourth technological mode, agricultural production can no longer be imagined without the creation and functioning of integrated digital environments in which the collection, analytical processing and redirection of information flows from various digital platforms, software, cloud services and predictive solutions is carried out in such a way as to make the functioning and interaction of all links in the agro-industrial production chain as efficient as possible: production, primary processing of agricultural products, their storage, transportation and sale. This study will examine the role of small agricultural formations in ensuring the food security of the Russian state in the context of their involvement in the processes of digitalization and innovative renewal of agricultural

[a] https//orcid.org/0000-0002-8036-2006
[b] https://orcid.org/0000-0001-6197-3621
[c] https://orcid.org/0000-0002-6364-9785

production in Russia and its transition to the technological mode of the AIC 4.0.

Let us recall that the share of small forms of management in the gross production of agricultural products in Russia is still very high: they account for up to half of the gross volume of agricultural products produced in the country. However, in terms of the pace of digitalization, small agricultural forms are significantly inferior to other entities of the agricultural structure, such as agricultural organizations and large agro-industrial associations, for which digitalization of production processes has already become quite an ordinary phenomenon. There is no doubt that small forms of management has a certain potential in the field of digitalization and technological modernization, however, its disclosure and full use in the conditions of modern agro-industrial production is a rather complex application problem of economics, the solution of which is the main purpose of this study.

2 THE ECOSYSTEM OF THE DIGITAL ECONOMY

The concept of the "ecosystem of the digital economy" as a specific phenomenon of the social and economic way of life of people does not have a generally accepted interpretation in the scientific community, since it is quite difficult and non-trivial task to clearly define the entire set of electronic platforms, digital products and services integrating various aspects of the consumption of "network goods"in the process of human socio-economic activity (Jacobides, Cennamo and Gawer, 2018). In a scientific and applied context, the term "ecosystem of the digital economy" can be defined as a certain kind of "digital environment", which is a complex of "electronic platforms integrating data on the dynamics of information flows and the potential for digital development of various spheres of human socio-economic activity" (Senyo, Liu and Effah, 2019). However, it would be wrong to assume that the digital ecosystem of the agricultural economy is limited only by a set of digital services and solutions. An equally important role in the formation of the digital ecosystem of agriculture is played by the system of training qualified personnel for the agricultural sector, the quality and quantity of agricultural innovations, the focus of scientific research on the creation of digital technologies, the appropriate information environment, and much more. (Popova, Lata and Melikhov, 2022).

In order to successfully address the challenges facing the Russian agro-industrial sector in ensuring food security, as well as maintaining Russia's leading position as a leading importer of agricultural products, it is necessary to build an effectively functioning digital ecosystem of agriculture that combines the digital potential of not only large agricultural producers, but also such participants in agro-industrial production as small forms of management. In this regard, a comprehensive scientific, practical and methodological analysis of the digital specifics of small agricultural formations, their economic efficiency, as well as the prospects for sustainable development and the development of practical recommendations for the introduction of modern digital technologies in small agricultural production, turns into one of the most urgent tasks facing domestic agricultural and economic science (Ivanova, Ovchinnikov, Lata, Korabelnikov, 2020).

According to the majority of researchers, the factor of sustainable digital development of the domestic agricultural sector should not be digital solutions episodically introduced by individual entities of the agricultural structure, but full-featured object-oriented digital environments designed to manage agricultural production and integrate information flows into a single data processing center in order to solve problems arising in the process of agricultural production in real time based on predictive modeling and the use of artificial intelligence (Pushpa and Ramachander, 2024). At the same time, the use of domestically developed hardware and software for building digital ecosystems will be of fundamental importance for the successful advancement of the Russian agro-industrial complex to the next technological mode. The necessary requirements for the functioning of such digital ecosystems will be the level of security, performance, as well as the ability to unify with other digital platforms and application solutions, including government information resources. It is on the basis of this approach that the digital ecosystem of agriculture of the future should be formed: combining agricultural innovations, integrated digital solutions and platforms and the widespread use of modern agricultural production technologies (Ivanov, Ovchinnikov, Kochetkova, 2019).

In the domestic scientific and expert community, the most widespread concept is that the main trends in the medium-term and long-term digital development of the agricultural sector of the economy should be a number of key digital technologies, each of which will develop in interconnected, but still different directions.

1. Automation and robotization of production processes. The need to introduce such technologies into the real sector of agro-industrial production is due to the need to reduce labor costs and eliminate heavy manual labor, as well as the shortage of personnel in the agricultural sector. The tasks of further automation and robotization of the main production processes remain relevant primarily in those segments of the agro-industrial complex that require qualified personnel, the shortage of which in agriculture is felt most acutely. Robotization and automation are already being widely implemented in the meat and dairy segment of agro-industrial production. In particular, milking robots and automated herd management systems are rapidly taking over the agricultural equipment and software market. The share of dairy farms using robotic milking systems demonstrates stable growth both in countries with a high level of development of agricultural technologies (USA and Canada, the European Union) and in countries with a catching-up type of development, which includes the Russian Federation. Although the pace of robotization of milking processes and automation of herd management in our country remains quite low. The introduction of robotic milking systems is inextricably linked with the integration of an economic entity into the digital ecosystem supplied by manufacturers of milking robots. This software allows to solve a very wide range of tasks, starting from the implementation of loose keeping of animals in a herd and robotization of their milking, and ending with the ability to monitor the health of livestock in real time using a sensor system united in the Internet of Things (Fountas, Espejo-Garcia, Kasimati, Mylonas and Darra, 2020).

2. Introduction of geoinformation systems and precision farming systems. The introduction of global information systems in the interests of agricultural production has recently become an integral part of the crop industry of agro-industrial production. The most popular systems from the point of view of agricultural producers are the so-called GIS (geodetic information systems), formed using federal and regional information resources, such as UFIS AL (Unified Federal Information System on Agricultural Lands), GLONASS, automated information system "Unified project environment" and other “big data” information systems. For example, precision farming systems, which have already become widespread among domestic producers of crop production, operate on the basis of GLONASS and GPS global positioning systems. Precision farming systems offered today on the digital services market are usually already equipped with the possibility of seamless integration with various digital platforms, and in the future have the potential to be combined into multifunctional systems of the M2M (or M2H) type, including by equipping agricultural machinery with global positioning and monitoring devices with the ability to receive data from satellites in real time (Ivanov, Ovchinnikov, Kupriyanova, 2019).

3. The Internet of Things. This technology, often referred to among experts as M2M, is a type of network in which interactions between devices are carried out directly “machine-to-machine”. Such a network is created by equipping various mechanisms with microchips, turning them into "smart" devices capable of interacting with each other without any intermediate information nodes. M2M technology opens up the broadest possibilities for creating integrated platforms for managing production processes based on the Internet of Things. Smart technologies will become a determining factor in the production of both industrial and agricultural products in the very near future. Unfortunately, in modern Russia, the use of Internet of Things technologies in the real sector of agro-industrial production is typical for large agricultural enterprises that have the necessary resources for the successful implementation of M2M systems. First of all, these are networked IoT sensor systems, video and audio monitoring devices, pilotless aerial vehicles, etc. Modern manufacturers of ready-made solutions for deploying an IoT network, in addition to the hardware, usually also provide digital services in the form of access to their own cloud services, remote administration systems, etc. For the Russian agro-industrial complex, the mass introduction of digital platforms based on Internet of Things technology is still the near future, however, the authors have no doubt that this technology is capable of becoming a point of growth in the digitalization of the domestic agricultural sector and will allow the integration of individual digital platforms into the regional and then federal ecosystems of the digital economy (Lata, Korabelnikov, Melikhov, 2023).

4. Automated management systems for agricultural enterprises. This direction of digitalization in the agro-industrial sector is currently the most developed and widespread thanks to automated management systems, which are represented in a wide variety in the global and Russian digital markets. The most common systems among Russian representatives of agricultural business are CRM, SCM, ERP, ERP II. Among the developers of such systems, it is worth highlighting the Russian 1C, KOMPAS, the German SAP, the

American Oracle, Workday, Inc., the international development group Infor, as well as many other similar companies offering ready-made digital solutions for automated management (Bohnsack, Rennings, Block and Broring, 2024).

It seems that the most likely trajectory for the development of ERP systems will be the introduction of artificial intelligence elements, cognitive and predictive technologies capable of predicting user actions and offering them the most optimal management solutions in terms of economic efficiency. (Yurchenko, 2019).

According to experts in the field of international consulting and studying trends in the development of national economic systems, the digital transformation of global agro-industrial production will contribute to:

- the growth of labor productivity in the agricultural sector of the economy;
- improving the quality and safety of food and agricultural products in general;
- reducing the energy and resource intensity of agricultural production;
- reducing costs and, consequently, increasing the profitability and efficiency of agricultural production (Li, Wang and Xie, 2022).

In the annual report published by the British consulting company PwC (Price waterhouse Coopers) on promising directions for the development of the global economy by the end of 2019, PwC specialists justify at least a ten percent increase in the number of farm animals and a reduction in costs by an average of 15-20% from the introduction of "digital farm" technologies (Ayaz, Ammad-Uddin, Sharif, Mansour, 2019). The results of PwC's research are generally consistent with the conclusions reached by the Russian expert community, represented by both state analytical centers and independent analysts: digitalization is a powerful engine of technological development in all sectors of the Russian economy and, above all, the agricultural one (Abashkin, Abdrakhmanova and Vishnevsky, 2024).

At the same time, predictive modeling of the digital development of domestic agricultural production should take into account a number of very significant risks accompanying the process of involving agricultural producers in digital business ecosystems. Even now, in the general context of digitalization, the desire of the main players in the IT market to impose a certain kind of dependence on one or another digital service on consumers of their services is clearly visible (Singh, Kolar, and Abraham, 2024). At the same time, users usually do not have a real opportunity to choose either the service itself or its supplier, since when purchasing technological equipment and hardware, the manufacturer is forced to use the digital business ecosystem imposed on it. In some cases, the lack of such a choice can create serious problems for users both in the context of technical support and in terms of access to digital services provided by the provider. As is known, the Russian economy has been forced to operate under sanctions for about ten years, one of the aspects of which is restriction (or prohibition) of access for Russian manufacturers to digital solutions and services controlled by unfriendly states. In this regard, an important factor ensuring the positive effect of digitalization should be the choice of a provider of digital solutions and services, in terms of further cooperation and compliance with Russian rules for the use of software. For example, the use of computer programs that are not included in the register of Russian software may create organizational, legal and administrative problems in the future related to the need for import substitution and a ban on the use of imported equipment and software. "Digital dependence" on a digital service provider can become a serious breach in the information security systems of both an individual business entity and the state as a whole, if digitalization is carried out on a foreign-made hardware and software base. There is only one way out in this case: the creation of digital solutions, platforms, operating systems (OS), data storage systems (DSS), cloud services, etc. based on domestically produced equipment and controlled by domestic software (Popova, Lata, Melikhov, 2023).

3 SMART FARMS

The creation of smart farms based on Internet of Things technology is no longer something unusual or ultra-innovative in modern agricultural practice, however, for the Russian agro-industrial complex it is still a rarity. According to the website https://robotrends.ru, robotic milking in our country is developing at a very slow pace in comparison with the corresponding indicators of the rest of the world. The chart below shows the dynamics of the growth of the number of smart dairy farms in Russia and the world. As we can see, while in the rest of the world the number of smart robotic dairy farms is in the hundreds of thousands, in Russia their number still does not exceed one thousand.

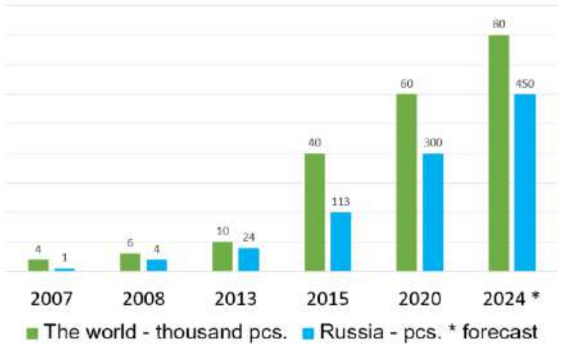


Figure 1: Dynamics of the number of smart farms using robotic milking systems.

The reasons for these statistics are the problems that have already become familiar to Russian small agricultural businesses: lack of their own financial resources and lack of access to cheap credit; high cost of imported equipment and absence of domestically produced milking robots on the market; lack of qualified personnel; complexity of the technology itself and unwillingness to introduce innovations; lack of the necessary material and technical base and much more. Nevertheless, the idea of a smart farm built on the basis of the Internet of Things is gradually gaining its segment in the Russian agro-industrial complex. As practice shows, M2M technology is most effective in the dairy farming segment. The smart dairy farm built on the basis of the IoT network includes:

- sensors implanted in farm animals;
- applicators and sensors installed in farm premises;
- various feed and fertilizer consumption controllers;
- devices for determining temperature and humidity levels in rooms;
- agricultural machinery monitoring devices.

All the above components equipped with the ability to connect to each other using M2M are combined into a single information and digital network with the ability to use cloud applications and remote administration systems (Adhiatma, Fachrunnisa, Nurhidayati and Rahayu, 2023).

On the technical side, the algorithm of the smart farm activity is a continuous flow of data received in real time from measuring and monitoring devices, which is sent to a relay device and then transmitted via cloud technologies to a single data processing center (DPC), where all necessary actions are performed with the information, using the vendor's computing power, if necessary. With this algorithm of functioning of the Internet of Things network, the manufacturer has the opportunity to remotely control its business activities by connecting to big data at the vendor's disposal. The vendor's DPC provides farmers with the opportunity to perform a real-time comparative analysis of the main indicators of their production, promptly receive a report on the health of animals, track meteorological information, and much more. Cognitive and predictive systems deployed using the vendor's cloud technologies will be able to predict the dynamics of animal growth, feed consumption, energy consumption, etc.

Before analyzing the market of agricultural equipment needed to deploy a smart farm based on IoT technology, one must be aware that most of the manufacturers operating on the Russian market until 2022 have announced the termination of their activities in the Russian Federation. For example, the WaveAccess Group, which offered ready-made IoT solutions based on the Microsoft Azure cloud, has almost completed its operations in the Russian Federation. Today, the company provides only limited technical support to those customers who purchased hardware and software before the imposition of sanctions. Microsoft also announced the suspension of sales in Russia and Belarus of all digital services provided, with the exception of updating operating systems already installed by Russian users.

Another significant drawback of the described technology, which is perhaps the main obstacle to the introduction of the Internet of Things into the real sector of agricultural production, is the extremely high qualification threshold for entering the technology. To overcome this threshold, it is necessary to significantly increase the level of personnel qualification requirements. The introduction of digital tools for deploying the Internet of Things network within a smart farm will require a significant revision of the recruitment organization, a change in the approach to business process planning, and changes in the work culture. In terms of logistics, smart farm equipment usually requires a complete upgrade of computer equipment, as well as the installation of additional equipment in order to integrate the IoT structure into the existing digital format of the farm. There are also a number of other factors that hinder the development of smart farms in the practice of domestic small businesses. Nevertheless, the number of "smart" dairy farms in the Russian agricultural structure is gradually growing (Popova, Lata, Melikhov, 2023).

4 ASSESSMENT OF THE ECONOMIC EFFICIENCY OF IOT TECHNOLOGY IN CONDITIONS OF SMALL AGRICULTURAL PRODUCTION

To conduct economic modeling of the implementation of individual elements of a digital ecosystem built on the basis of Internet of Things technology, an abstract model of a small dairy farm with a milking herd of 100 heads of cattle was created. On the basis of this farm, it was planned to deploy individual components of the IoT network manufactured by the Austrian company SmaXtec. A peasant farm with the necessary human and material resources, located in one of the most promising natural and climatic zones of the Volgograd region, was chosen as an experimental site for measuring the numerical indicators of economic activity. As a result of the conducted research, the necessary information was obtained about various parameters of the economic activity of a "smart" dairy farm, including: production volumes and its profitability level, climatic conditions, information and material flows, movement of labor resources, the level of personnel qualifications, infrastructure, as well as the architecture of the elements of the digital ecosystem used in a specific peasant (farm) enterprise (Popova, Lata and Melikhov, 2023).

The assessment of the economic efficiency of the introduction of individual elements of the Internet of Things technology in the production of whole milk was carried out using investment analysis methods by calculating dynamic indicators for assessing the efficiency of investments: investment payback periods, the amount of net discounted income, the investment project profitability ratio, the internal rate of return, and the investment profitability index. To simplify the calculations, it was postulated that the total costs of purchasing the necessary equipment and materials amount to 100% of the investment cost of the project, carried out using own funds.

Table 1: Investments in the "digital" dairy farm project, RUB.

Name	Price RUB/piece	Cost per 100 heads, RUB.
Electronic thermometers	154	15,400
Basic bolus	9,312.85	931,285
Bolus pH.	10,782.2	1,078,220
Base station	68,621	137,242
Repeater /	24,017.35	48,034.70
Climate control system	16,665.1	16,665.10
Applicator	7,842.4	784,240
Cow movement activity sensor "Ovi-bovi"	7,352.25	735,225
Receiving unit "Ovi-bovi"	73,522.5	73,522.5
External antenna	14 704,5	14 704,5
1C: Enterprise 8. Breeding in animal husbandry. Cattle.	140,000	140,000
Computer equipment	100,000	100,000
Total:		4,074,539

As shown in the table above, the total investment cost of the project in rubles was 4,074,539 rubles.

To deploy a smart farm based on the Internet of Things technology, the domestic software 1C: Enterprise 8. Breeding in animal husbandry. Cattle. was used. This application solution has a number of advantages compared to foreign analogues, since it was developed taking into account the requirements of Russian legislation on livestock breeding and is intended for building a business ecosystem for automating herd management.

Research has shown that the positive economic effect of implementing the smart farm investment project based on the Internet of Things technology is mediated by a reduction in labor costs, a general reduction in costs, including the cost of veterinary services, an increase in animal productivity, and an improvement in the quality of milk, which leads to a reduction in the costs of its storage and primary processing.

Table 2: Indicators of economic design of a "digital" dairy farm, RUB.

Indicators	Technologies		Efficiency per 100 heads, RUB.	Increase in %
	Regular	Digital		
Purchase price, RUB/kg	37.00	37.00	-	-
Annual yield per head/kg.	6,812	~ 7,500	2,545,600	110
Labour saving, people/hour	-	~ 25	425,000	-

Operating costs, head/RUB.	40,378	~ 50,000	-99,622	125
Veterinary services, head/RUB.	28,116	~ 25,000	311,600	89
Economic effect	-	-	3,182,578	~ 17.5
NPV at r=20%	~ 1,852,160			

An important role in increasing the economic feasibility of digitalizing a dairy farm is played by optimizing the herd management process and the possibility of keeping animals loose, which has a positive effect on their health. As a result of economic modeling of a "smart" digital dairy farm, the authors came to the conclusion that the economic effect of implementing this technology could be in the range of 15 to 20 percent of the investment cost of the project.

As a result of the conducted research, the following results were obtained.

The discounted payback period (*DPP*), i.e. the period of time during which the costs of technological re-equipment and deployment of the Internet of Things network within the smart dairy farm will be fully compensated, was calculated using the formula:

$$DPP = \min_{n},\left(\sum_{t=1}^{n} CF_i/(1+r)^i - CI\right) \geq 0 \qquad (1)$$

where *CFi* is the cash flow in the i-th time period;
CI is the initial cost of the investment.

Based on the assumption of a 10% average annual increase in animal productivity in the case of the implementation of the smart dairy farm project (which is a fairly realistic indicator based on previously obtained data), the costs of technological re-equipment and deployment of the Internet of Things network within the smart dairy farm will be compensated within the first two years of the project implementation. The diagram below shows the cumulative and discounted cash flows. The value of the discounting rate was taken as r = 20.

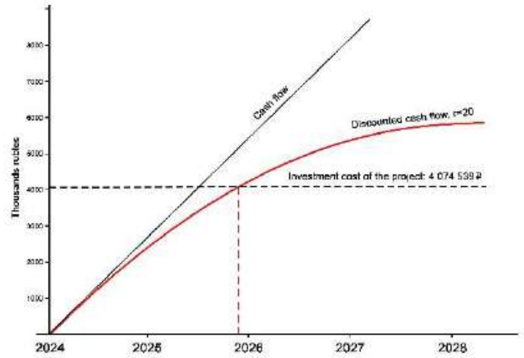


Figure 2: Payback period for the digital dairy farm project.

In case of refusal to use credit resources for the implementation of an investment project, net present value (NPV) can be determined by the formula:

$$NPV = \sum_{t=1}^{n} CF_i/(1+r)^i - CI \qquad (2)$$

It should be borne in mind that the forecast obtained as a result of analytical calculations, which is not bad from the point of view of economic feasibility, is a consequence of: firstly, the assumption of a 10% increase in the productivity of the milking herd, and secondly, the refusal to use credit resources, as a result of which the discounted cash flow does not depend on the credit burden. With this assumption, the net present value of the investor for the entire period of the project implementation should be *NPV* = 1,852,160 rubles.

Let us repeat: the data obtained in the process of investment analysis are conditional and are the result of economic modeling of a smart farm. The real values of the indicators of economic activity of a farm may differ significantly from those obtained analytically. The practical implementation of an investment project to create a digital smart farm based on a peasant (farm) enterprise may require significantly higher costs, including the implementation of various organizational and technical measures that were not taken into account in this analysis. Experience shows that the process of digitalization of agricultural production, as a rule, does not lead to a rapid economic effect and, often, the technical re-equipment of the farm in order to create a "smart farm" is more a work for the future, a kind of foundation for future development. Nevertheless, the conducted economic analysis shows that, under certain conditions, investing in agricultural innovations and digitalization of the agro-industrial complex can yield good results not only in the context of digital development, but also in terms of investment profitability.

5 CONCLUSIONS

Summing up the results of the study, we can come to a number of conclusions, the main one of which, apparently, should be considered the fact that the mass digitalization of agriculture in Russia remains a matter of the near future. The main channels for the penetration of digital technologies into agro-industrial production will be robotization and automation of agricultural production processes; the use of GIS and precision farming systems; deployment of IoT networks using cloud and "big data" technologies; the use of cognitive, predictive technologies, artificial intelligence, etc. The method for integrating the specified areas into a single information and digital environment should be the “ecosystem of the digital economy of agribusiness”, by which the authors mean “a set of technological platforms, applied Internet services, analytical and information systems created on the basis of a computer network infrastructure, possessing the properties of self-regulation, adaptability and sustainability for the purpose of joint production of agricultural products or their promotion, exchange of information and evolutionary development of the agricultural sector of the economy”.

Along with the obvious advantages of introducing digital ecosystems into agricultural production, it should be noted that modern Russian agribusiness faces a number of problems that objectively hinder the digitalization of agriculture, which can be combined into three groups: logistical and technological problems, financial and monetary difficulties and personnel problems. It seems that the solution to the first two groups of problems lies in the field of organizational and economic measures, while the personnel difficulties of the modern Russian agro-industrial complex are systemic in nature and cannot be solved without serious changes in the field of education, science, scientific, technical and technological policy of the state.

Another important conclusion arising from the study is that achieving a positive economic effect from the introduction of digital technologies in small agricultural production is usually possible only if small farms acquire the necessary machinery and equipment not through credit resources, but through self-financing or attracting investments, including venture capital investments. In this regard, it seems appropriate to search for additional sources of financing for those small agribusiness entities that actively use advanced technologies, create innovative products, apply digital solutions in their business activities, and attract research and educational institutions to participate in production activities. It is probably necessary to consider at the state level the possibility of grant support for farms implementing innovations and digital technologies, or subsidizing small agricultural formations from the regional budget in order to reimburse them for part of the direct costs associated with the purchase of equipment and technical means.

ACKNOWLEDGEMENTS

The study was supported by the Russian Science Foundation, Grand No. 24-28-00066 "Formation of digital mechanisms for the sustainable development of small agribusiness", https://rscf.ru/project/24-28-00066/.

REFERENCES

Ayaz, M., Ammad-Uddin, M., Sharif, Z., Mansour, A., Aggoune, E.-H. M., 2019. Internet-of-Things (IoT)-Based Smart Agriculture: Towards Making the Fields Talk. IEEE Access, 7, 129551-129583.

Abashkin, V. L., Abdrakhmanova, G. I., Vishnevsky, K. O., Gokhberg, L. M., 2024. Indicators of the digital economy: 2024: a statistical collection (National research. Higher School of Economics, Moscow: ISIEZ HSE, 2024) p. 276.

Adhiatma, A., Fachrunnisa, Nurhidayati, O., Rahayu, T., 2023. Creating digital ecosystem for small and medium enterprises: the role of dynamic capability, agile leadership and change readiness. *Journal of science and technology policy management*, 14, 5, 941–959.

Bohnsack, R., Rennings, M., Block, C., Broring, S., 2024. Profiting from innovation when digital business ecosystems emerge: A control point perspective. *Res. Policy*, 54, 104961.

Fountas, S., Espejo-Garcia, B., Kasimati, A., Mylonas, N., Darra, N., 2020. The future of digital agriculture: technologies and opportunities . IT Prof., 22, 1, 24 – 28.

Ivanov, V. V., Ovchinnikov, A. S., Kupriyanova, V.S., 2019. Methodology for sustainable development of the agro-industrial complex. News of the nizhnevolzhsk agricultural university complex: science and higher professional education, 4 (56), 15–25.

Ivanov, V. V., Ovchinnikov, A.S., Kochetkova, O. V., 2019. Conceptual foundations of the digital transformation of the agro-industrial complex of the Volgograd region. News of the nizhnevolzhsk agricultural university complex: science and higher professional education, 2 (54), 18–25.

Ivanova, N., Ovchinnikov, M., Lat,a M.S., Korabelnikov, I.S., 2020. Digital agriculture: opportunities for the development of small agribusinesses and the respective problems. *Lecture Notes in Networks and Systems*, 111, 593–600.

Jacobides, M.G., Cennamo, C., Gawer, A., 2018. Towards a theory of ecosystems. *Strateg. Manag. J.,* 39, 2255–2276.

Lata, M. S., Korabelnikov, I. S., Melikhov, P. A., 2023. The digital economy of the agro-industrial complex: a textbook. p. 168.

Popova, L. V., Lata, M. S., Kleiman, E. V., Melikhov, P. A., 2023. Sustainable development of the agro-industrial complex of the Volgograd region in the context of digital transformation. *Regional economy. The South of Russia,* 11, 2, 217-229.

Popova, L. V., Lata, M. S., Melikhov, P. A., 2023. Formation of digital business ecosystems in the agricultural sector of the regional economy. *Bulletin of the Academy of Knowledge*, 4 (57). 238-246.

Popov,a L. V., Lata, M. S., Melikhov, P. A., Batova, V. N., 2022. Digital ecosystems of small agribusiness under sanctions. Regional economy. *The South of Russia,* 10. 3. 144-156.

Pushpa Gowri, D., Ramachander, A., 2024. Digital Agriculture. In Digital Agricultural Ecosystem (eds K. Singh and P. Kolar).

Senyo, P. K., Liu, K., Effah, J., 2019. Digital business ecosystem: Literature review and a framework for future research. *International Journal of Information Management,* 47, 52–64.

Singh, K., Kolar, P., Abraham, R., 2024. Digital Agricultural Ecosystem. In Digital Agricultural Ecosystem (eds K. Singh and P. Kolar).

Ying, Li, Yating, W., Lei, W., Jingci, X., 2022. Investigating the effects of stakeholder collaboration strategies on risk prevention performance in a digital innovation ecosystem. *Industrial management & data systems*, 122, 9, 2045–2071.

Yurchenko, I. F., 2019. Digital technologies as a factor in the competitiveness of enterprises in the reclamation sector of the economy. News of the Nizhnevolzhsky Agro-University Complex: science and higher professional education, 1 (53), 313–320.

Compression Parallel to Grain of Finger-Jointed Pine Specimens: Experiment and Modeling for Determination of Elastic Modulus

Gennady Kolesnikov[a], Timmo Gavrilov[b]
Petrozavodsk State University, 33, Lenin Avenue, Petrozavodsk, Republic of Karelia, Russia
kgn@petrsu.ru, gavrilov@petrsu.ru

Keywords: Finger-jointing technology for wood, Modulus of elasticity, Compression, Peak load, Stress concentration.

Abstract: The practical realization of sustainable development concepts implies the application of new material processing technologies, among which wood as a renewable resource with a low carbon footprint occupies a special place. Researchers have developed many promising technologies for wood processing, but this paper discusses only one of them that fully meets the requirements of sustainable development. This is a finger-jointing technology for wood. The paper deals with compression tests of pine specimens with initial dimensions of 40×40×80 mm with and without finger joints. Experiments have shown that the finger joint reduces the peak load on the specimen by 11 %. The peak load is reduced caused stress concentration, which is consistent with numerical modelling results in existing studies. In addition, the finger-jointed specimen showed a disproportionate 22 % reduction in relative strain at the peak point. These changes mean a decrease in plastic properties and an increase in brittleness under the influence of the physical and mechanical properties of the adhesive in the gear joint. This paper proposes two versions of the equation for modelling the behavior of wood in load-displacement and stress-strain coordinates. The relevance and feasibility of such research is because finger joint technology minimizes wood waste and ensures sustainable wood management to sustainable development.

1 INTRODUCTION

Rational use of resources and minimization of production and consumption waste are among the key points in the concepts of sustainable development at the global and regional levels. The practical realization of sustainable development concepts implies the application of new material processing technologies, among which wood as a renewable resource with a low carbon footprint occupies a special place (Linkevičius, 2023; Sikkema, 2023; Stanciu, 2020). Researchers have developed many promising technologies for wood processing (He, 2023; Pramreiter, 2023), but this paper discusses only one of them that fully meets the requirements of sustainable development. This is a finger jointing technology for wood (Ahmad, 2017; Faircloth, 2023; Muthumala, 2021; Stolze, 2021).

The need for rational utilization of wood has predetermined the development and widespread use of finger joint technology. This technology makes it possible to obtain almost endless blanks from small pieces of wood for building and furniture constructions (Hou, 2022; Hou, 2023). Thus, this technology minimizes wood waste and ensures sustainable use of wood, which motivates experimental and theoretical research in this field. For example, according to a study (Le, 2023), a modified "firefly algorithm" determines finger-joint parameters that maximize joint strength while reducing waste in the manufacture of timber structures. Despite the advances in this field, the issues related to modelling and experimental studies of the peculiarities of wood behavior under load remain relevant (Stolze, 2023; Walley and Rogers, 2022). One of such questions concerns the study of wood condition in joints of wooden structures under compression, bending and tension. In this direction, along with those presented in the list of cited literature, important is the study (Vega, 2020), in which the authors, using the finite element method, determined the areas of stress concentration in finger

[a] https://orcid.org/0000-0001-9694-0264
[b] https://orcid.org/0000-0003-3671-0971

joints, which is important for predicting wood damage and failure in the joint zone.

Purpose of this work: experimental study of the effect of a finger joint on the strength of pine specimens in compression along the grain and modelling of their behavior.

2 METHODOLOGY AND RESULTS

2.1 Experiment

To achieve this goal, we tested specimens made of pine with initial dimensions of 40×40×80 mm with and without finger joints. The relative humidity of the specimens was 12 %. A SHIMADZU testing machine was used in the experiments (Fig. 1).

Figure 1: Testing machine.

Figure 2 shows pine specimens without joints, before and after testing.

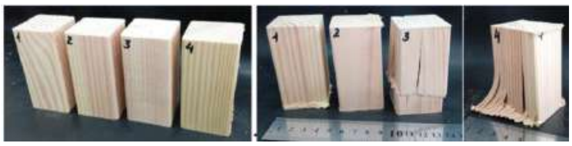


Figure 2: Specimens without joints before and after testing.

Figure 3 shows the curves in load-displacement coordinates for the specimens in Figure 2 under controlled displacement at 5 mm/min. The average force and displacement values at the peak are 73.9 kN and 1.484 mm, respectively.

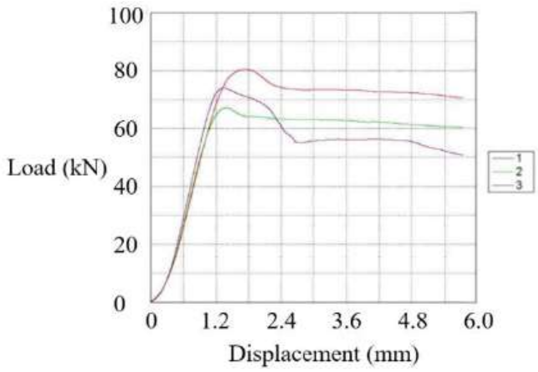


Figure 3: Experimental curves for specimens according to Figure 2.

Figure 4 shows specimens with initial dimensions of 40×40×80 mm, with finger joints.

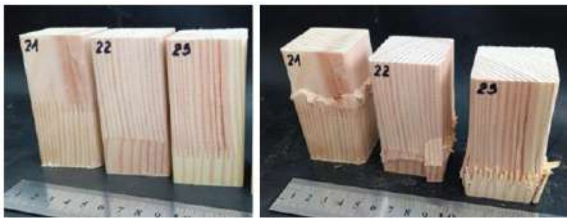


Figure 4: Specimens with finger joints before and after testing.

Figure 4 shows that finger joints localize wood damage, i.e. they are damage attractors. This fracture pattern is consistent with the results of numerical simulations (Vega, 2020), which predict an increase in stresses in the region of each vertex (Fig. 5) and, consequently, the localization of the onset of fracture in the joint. As a result, the predicted strength of specimens with finger connections decreases compared to the strength of similar specimens without connections.

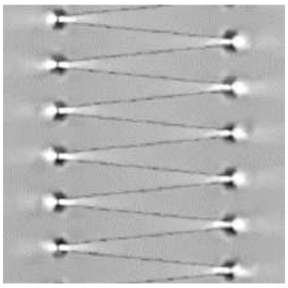


Figure 5: Stress concentration in a finite element model of joint (Vega, 2020).

Fig. 6 shows curves in load-displacement coordinates for specimens from Fig. 4 under controlled displacement at a speed of 5 mm/min. The average values of force and displacement at the peak point are 65.816 kN and 1.155 mm, respectively.

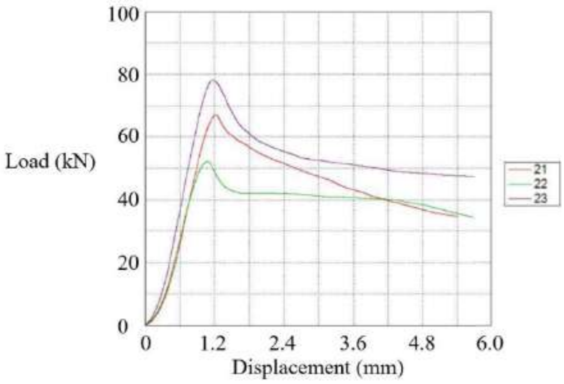


Figure 6: Experimental load-displacement curves for specimens according to Figure 4.

Table 1 combines data for specimens with and without joints for further analysis.

Table 1: Averaged experimental data for specimens with and without joints.

Specimens:	In peak point:			
	Displacement, mm	Load, kN	Stress, MPa	Strain
Without joints	1,484	73,9	46,2 (100%)	0,01855 (100%)
With joints	1,155	65,8	41,1 (89%)	0,01444 (78%)

Comparison of the experimental data (Table 1) shows that the average value of the load at the peak point for specimens with finger connections is 89 % of the strength of the specimen without connections. Accordingly, the conditional stiffness is 73.9 / 1,484 ≈ 49.8 kN/mm.

The average displacement (i.e., height reduction) for specimens with finger joints decreased disproportionately to 78% of the displacement for the specimen without joints. Accordingly, the conditional stiffness is 65.8 / 1,1554 ≈ 57.0 kN/mm. The relative strain decreased by 22 %, while the strength decreased by only 11 %, which can be interpreted as a decrease in plastic properties and an increase in brittleness in the finger joint area. These changes caused by the physical and mechanical properties of the adhesive that was used in the finger joint (Vega, 2020).

Thus, the finger connection reduces the strength of the specimens but increases the stiffness compared to specimens without connections.

2.2 Modelling

This part of the paper focuses on the determination of the tangent modulus of elasticity of wood using experimental data and mathematical modelling. Note that the values of the modulus of elasticity of wood depend on a number of factors (Sun, 2022; Verbist, 2020; Arriaga, 2023). E.g., the angle of deviation of the grain from the longitudinal axis of the specimen affects the value of the elastic modulus. The reduction in elastic modulus compared to a sample without deviations can exceed 50 % (Mania, 2020).

We use the following approach to determine the tangent modulus of elasticity of wood.

We approximate the experimental data (Figures 3 and 6) by a curve line with the equation from (Shekov, 2023). This equation can be written in coordinates load (F) – displacement (u) (1) or stress (σ) – strain (ε) (2):

$$\frac{F}{F_{peak}} = \left(\frac{u}{u_{peak}} e^{\frac{1}{n}\left(1-\frac{u^n}{u_{peak}^n}\right)}\right)^B; \qquad (1)$$

$$\frac{\sigma}{\sigma_{peak}} = \left(\frac{\varepsilon}{\varepsilon_{peak}} e^{\frac{1}{n}\left(1-\frac{\varepsilon^n}{\varepsilon_{peak}^n}\right)}\right)^B. \qquad (2)$$

The parameters n and B are determined during model calibration, e.g., using the least squares method, as shown (Stojković, 2017). However, for equations (1) and (2), it is simpler to apply the random search method (Arora, 1995), which is implemented in this paper. To ensure the universality of the model, but not to increase the number of equations, we use equation (1) (or (2)) but with different parameters n and B for the left (pre-peak) and right (post-peak) branches. For example, for the left branch: $0 \le u \le u_{peak}$, $n = n_l$, $B = B_l$; for the right branch: $u_{peak} \le u$; $n = n_r$; $B = B_r$. Figure 7 illustrates the approximation of the experimental data from Figure 3.

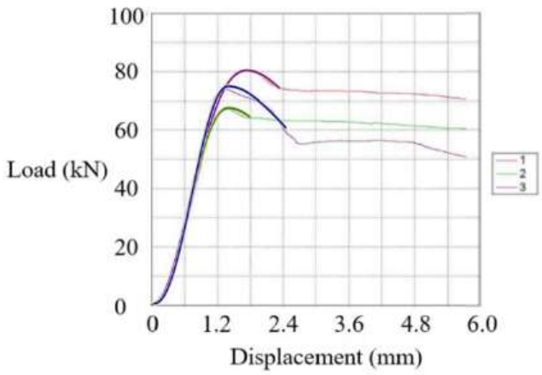


Figure 7: Approximation of the experimental data from Figure 3 (thickened curves).

Using equation (2) we determine the inflection point on the ascending branch of the curve from the condition $\frac{d^2\sigma}{d\varepsilon^2} = 0$. Since the second derivative is zero, the value of the first derivative is extreme at this point. Thus, we determine the largest value of the tangent modulus of elasticity $E = \frac{d\sigma}{d\varepsilon}$.

For specimens 1, 2 and 3 (Figure 2), we obtained, respectively, the following values of elastic modulus: 3.812, 4.195 and 4.457 GPa; the average value is 4.155 GPa. In specimen 1, the fibers are significantly deviated from the longitudinal axis of the specimen (Fig. 2), which reduces the value of elastic modulus. These results are in agreement with existing studies (Mania, 2020).

For specimens 21, 22 and 23 (Figure 4), we obtained, respectively, the following elastic modulus values: 4.850, 3.908, and 4.664 GPa; the average value is 4.474 GPa, which is 7.7 % higher compared to specimens without finger joints. The increase in the elastic modulus can be explained by the above-mentioned influence of the glue in the joint, but the influence of the natural variation of the physical and mechanical properties of wood cannot be ruled out either (Mania, 2020; Vega, 2020; Walley and Rogers, 2022). In general, the obtained values of elastic modulus are low, which is characteristic of low-density wood of immature forests.

3 DISCUSSION

The use of Equation (1) provides an acceptable accuracy of approximation of wood test results in compression parallel to the grain (Figure 7). Equations (1) and (2) use the same parameters n and B, respectively, and the accuracy of approximation of the experimental data in load-displacement and stress-strain coordinates is the same. The main result of the modeling is an accurate analytical determination of the tangent modulus of elasticity at the inflection point of the pre-peak curve. For specimens 1, 2, and 3 without connections (Figure 2) discussed above, the inflection point corresponds to a load equal to 40-50% of the peak load (Figure 8). For specimens with finger connections (Figure 4), the load at the inflection point is 50-60 % of the peak load (Figure 9).

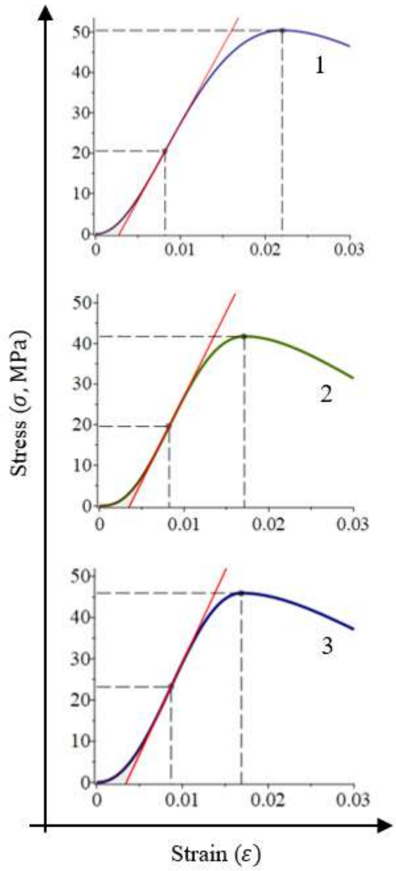


Figure 8: To determination of elastic modulus of specimens 1, 2 and 3.

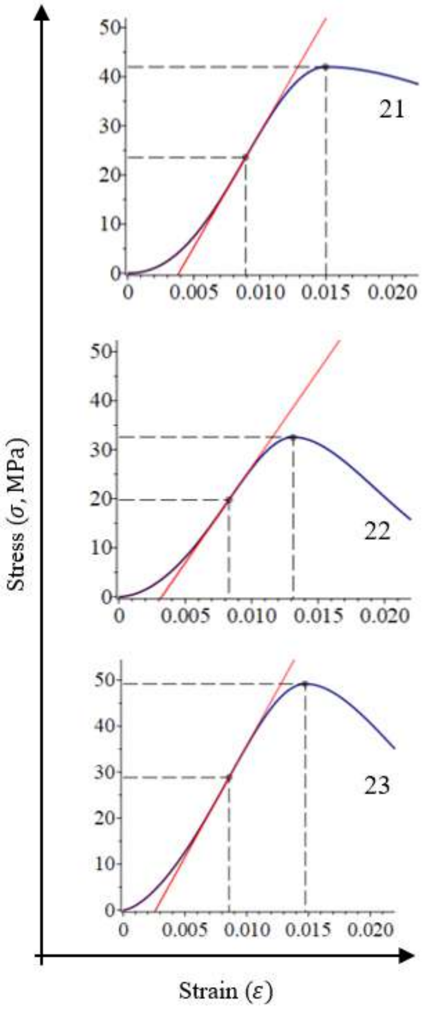


Figure 9: To determination of the modulus of elasticity of specimens 21, 22 and 23.

4 CONCLUSIONS

In this study, a methodology for determining the modulus of elasticity of wood with and without finger joints in compression parallel to the grain is proposed based on the analysis of experimental data using mathematical modeling.

The experiments showed that the presence of the finger joint reduced the peak load on the specimen by 11 %. The peak load reduction is due to the effect of stress concentration near the tops of the finger joint elements.

The finger joint disproportionately decreased the relative strain at the peak point by 22 %, i.e., decreased ductility and increased brittleness. Other things being equal, these changes depend on the properties of the adhesive in the finger joint.

Two versions of the equation for modeling the behavior of wood in load-displacement and stress-strain coordinates are proposed. The largest value of the tangent modulus of elasticity was determined using the condition $\frac{d^2\sigma}{d\varepsilon^2} = 0$. A distinctive feature of this approach is the reduction of uncertainty in selecting the coordinates of the point with the highest elastic modulus (Figs. 8 and 9).

The results obtained are consistent and adequate from the physical point of view. However, the amount of experimental data is small, so the research should be continued. Research in the indicated direction is relevant and expedient, as the finger-joint technology allows minimizing the amount of wood waste and ensuring rational use of wood for sustainable development.

REFERENCES

Ahmad, Z., Lum, W. C., Lee, S. H., Razlan, M. A., Mohamad, W. H. W., 2017. Mechanical properties of finger jointed beams fabricated from eight Malaysian hardwood species. *Construction and Building Materials*, 145, 464-473.

Arora, J. S., Elwakeil, O. A., Chahande, A. I., Hsieh, C. C., 1995. Global optimization methods for engineering applications: a review. *Structural optimization*, 9, 137-159.

Arriaga, F., Wang, X., Íñiguez-González, G., Llana, D. F., Esteban, M., Niemz, P., 2023. Mechanical properties of wood: a review. *Forests*, 14(6), 1202.

Faircloth, A., Kumar, C., McGavin, R. L., Gilbert, B. P., Leggate, W., 2023. Mechanical Performance and Bond Integrity of Finger Jointed High-Density Sub-Tropical Hardwoods for Residential Decking. *Forests*, 14(5), 956.

He, S., Zhao, X., Wang, E. Q., Chen, G. S., Chen, P. Y., Hu, L., 2023. Engineered wood: sustainable technologies and applications. *Annual Review of Materials Research*, 53, 195-223.

Hou, J., Taoum, A., Kotlarewski, N., Nolan, G., 2022. Study on the effect of finger joints on the stiffness of fibre-managed E. nitens sawn boards. *Buildings*, 12(12), 2078.

Hou, J., Taoum, A., Kotlarewski, N., Nolan, G., 2023. Study on the Effect of Finger-Joints on the Strengths of Laminations from Fiber-Managed Eucalyptus nitens. *Forests*, 14(6), 1192.

Le, S.T., Nguyen, T.N., Bui, D.-K., Ha, Q.P., Ngo, T.D., 2023. Modelling and Multi-Objective Optimisation of Finger Joints: Improving Flexural Performance and Minimising Wood Waste. *Buildings* 2023, 13, 1186.

Linkevičius, E., Žemaitis, P., Aleinikovas, M., 2023. Sustainability impacts of wood-and concrete-based frame buildings. *Sustainability*, 15(2), 1560.

Mania, P., Siuda, F., Roszyk, E., 2020. Effect of slope grain on mechanical properties of different wood species. *Materials*, 13(7), 1503.

Muthumala, C. K., De Silva, S., Arunakumara, K. K. I. U., Alwis, P. L. A. G., 2021. Failure modes and compression strength of seven finger-jointed wood species from Sri Lanka. *Journal of Failure Analysis and Prevention*, 21, 2215-2223.

Pramreiter, M., Nenning, T., Huber, C., Müller, U., Kromoser, B., Mayencourt, P., Konnerth, J., 2023. A review of the resource efficiency and mechanical performance of commercial wood-based building materials. *Sustainable Materials and Technologies*, e00728.

Shekov, V., Kolesnikov, G., 2023. Differential Energy Criterion for Brittle Fracture: Conceptualization and Application to the Analysis of Axial and Lateral Deformation in Uniaxial Compression of Rocks. *Materials*, 16(13), 4875.

Sikkema, R., Styles, D., Jonsson, R., Tobin, B., Byrne, K. A., 2023. A market inventory of construction wood for residential building in Europe–in the light of the Green Deal and new circular economy ambitions. *Sustainable cities and society*, 90, 104370.

Stanciu, M. D., Teodorescu, H. D., Vlase, S., 2020. Degradation of mechanical properties of pinewood under symmetric axial cyclic loading parallel to grain. *Polymers*, 12(10), 2176.

Stojković, N., Perić, D., Stojić, D., Marković, N., 2017. New stress-strain model for concrete at high temperatures. *Tehnički vjesnik*, 24(3), 863-868.

Stolze, H., Gurnik, M., Kegel, S., Bollmus, S., Militz, H., 2023. Determination of the Bonding Strength of Finger Joints Using a New Test Specimen Geometry. *Processe*s, 11(2), 445.

Stolze, H., Schuh, M., Kegel, S., Fürkötter-Ziegenbein, C., Brischke, C., Militz, H., 2021. Monitoring of Beech Glued Laminated Timber and Delamination Resistance of Beech Finger-Joints in Varying Ambient Climates. *Forests*, 12(12), 1672.

Sun, J., Zhao, R., Zhong, Y., Chen, Y., 2022. Compressive mechanical properties of larch wood in different grain orientations. *Polymers*, 14(18), 3771.

Vega, A., Baño, V., Cardoso, A., Moya, L., 2020. Experimental and numerical evaluation of the structural performance of Uruguayan Eucalyptus grandis finger-joint. *European Journal of Wood and Wood Products*, 78, 923-932.

Verbist, M., Branco, J. M., Nunes, L., 2020. Characterization of the mechanical performance in compression perpendicular to the grain of insect-deteriorated timber. *Buildings*, 10(1), 14.

Walley, S., Rogers, S., 2022. Is Wood a Material? Taking the Size Effect Seriously. *Materials*, 15 (15): e5403.

Formation of Future Marketers' Digital Competence in Higher Education Institutions

Babeshkova E.[1], Leonteva I.[2] and Pleshkov K.[3]
The Chuvash State University, Moskovsky prospect, Cheboxary, Russia
babeshkova@inbox.ru, leo-cbx@yandex.ru, pleshkov_kv@mail.ru

Keywords: digital competencies, digital technologies, the marketing specialist digital competence, marketers training.

Abstract: This article presents the results of the research devoted to the issues of future marketers' digital competence formation while studying under the bachelor's degree program at a higher education institution. In the course of the study the main components of digital competence were determined and the necessity of their development by future marketers studying under the bachelor's program at the university was justified. The place of digital competencies in the competence model of a university graduate to achieve the goal of its compliance with the labor market requirements in the digitalization context has been determined. The specificity of digital competencies is substantiated, which consists in the fact that in the context of practical application they often act not as independent competencies, but as tools for the implementation of other competencies. To determine the current requirements for candidates for the position of a marketer, the relevant requests of employers were studied, which made it possible to identify the main expected competencies and use them to create a profile of the marketer's competencies digital component. The Integrated System of Digital Competence Formation has been proposed, which will allow shifting the focus in the future marketers training to ensure their compliance with the needs of the digital economy, which in turn will provide them with competitive advantages in employment.

1 INTRODUCTION

One of the key directions of the Federal project "Personnel for the Digital Economy", developed within the framework of the National Program "Digital Economy of the Russian Federation", is to provide the digital economy with competent personnel. An important role is assigned to the professional education system, including higher education institutions, whose task is to train specialists with developed digital competences, regardless of profession and position, industry and company's sphere of activity.

The article is devoted to the issue of future marketers digital competence formation studying under the bachelor's degree program at the university.

The purpose of the study is to develop a comprehensive system of the marketer digital competence formation and the conditions for its implementation in higher education institution.

The scientific novelty of the research consists in the construction of the marketer's competencies digital component profile and developing on this basis a comprehensive system for the formation of digital competence for bachelor's degree training in marketing.

The practical significance of the research results lies in the possibility of their application by universities in the development of the future marketers' digital competence trajectory formation.

The marketing profession is one of the most multifaceted in the labor market. The duties of a marketer include research of commodity markets, study and formation of target audience, competitive analysis, improvement of assortment, development of pricing policy, formation of distribution channels, development of marketing communications system, formation of marketing strategy and management the

[1] https://orcid.org/0009-0000-8449-0163
[2] https://orcid.org/0009-0003-7719-9214
[3] https://orcid.org/0009-0009-3815-0892

of the marketing activities efficiency. The quality of these tasks depends on the level of professional competence of a particular marketer, which is formed in the course of mastering professional competences included in the competence model of a university graduate.

The competence model of a university graduate, which is his/her reference structural and conceptual image, along with professional competences, includes supraprofessional competences reflecting employers' requirements to a young specialist that go beyond his/her professional knowledge and are relevant for any profession and any type of work. Supraprofessional competences allow to improve the quality of professional tasks fulfilment (which is important for employers) and also play a determining role in the further professional career of an employee (which motivates students to develop these qualities themselves) (Leonteva and Pleshkov, 2021)., Such supraprofessional competencies as the ability to adapt quickly (both professional and social), the desire for constant development and improvement, analytical thinking, creativity, communication skills, the ability to multitask, manage a team, and make quick decisions in non-standard situations are the most important for a marketer.

However, mastering only the above competences (both professional and supraprofessional) is not enough for a future marketer to be in demand on the labour market. Digital transformation, which is actively penetrating into all spheres of social life, imposes strict requirements to the digital competence of university graduates, which necessitates the active integration of digital technologies into the educational process. Digital competence of a marketer is characterized by his/her ability to work with information in the digital environment, use models, mechanisms, methods and tools of digital management in the development of marketing solutions, form communicative relations with clients, partners and colleagues on the basis of digital technologies, comply with digital etiquette, ensure digital security, use the technical capabilities of modern digital devices and technologies and other aspects.

Considering the place of digital competencies in the competence model of a university graduate, it should be noted that digital competences can be included both in the group of supraprofessional and in the group of professional competencies, depending on their role. Supraprofessional digital competencies are universal for all spheres of professional activity, they are basic in relation to professional digital competences. Professional digital competences are necessary to solve specific professional tasks, their development is impossible without mastering professional digital competences. The specificity of digital competences lies in the fact that in the context of practical application they often act not as independent competences, but as tools for realizing other competences.

The trajectory of the future marketer digital competence formation covers all stages of the life cycle of the competence formation of a university graduate, among which the authors distinguish the following stages: preliminary, the competences formation within the future profession framework, the formation competences in accordance with a professional role. (Leonteva, Pleshkov and Nikolaev, 2021) The preliminary stage covers the pre-university period and is primarily related to the formation of supraprofessional digital competences. At the stage of competence formation within the future profession framework, digital competences are mastered in the process of studying at a university in the educational program "Marketing". The formation of digital competences in accordance with the professional role determined by the specifics of the marketers functional responsibilities in a particular organization occurs during employment after being employed. At the same time, some specific competences can be formed in students while they are still studying at the university (during internships, case studies, course projects, graduate qualification works ordered by employers, etc.).

2 METHODOLOGY

The methods of analysis and synthesis, generalisation and systematisation, content analysis were used in the course of the research.

The theoretical basis of the study was the scientific works of domestic and foreign authors, devoted to the application of the competence approach in marketers training (Rakhova, 2023; Tatarinov, 2019; Crittenden and Peterson, 2019; Wrona, 2015; Galeeva, 2015; Mkhitaryan and Danchenok, 2015), the technology of students digital competences formation in the university (Achkasova, Panasyuk, Shirokolobova and Larionova, 2022; Dmitriev, Alyabin, Brovko, Dvinina and Demyanova, 2021; Zhao, Sánchez Gómez, Pinto Llorente and Zhao, 2021; Zykova, Konovalova, Malinina, Ushakova and Khudyakova, 2021; Gladilina and Krylova, 2019; Sicilia, García-Barriocanal and Sánchez-Alonso, 2018; Torres-Coronas and Vidal-Blasco,2015), methodological aspects of the digital technologies in the educational process introduction (Selyutin, Yaremko and Glebova, 2023; Karstina, 2021; Koloskova, 2021; Andryukhina, Sadovnikov, Semenova, Sumina and Tserkovnikova, 2021; Armah and Westhuizen, 2020; Colás-Bravo, Reyes-de-Cózar and Conde-Jiménez, 2019). Materials provided on job search websites were used in the study of employer enquiries.

The structure of the research study includes:

Definition of digital competence and justification of the need for future marketers to master digital competencies.

Determination of the place of digital competences in the competence model of a university graduate - future marketer.

Identification of requirements for candidates for the position of a marketer based on the study of employers' requests.

Creating a profile of the digital component of the marketer's competences.

Development of the Integrated System of future marketer Digital Competence Formation.

3 RESULTS OF THE RESEARCH

Satisfaction of employers as consumers of the educational process result is the main criterion of the university graduates training quality (Pleshkov, Leonteva and Trukova, 2019). That is why job search websites were studied to form a complete picture of the competences that marketers should possess. In the course of the study, vacancies in the city of Cheboksary were reviewed and the requirements for candidates for the position of a marketer were identified.

Fifty-three vacancies for the position of a marketing specialist in various variations were considered: marketer, marketing manager, marketing specialist, etc. Among the considered vacancies there were offers from eight representatives of large businesses, three - medium-sized businesses, the rest - representatives of small businesses.

When analyzing the posted vacancies, the needs of employers were studied from the point of view of personal and professional competences possessed by candidates. According to the results, it was found that 26 vacancies out of 53 contained requirements for candidates' personal competences, and some vacancies contained only one desired personal competence "ability to work in multitask mode", "communication skills" or "creativity", and some contained a whole set of required personal skills (up to seven). The most demanded personal competences were: communication skills (17.54% in the total structure of required personal skills), analytical mindset (14.06%) and creativity (12.28%). The second group in terms of the demand for personal competences is: ability to multitask (10.52%), ability to work in a team (8.77%), result-orientation, initiative and responsibility, aspiration for growth and development, which scored 7.02% each. Such personal competences as not being afraid of difficulties, ability to take responsibility, smartness, systematic approach to problem solving and attention to details are found in the posted vacancies only once each.

Among the professional competences required of marketers, the most demanded were: the ability to develop advertising materials, including the ability to interact with advertising agencies to create advertising materials (18.79% of the total structure of required professional skills), the ability to assess the effectiveness of advertising (11.52%), knowledge of methods of market analysis (10.3%), the development and implementation of marketing strategy (9.7%) and the ability to analyze the target market with the identification of the needs of target consumers (9.7%). The obtained data show that for employers the most demanded professional competences are the ability to organize and conduct effective advertising campaigns in accordance with the developed marketing strategy, as well as the ability to analyze the market and target consumers. In the second place by the degree of importance and demand for employers were competences in the sphere of planning, development and implementation of marketing activities (9.09%), skills in competitor analysis (7.88%), skills in determining the results of the organization's activity and analysis of its efficiency (6.67%). Also in this group of professional skills were included competences in the sphere of marketing budget management (formation, control, optimization), which occupy 4.85% of the total volume of required professional competences of a marketer. The same share is occupied by the ability to organize and ensure the organization's participation in exhibitions.

The least demanded professional competences were: the ability to develop and implement the organization's development strategy, product portfolio management and pricing policy management, which together scored 4.85% in the total structure of professional competences required by employers.

The study examined as a separate group the required digital competences specified by employers in posted vacancies. Various digital competences were mentioned 133 times, among which the most demanded was "social media skills", which includes knowledge of advertising tools and the peculiarities of each social network, content creation and maintenance of social media accounts. This competence occupies 29.32% of the total structure of required digital skills. In second place in terms of demand were the skills of creating and developing an organization's website, which took a share of 18.8% among the digital competencies specified in the vacancies. In line with employers' demands, marketers need to understand how websites are built and run on different platforms, and how website and content are optimized to improve their performance.

In the third place in terms of employers' demand for digital competences with a share of 11.28% is the need for skills in graphic editors to develop and coordinate advertising materials.

Also relatively important competences are the ability to work with Microsoft Office package and CRM-systems, which occupy 6.02% and 5.26%, respectively, in the total structure of digital competences.

An insignificant number of employers noted the need to be able to use specialized services such as Yandex Direct, Yandex Metric, Yandex Maps, 2gis, as well as to know the basics of working in the 1C system.

Thus, based on the analysis of posted vacancies for the position of marketing specialist, we can conclude that among the professional competences of candidates for the position under consideration the most important are skills in the development of advertising materials and the use of social networks in promoting the company's business. Also, the results of the analysis show that there is currently a need in the labor market for marketers with a wide range of digital skills necessary for the successful functioning of the company in the conditions of total digitalization.

Digital competences, as emphasized above, are not just a standalone group of skills, but rather an integral component of any competence needed by a marketer. This is because all aspects of modern marketing activities are inevitably linked to digital technologies and tools. Everything from planning and executing advertising campaigns to analyzing consumer behavior and optimizing customer experience requires a deep understanding of digital platforms, analytical methods and advanced technologies. Let's highlight the digital component of a marketer's professional competences, highlighted in accordance with employers' requests in the posted vacancies (Table 1).

Table 1: Profile of the marketer's competences digital component.

Professional competences of a marketer	Digital competence component	Digital tools
Knowledge of the modern marketing basics	Mastery of information resources for studying marketing concepts and strategies, mastering new trends in the digital environment	Internet, electronic library systems, specialized chat rooms and forums.
Marketing research	Mastery of online questionnaires, social media and other tools for collecting and analyzing data.	Online survey services - Hotjar, SurveyMonkey; data analysis and result visualization - Metabase.
Target audience (consumers) analysis	Use of digital tools and technologies to collect, analyze and interpret consumer data. Ability to work with customer relationship management software systems.	Parsers for searching target audience from various sources. Analytical platforms - Yandex.Metrica, KISS Metrics, Adobe Analytics; keyword and search query analysis - Yandex.Wordstat, Semtools. CRM systems - Salesforce, Bitrix24, HubSpot.
Market analysis	Mastery of analytical tools and programs for collecting, analyzing and interpreting data on the market and its dynamics	Internet: World Bank data, Statista data collection; MS Excel package for basic calculations.

Professional competences of a marketer	Digital competence component	Digital tools
Competitive analysis	Possession of software tools for competitive analysis and competitor monitoring.	SimilarWeb, SEMrush, Ahrefs - allows you to analyze competitors' activity, their traffic, advertising campaigns and other indicators.
Analysis of promotion channels	Ability to search, analyze and evaluate promotion channels in the digital environment	Web analytics tools, analytical tools for tracking key promotion channel metrics, analytical tools for social platforms.
Strategic planning of marketing activities	Possession of marketing process automation and project management tools	Kaiten for marketing team collaboration, Trend ERP for business automation, i2c Engage for marketing planning, etc.
Media planning	Ability to use digital channels and tools to develop and optimize marketing communications, to select the most effective combination of advertising platforms	MS Excel package, any other spreadsheet service; specialized resources for media planning (e.g. MediaScope research); planning software for TV (PaloMars), radio (Radio AdsMan Pro), etc. advertising; social network advertising offices.

Professional competences of a marketer	Digital competence component	Digital tools
Budgeting of marketing activities	Knowledge of data mining tools and ability to use software products to define, allocate and optimize marketing budgets	Online resources, databases, specialized programs and tools for cost accounting and planning (Adesk, Calltouch), forecasting tools (Tableau) and budget modeling (Beyond, Adaptive planning, BPlan).
Developed communication skills	Use of information and communication tools and specialized platforms to effectively engage with target audiences and manage communication channels	Services for managing communications and loyalty programs (LeeLoo.ai, 1-Rarus, BonusPlus), messengers (Telegram, Viber, BotHelp.io), social networks, email and mail services, communication services (Sberbusiness Bot) and chat bots (Chaport), speech technology tools (automated call centers, voice mailings), and platforms for intra-branch communications.

Professional competences of a marketer	Digital competence component	Digital tools
Product portfolio management	Possession of tools for effective management and development of the product line	Complex solutions for analytics and product assortment management (Business-BI for Category Management, Product Assortment Management m 1-C), software for retail assortment management (Analyse2, Item Planning, Aptos Merchandising), complex software for analytics and trend identification for assortment optimization (Power BI, DataWeave).
Pricing policy management	Monitoring and optimizing pricing policy using information and communication technologies and relevant software products	Competitor price monitoring tools (Pricer24, Minderest), MS Excel package for data interpretation, price parsers from websites, SaaS services, pricing automation systems (Contour.Market, imPrice).
Product/service fulfilment management	Ability to optimize the distribution system in online and offline channels using appropriate digital tools	E-commerce, marketplaces; predictive analytics, inventory optimization, omnichannel distribution (ikas, Shopware), personalization and automation of product recommendations (Flocktory, RichRelevance, Leadhit).
Promotion of goods/services	Ability to apply digital technologies and tools to promote goods and services both offline and online	Interactivity showcases; digital media; interactive projections; QR codes; Content marketing (websites, blogs, SMM); Performance marketing (contextual and targeted, CPA networks); CRM marketing (Push notifications, email marketing, SMS marketing and calls); SEO; Affiliate marketing; Influencer marketing (influencer marketing). Automated advertising management services.
Development of advertising materials	Ability to create effective and attractive materials to promote the company's goods and	Creating advertising creative using graphic tools (Supa, Picselcut, etc.), creating video content

Professional competences of a marketer	Digital competence component	Digital tools
	services, taking into account the characteristics of the target audience and the specifics of the means of advertising communication with the use of digital tools.	(Synthesia), creating text content (text.ru with AI, , creating infographics, creating audio content (Descript, Capcut).

The need to create a profile of the digital component of a marketer's competences is due to the strong dependence of all marketers on digital technologies. Consumers are spending more and more time online, so companies must utilize the potential of the digital environment to attract, engage and retain customers. In addition, the level of development of digital technologies during the fourth industrial revolution - Industry 4.0, has led to the fact that the possession of digital competencies becomes an integral element of the future marketer's competitiveness in the labor market. This indicates the need to form digital competence of future marketers in the process of professional training in higher education. To solve this problem, the authors propose the creation of the Integrated System of Digital Competence Formation for the training of bachelors in the field of marketing.

The complex system of formation of digital competence of future marketers is a system of interrelated and interdependent elements, functions and processes, which together provide training for the digital economy in the field of marketing.

The complex system of forming digital competence is based on three interrelated elements (Figure 1):

1. Teachers with relevant expertise in marketing and digital technologies.

2. Methodology that defines the ways, methods, principles, approaches that form the learner's digital competence.

3. Equipment and software necessary for mastering digital competences.

The Integrated System of Digital Competence Formation will provide students with an opportunity to bridge the gap between theory and practice, developing their digital competences in marketing, taking into account the needs of the labor market in the conditions of total digitalization.

It should be noted that the practical implementation of the Integrated System of Digital Competence Formation implies its dependence on the individual needs of students, existing programs and resources, the specifics of marketing education and labor market requirements. In this regard, one of the key characteristics of the Integrated System of Digital Competence Formation for future marketers is its flexibility and adaptability to changes in external and internal conditions, which implies the ability of the system to respond to changes in such factors as new technologies, market requirements and the marketing industry.

An important point, in addition, is the interdependence of the system elements, which is expressed in the mutual coordination and mutual adaptation of the essential characteristics of each element included in the Integrated System of Digital Competence Formation. For example, the emergence of new digital marketing tools may entail the need to include them in the system within the framework of training, which will require updating methodological techniques and training of pedagogical staff corresponding to the new conditions.

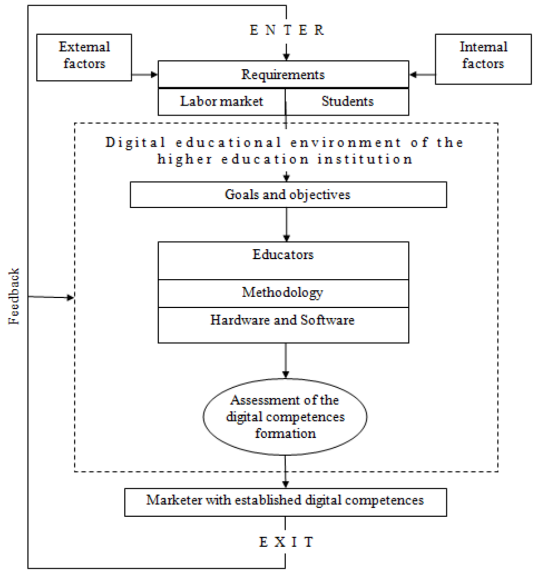


Figure 1: Integrated System of Digital Competence Formation.

4 DISCUSSION OF THE RESULTS

The creation and implementation of the Integrated System of Digital Competence Formation of future marketers can be a necessary preparatory stage in addressing the question of what exactly should be focused on in the training of bachelors receiving professional education in the field of marketing, in accordance with the prospective requirements of the market in the conditions of digitalization. At the same time, one of the most significant opportunities for overcoming the diversity of interpretations and multidimensionality of digital competence of future marketers is a certain individualization of the digital competence formation trajectory.

5 CONCLUSION

Thus, digital competencies are becoming an indispensable element of the competency model of a future marketer and a guarantee of his or her relevance in the labor market. Employers are increasingly expecting marketers to be able to effectively and creatively use digital technologies in their professional activities, to apply the whole range of technical, cognitive, emotional and social skills to adapt to the dynamic requirements of the digital environment, to communicate with target audiences, to solve problems and make decisions, as well as for self-development and innovation. It should be borne in mind that digital competence cannot be built once and for all. It requires continuous development and improvement in accordance with the changes taking place in socio-economic systems.

REFERENCES

Achkasova, O.G., Panasyuk, V.P., Shirokolobova, A.G., Larionova, J.S., 2022. A model for developing cross-curricular digital competences of higher education students in non-core areas IT areas in the process of additional education. *Bulletin of Mininn University.* T. 10, №2. C. 4.

Andryukhina, L., Sadovnikov, N., Semenova, S., Sumina, T., Tserkovnikova, N., 2021. Ecosystem Functions of Individual Style in a Digital Educational Environment. *TEM Journal.* Vol. 10. No. 1. P. 405-413.

Armah, J., Westhuizen, D., 2020. Embedding Digital Capability into the Higher Education Curriculum: The Case of Ghana. *Universal Journal of Educational Research.* Vol. 8. No. 2. P. 346–354.

Colás-Bravo, P., Reyes-de-Cózar, S., Conde-Jiménez, J., 2019. The development of the digital teaching competence from a sociocultural approach. Comunicar. Vol. 27. No. 61. P. 19-30.

Crittenden, V.L., Peterson, R.A., 2019. Keeping the Marketing Curriculum Current in an Era of Digital Disruption. *Journal of Marketing Education.* No. 2. P. 75–76.

Sicilia, M.-A., García-Barriocanal, E., Sánchez-Alonso, S., 2018. Digital Skills Training in Higher Education: Insights about the Perceptions of Different Stakeholders. 6th International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM). New York: Association for Computing Machinery. P. 781–787.

Dmitriev, Ya.V., Alyabin, I.A., Brovko, E.I., Dvinina, S.Yu., Demyanova, O.V., 2021. Fostering university students' digital skills: de jure vs de facto. *University governance: practice and analysis*. T. 25, № 2. C. 59–79.

Galeeva, R.B., 2015. Marketing Specialists' Professional Activities Model as a Foundation For Training Content Design. Procedia – Social and Behavioral Sciences. P. 1528–1537.

Gladilina, I.P., Krylova, M.E., 2019. Digital competencies in the structure of the competency-based approach of social and professional formation of an individual. Modern teacher education. № 11 C. 13-15.

Karstina, S.G., 2021. Development of a toolkit for assessing digital competencies of engineering students. *Kazan Pedagogical Journal*. № 5 (148). C. 112–119.

Koloskova, G.A., 2021. Digital educational environment and its role in the formation of professional competencies of students. *Teaching Methodology in Higher Education.* Vol. 10. No 37. P. 99–106.

Leonteva, I., Pleshkov, K., Nikolaev, E., 2021.Life Cycle of Professional Competence Formation: Students' Opinion on University-Employer Engagement. Proceedings of the 37th International Business Information Management Association (IBIMA), 30-31 Cordoba, Spain. P. 3084-3087.

Leonteva, I.A., Pleshkov, K.V., 2021. The competence model of a university graduate as the competence formation basis in the conditions of changing needs of the regional labor market. *Economics and business.* № 7. C. 561-565.

Mkhitaryan, S.V., Danchenok, L.A., 2015. Forming competencies marketers focused on business needs. *MBA marketing. Marketing management of the enterprise.* T. 6. № 4. C. 195-201.

Pleshkov, K., Leonteva, I., Trukova, A., 2019. Study of the Level of Employers' Satisfaction with the Quality of Training in Universities. Proceedings of the «New Silk Road: Business Cooperation and Prospective of Economic Development» (NSRBCPED – 2019), Series: Advances in Economics, Business and Management Research. Vol. 131. C. 786-789.

Rakhova, M.V., 2023. Formirovanie professionalnyh kompetentsiy pri podgotovke marketologov: formy effektivnogo vzaimodeystviya obrazovatelnyh organizatsiy i predstaviteley biznesa [Developing professional skills in educating marketers: forms of effective interaction between educational organizations and representatives of the business community]. Economics, business and law. 2023. Том 13. № 9. С. 3619–3630.

Selyutin, V.D., Yaremko, N.N., Glebova, M.V., 2023. Methodology of formation of digital competence of bachelors in the system of pedagogical education. World of Science. Pedagogy and psychology. 11(4): 06PDMN423.

Tatarinov, K.A., 2019. Competence requirements and features of teaching marketologists in the Russian university. *Azimuth of research: pedagogy and psychology*, T. 8. № 1 (26). С. 258-260.

Torres-Coronas, T., Vidal-Blasco, M.-A., 2015. Students and Employers' Perception about the Development of Digital Skills in Higher Education. *Revista de Educacion.* Vol. 367. P. 63–89.

Wrona, S., 2015. Wymagania kompetencyjne w zawodzie marketingowca – przygotowanie do zawodu a realia rynkowe (studenci/absolwenci uczelni kontra pracodawcy). *Problemy zarządzania, Finansów i mar¬ketingu*. Vol. 2. No. 41. P. 345–357.

Zhao, Y., Sánchez Gómez, M.C., Pinto Llorente, A.M., Zhao, L., 2021. Digital Competence in Higher Education: Students' Perception and Personal Factors. *Sustainability.* Vol. 13 (21). Art No. 12184.

Zykova, N. V., Konovalova, L. V., Malinina, Y. S., Ushakova, T. N., Khudyakova, O. N., 2021. Improving Digital Competences of Students-Bachelors of the Field of Study 38.03.02 "Management». *Pedagogy. Theory & Practice.* Volume 6. Issue 4. P. 605-615.