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URBAN STUDIES

Modern Methods for Studying the Spatial Structure of Urban Agglomerations (a Case Study of the St. Petersburg Urban Agglomeration)

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Abstract—the article reviews and substantiates research methods and data sources on the dynamics of the spatial structure of the largest urban agglomerations in Russia. The object of the study is modern methods for studying urban agglomerations based on new data sources. A case study of the number two urban agglomeration in Russia—St. Petersburg urban agglomeration—shows that interdisciplinary synthesis of socioeconomic geography, regional economics, urban studies, geoinformatics and cartography, land management, and variety of data sources (mobile network operators' data, tax statistics, housing construction, satellite observations, retail chain activity, and road networks), as well as modern GIS equipment, make it possible to evaluate this structure, its changes, and fluctuations. The main objective of the study is to critically rethink the methods of studying the spatial structure of one of the largest urban agglomerations in Russia that developed in the turbulent period between 2014 and 2022. Using a deductive approach, the authors inventoried the available methods for studying urban agglomerations and traditional data sources and obtained updated methods and new sources. Next, the advantages and disadvantages of each group of methods are identified. Using bibliographic analysis, the authors identified the limitations and possibilities for empirical content (availability of specific data sources). Based on their own critical analysis, the authors offer a final expert assessment of the applicability and usefulness of the methods specifically for the St. Petersburg urban agglomeration. The authors' contribution lies in the adaptation of modern groups of methods for studying the spatial structure of cities to study the considered urban agglomeration, taking into account the local specifics. It is expected that development of a modern methodology for studying the spatial structure of the St. Petersburg urban agglomeration, based on a symbiosis of modern methods and data sources, will contribute to studying Russia's largest urban agglomerations.

Keywords: urban agglomeration, spatial structure, dynamics of spatial structure, methods, data sources
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INTRODUCTION

Cities play an important role in the life of society, and this role continues to increase with urbanization in the world: in 2020, more than 56% lived in cities, and by 2030, the share of city dwellers will increase to 60%, or up to 5.2 bln people.[1] The development of cities and their efficiency depend on many factors: economic-geographical position; the influence of the economic situation at the regional, national, and global levels; changing technological structures and, not least, the spatial structure of the city (Lappo, 1997). Functional (land use options) and morphological (number of stories, relative position of houses, etc.) elements of the city space affect the comfort of the urban environment and the efficiency of spatial organization, which ultimately affects the socioeconomic development of the city (Conzen, 2002).

The relevance of spatial structure studies is increasing, not least due to an increase in the quantity, quality, and, in particular, availability of data, allowing the use of new research methods or more efficient use of old ones. Such data include remote sensing data (e.g., recording changes in land use (Li et al., 2013)), mobile network operators' data (Babkin, 2020, 2021), regis-

[1] World Cities Report 2022: Envisaging the Future of Cities. UN Habitat. https://unhabitat.org/wcr/. Accessed December 18, 2022.

tries of economic entities (e.g., based on the SPARK database of Interfax (Lachininskii and Sorokin, 2021)), open map data (e.g. Open Street Map (OSM) (Li et al., 2020)), point of interest data (Zhou et al., 2021), age of houses (e.g., housing and communal services reform data (Kukina, 2021)), etc., as well as their integration (e.g., remote sensing and OSM data to identify types of new development (Schiavina et al., 2022)). A specific feature of the indicated data is that they are independent of administrative-territorial division (ATD, primary third-level and fourth-level of administrative divisions): they allow one to obtain a more objective picture of spatial phenomena and eliminate the error of modified areal areas.[2]

However, most data (in general, this does not apply to remote sensing data) used by researchers have their own individual characteristics. For example, researchers extract data on economic entities from registries formed with varying degrees of completeness; they may include only legal persons (Lachininskii and Sorokin, 2021) or individuals (individual entrepreneurs) (Chistyakov et al., 2020). Here, as an example, we can use housing stock data: e.g., researchers from Poland use only information about the location of buildings and the year of their construction (Pirowski and Bartos, 2018), while in Russia, as part of the housing and communal services reform project, there are data on the number of floors, the residential and nonresidential area of buildings (Planirovanie ..., 2021). There are also options when researchers create unique data sets that are difficult to generate for other territories (e.g., housing project data) (Kurichev and Kuricheva, 2020). These differences are generally associated with differences in the pace of digitalization and availability of open data, which, on the one hand, is an obstacle to absolutely accurate replication of research for any territory, and on the other, makes it possible to improve or create new ones.

The individuality of the data necessitates updating the methodology and empirical base in the context of studying St. Petersburg. This will allow us to consider the spatial structure of the St. Petersburg urban agglomeration in a new way and to obtain a more objective picture of certain elements of the urban agglomeration space.

MATERIALS AND METHODS

To update the methods and data sources for studying urban agglomerations, modern geographical and socioeconomic studies on urban issues were reviewed based on a general interdisciplinary spatial paradigm. The methods were divided into groups depending on the data used and were adapted for studying the St. Petersburg urban agglomeration, considering the supply of available data.

Four groups of methods for studying the spatial structure of urban agglomerations can be distinguished depending on the types of data used:

(1) Remote sensing data;

(2) Data on buildings and location of economic actors (legal persons and retail chains);

(3) Mobile network operators' data;

(4) Road network data.

This list is not exhaustive, but for the St. Petersburg urban agglomeration, it is the most suitable, because these groups of methods have already undergone some testing and can be used in future studies.

Remote Sensing Data. The use of multispectral satellite imagery to study the spatial structure of cities is an extremely common research method, especially in developing countries (Li et al., 2013; Perez et al., 2019). Most often, Landsat satellite images, which have a long time series, are used for such studies, but such satellite images, with a spatial resolution of up to 30 m, cannot take into account the functional heterogeneity of a city and its new territories (Roni, 2018). Of course, some researchers obtain very high-resolution satellite images (1–10 m) with which it is possible to identify the functional features of the territory (Li et al., 2013). However, not everyone can obtain similar data. In general, the qualitative classification of satellite images is often a labor-intensive process, the reproducibility of which for other territories on the part of subsequent researchers is difficult (in particular, not by remote sensing specialists) (Atlas ..., 2020).

Remote sensing data can be adapted for the St. Petersburg urban agglomeration using already processed remote sensing data. This will allow a larger circle of researchers to use such materials and will also simplify the possibility of replicating such research for other territories. The highest quality version of processed remote sensing data, according to the authors, is from the *Global Human Settlement Layer* (GHSL) project (Schiavina et al., 2022).

In summer 2022, an updated set of materials was released containing 2018 data on urban development with a spatial resolution of 10 m (classification based on machine learning of Sentinel-2 images), number of stories (based on integration with a digital elevation model) and functional purpose (based on integration with functional zoning in the OSM project), and development with a spatial resolution of 100 m to study the spatial structure in the moment. To study the dynamics of development, it is possible to use older data with a spatial resolution of 30 m (Landsat images) for 1975–2015 (Fig. 1). It is also possible to extract quantitative characteristics by aggregating data on a regular grid (e.g., 250 m or 1 km (Atlas ..., 2020)) by administrative-territorial unit.

[2] Science Direct: Modifiable Areal Unit Problem. www.sciencedirect.com/topics/earth-and-planetary-sciences/modifiable-areal-unit-problem. Accessed May 20, 2022.

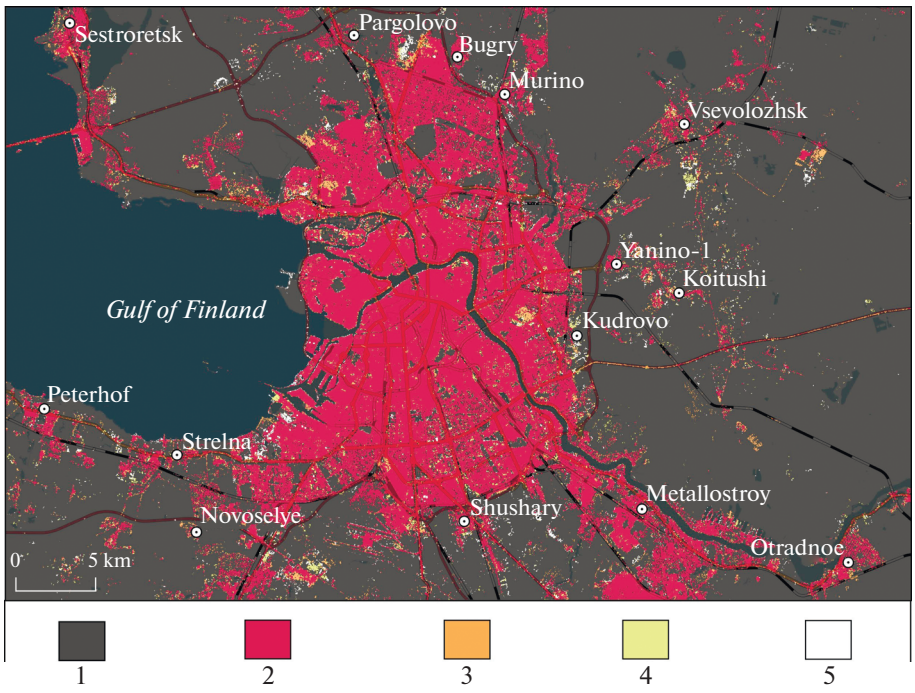

Fig. 1. Period of appearance of urban development: 1, no development; 2, existed in 1975; 3, from 1975 to 1990; 4, from 1990 to 2000; 5, from 2000 to 2015.
Source: Global Human Settlement Layer (GHSL) project data, spatial resolution 30 m.

This method of assessing the spatial development of an urban agglomeration can be applied to identify and describe almost all processes in an urban agglomeration. It is possible to characterize urbanization, expressed in this method as the emergence of new urban development cells adjacent to the urban core, or suburbanization, expressed as the emergence of urban cells.

The advantages of this technique are complete independence from the data of statistical services, because they are not used at all in remote sensing. As well, these data have the important property of capturing a full-fledged time slice: the satellite image provides unambiguous information about the space in the studied period, in contrast to data on the age of buildings, when it is unknown what stood in this place prior to the year of construction. A possible drawback of this method is the creation of a new error of modified areas in the form of satellite image cells (in general, this is not so critical with a resolution of 30 by 30 m). Another disadvantage is the lack of account for filling of a cell space with buildings: because cells with a size of 30 by 30 m are simply divided into developed and undeveloped (without taking into account, e.g., the number of stories); a development cell can be, e.g., an industrial center, a historical area of the center, new multistory buildings, etc., whereas remote sensing data cannot be used to determine this.

Building Data. The study of development based on data on most buildings in the city has become much more accessible due to the advent of geoinformation tools (Carra and Barthelemy, 2019). Data on the age of buildings makes it possible to study the dynamics of the spatial structure of the city, and data on the number of stories and, in particular, living space make it possible to indirectly examine the population density in the urban space (Pirowski and Bartos, 2018). It is also possible to study housing construction based on the mapping of large housing projects and analysis thereof (Kurichev and Kuricheva, 2020).

However, according to the authors, housing and communal services reform data are the most significant, which are open and available for download.[3] They contain information on the residential area of apartment buildings, the year and series of construction, the infrastructure of the apartment building, and, most importantly, the address in accordance with the Federal Information Address System (FIAS). This makes it possible to georeference the housing and communal services reform data as points using geocoding and to subsequently use it for analysis of housing construction, separate from ATD. These housing and communal services reforms are already actively used in research by urban planners, architects (Kukina et al., 2021), urbanists (Planirovanie ..., 2021), cartographers (Baryshkin and Alekseenko, 2022), etc. Large-scale housing construction causes changes in the set-

[3] Housing and communal services reform, open data. https://www.reformagkh.ru/opendata. Accessed July 18, 2022.

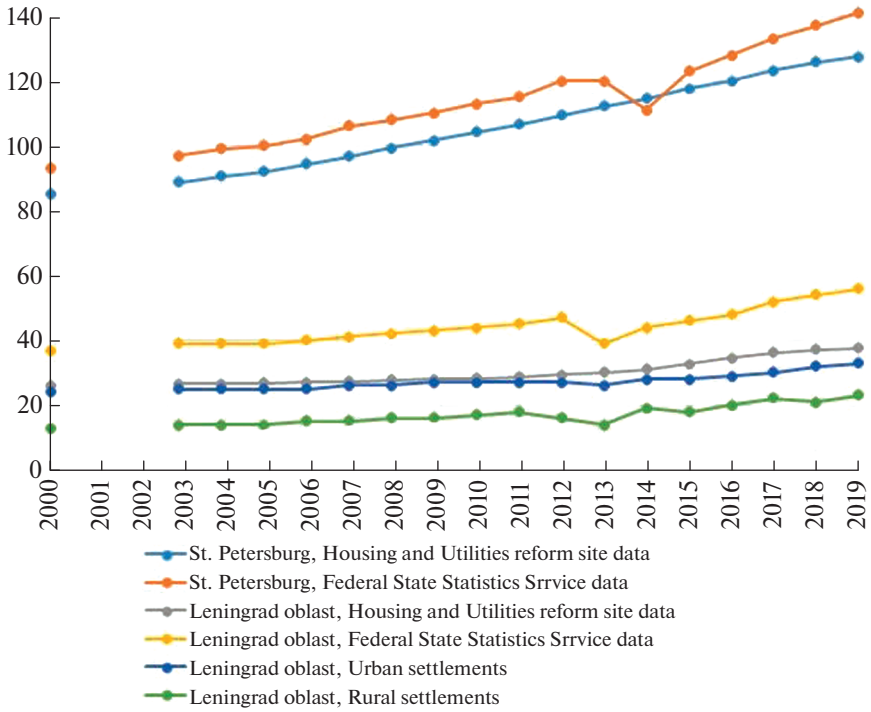

Fig. 2. Area of housing stock in Leningrad oblast and St. Petersburg, mln m^2.
Compiled by author.

tlement pattern, spatial structure of jobs, commuting migration, and transport flows in the urban agglomeration, and in terms of migration inflow, it is associated with the national settlement system and interregional inequality (Kuricheva, 2017).

This method can be adapted for the St. Petersburg urban agglomeration since, in general, the housing stock primarily comprises apartment buildings: underestimation of the housing stock due to lack of data on individual housing construction in St. Petersburg is 7.8%, and in Leningrad oblast, 31.8% (Fig. 2).

An example is use of a hexagon grid to display spatial patterns of housing commissioning in 2000–2008 (Fig. 3), a period for which quantitative assessments are difficult due to the predominance of point, compact development.[4]

These housing and communal services reforms make it possible to study the population distribution in the urban agglomeration space: both directly, with the indicator of housing provision, and indirectly, with the redistribution of statistical data among houses based on their area (the basis of the dasymetric method of displaying spatial phenomena (Petrov, 2012)). The spatiotemporal dynamics of housing construction should be considered based on year of construction data.

As for shortcomings, it should be noted that it is impossible to record a complete time slice (the data is simply updated, and archived versions are not yet available), because it is impossible to establish what was at the site of an apartment building prior to its construction (this will become particularly important in the case of a full-fledged renovation in St. Petersburg). Another disadvantage is the lack of data on multiapartment buildings, which can make it difficult to use this method for studying suburban areas outside the urban core.

Data on the Location of Economic Actors. Databases on legal persons, actively used in the study of enterprise economics, are also beginning to be actively used in economic–geographical studies (Chistyakov et al., 2020; Hegyi et al., 2021; Lachininskii and Sorokin, 2021).

Data on localization and revenue of legal persons are primary statistical data aggregated at the level of ATD cells. Accordingly, these data make it possible for the researcher to obviate ATD data and independently transform primary data. The development of this area has largely become possible due to the increased availability of geocoding tools, which make it possible to convert a huge number of addresses of legal persons into geographic coordinates. Also, data on the location of economic actors are provided by cartographic reference books, and the 2GIS company at the end of 2022 presented its product 2GIS Pro, is a tool for ana-

[4] How new buildings in St. Petersburg have changed: from the 1940s to the present. https://www.fontanka.ru/2018/05/18/066/. Accessed May 20, 2022.

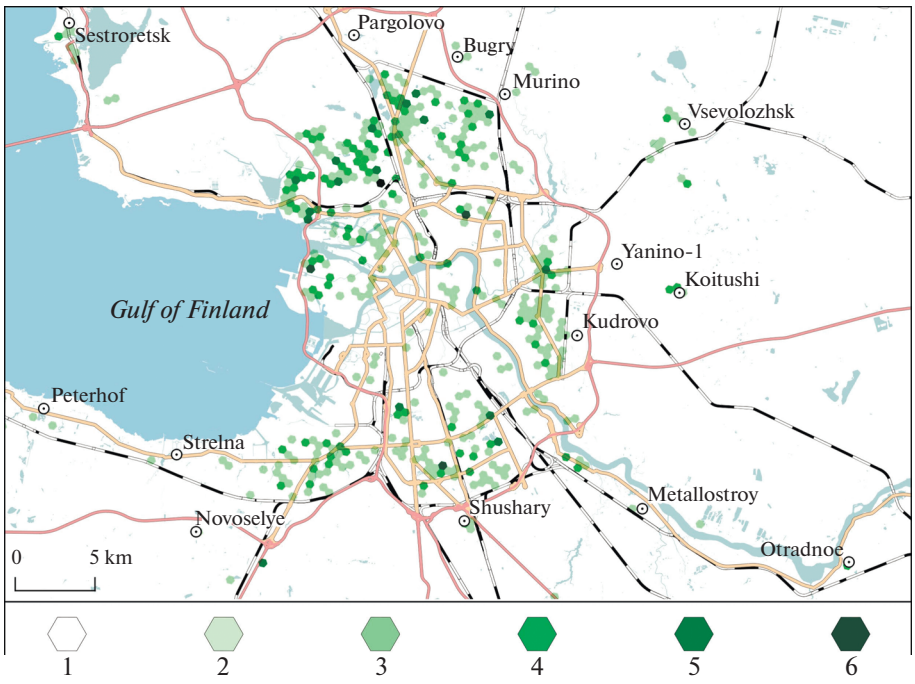

Fig. 3. Commissioning of housing stock of apartment buildings in 2000–2008, thous. m^2 in 0.25 km^2 hexagon: 1, none; 2, 1–50; 3, 50–100; 4, 100–150; 5, 150–250; 6, 250–400.
Source: housing and communal services reform data.

lyzing and visualizing data on a map,[5] which can be used in urban research.

Studies of the spatial structure of the St. Petersburg urban agglomeration are possible using the SPARK-Interfax database, to which an increasing number of Russian universities and, therefore, researchers are gaining access.[6] This system makes it possible to obtain information on financial reporting indicators, including revenue, through which the gross domestic product (GDP) of municipalities has been indirectly assessed[7] (Chistyakov et al., 2020); accordingly, it is also possible to evaluate arbitrary areas of the city, which provides insight into the spatial distribution of economic activity. Also, based on data from registries of legal persons, it is possible to study dacha suburbanization, mainly in municipalities, based on agricultural censuses (Krasnov and Logvinov, 2022; Makhrova, 2021). From registries of legal persons, it is possible to generate spatial data on nonprofit partnerships (the main form of existence of summer residents) and obtain their distribution pattern in the suburbs.

There are several advantages of methods based on the SPARK-Interfax database. First, researchers can assess the economic activity of a particular territory without reference to the ATD. Second, the time series of the SPARK-Interfax database is significantly longer than that of most data from the municipal indicators database: 1999 vs. 2009–2011. Third, data from registries of legal persons include lines from financial statements, from which one can independently calculate macroeconomic indicators for analysis (e.g., (Chistyakov et al., 2020)).

However, there are a number of shortcomings in the data for registries of legal persons. First, the SPARK-Interfax database uses a constantly updated database of the Unified State Registry of Legal Persons (USRLP), which is why the addresses of organizations in the samples are relevant today. Therefore, e.g., in the data sample for 2000, the address of Gazprom is invalid.[8] This significantly limits spatiotemporal studies based on data from the registry of legal persons. Second, downloads indicate the address of only the main division, without the addresses of branches, which is why it is impossible to obtain a complete picture of the distribution of economic activity in the territory. The last drawback can generally be solved by integration with directory data, such as 2GIS for today or Yellow Pages for earlier periods.

[5] 2GIS Pro: visualizing data sets. https://vc.ru/services/557545-2gis-pro-vizualiziruem-massivy-dannyh. Accessed December 26, 2022.

[6] Interfax LAB is expanding academic cooperation with universities. https://spark-interfax.ru/articles/interfax-lab-rashiryaet-sotrudnichestvo-s-universitetami/. Accessed May 20, 2022.

[7] Spatial Development Strategy of the Russian Federation for the Period until 2025. Approved by Order no. 207-r of the Russian Federation Government of February 13, 2019.

[8] The address of Gazprom in 2000 was the Lakhta Centre (Lakhta-Olgino municipal okrug) in the city of St. Petersburg.

Mobile Network Operators' Data are actively used in studies of the spatial structure of cities and their diurnal rhythms, making it possible to consider the movements and distribution of the population (Babkin, 2021). In Russia, research based on mobile network operators' data is done primarily in Moscow (Babkin, 2020). Unfortunately, a similar study for other Russian cities cannot be realized due to lack of access to mobile network operators' data. For St. Petersburg, this direction has only just been declared, because this system was only recently received[9] and large studies are lacking.

Mobile network operators' data make it possible to estimate the nighttime and daytime population with subsequent delimitation of the urban agglomeration (Makhrova and Babkin, 2020), estimate the real population in the urban agglomeration (Makhrova and Babkin, 2022), study the characteristics of the *dacha* population (Makhrova et al., 2022), etc. The most important advantage of mobile network operators' data is the ability to consider not just annual, but also seasonal, monthly, and daily dynamics, and to distinguish the nighttime and daytime population of the territory. The disadvantage is the issue of data availability, due to which it is not yet possible to repeat studies based on mobile network operators' data by other researchers and in other cities.

Road Network Data. Transport infrastructure is the most important element of any urban agglomeration. E.N. Pertsik (2009) formulated the following definition of the concept of "urban agglomeration:" "A system of territorially close and economically interrelated populated areas, united by stable labor, cultural, social, and production ties; common social and technical infrastructure; and intensive commuting movements." Obviously, even in the very definition of this concept, transport infrastructure plays a decisive role: all types of connections take place, as well as commuting.

The transport infrastructure of an urban agglomeration performs three main functions (Kel'bakh, 2013):

(1) Providing intracity connections. This role is played by the road network of the cities included in the urban agglomeration.

(2) Providing urban agglomeration connections. This role is played by roads that connect settlements that are part of an urban agglomeration.

(3) Providing external relations. This role is played by roads that connect the transport infrastructure of the urban agglomeration with the outside world.

Connecting functions are performed by roads of various classes. The classification of the city's road network is regulated by construction norms and rules.[10] Within the framework of this document, various classes of highways are distinguished, including expressways, continuous traffic highways, urban highways with regulated traffic of classes I and II and district highways.

Spatial analysis of road network data in conjunction with other types of data allows us to draw conclusions about the level of development of individual territories of the urban agglomeration, as well as the degree of their connectivity among themselves and the core of the urban agglomeration. In addition, it is possible to analyze external connections and identify contact zones at the intersection of the boundaries of the urban agglomeration and the main external highways, which are of particular importance and are often industrial and logistics centers.

A special role is played by data on the future development of the road network, which makes it possible to obtain information on the directions of spatial development of the urban agglomeration. The sources of such data may be territorial planning documents, among which are: territorial planning schemes (regional and municipal), master plans, other documents (e.g., Concept of Joint Urban Development of St. Petersburg and the Territories of Leningrad Oblast, Concept for the Development of the Transport System of St. Petersburg). Such documents contain information about the most important projects in the field of transport infrastructure.

However, the construction and reconstruction of transport infrastructure is often a complex and expensive undertaking, and therefore it is not always possible to quickly implement even the most important projects. Therefore, documents containing information about priority projects in the field of transport infrastructure, the implementation of which is scheduled for the near future, play a special role. Data sources can be regional investment programs in the field of transport and materials from the national project "Safe Quality Roads," approved territory planning projects (for linear objects).

Data on the future development of the road network make it possible to determine the directions of spatial development of the urban agglomeration and predict the possible transformation of the role of individual territories and the dynamics of connections between them.

An important advantage of using road network data is their versatility, accessibility, and ease of processing and interpretation. It is important to remember that the best results can be achieved when using road network data in combination with other types of data.

[9] The authorities of St. Petersburg will collect data from SIM cards of city dwellers and guests. https://www.rbc.ru/spb_sz/05/10/2021/615c1d8d9a79475c9ac44ce4. Accessed July 18, 2022.

[10] Construction norms and rules SNiP 2.07.01-89* Urban Planning. Planning and Development of Urban and Rural Settlements (approved by Decree of the USSR State Construction Committee no. 78 of May 16, 1989).

Table 1. Authors' ratings of considered methods and data sources for purpose of studying spatial structure of St. Petersburg urban agglomeration

Formulated research problem	Proposed group of methods	Authors' rating (from 1 to 5)	
		usefulness of method for given problem	feasibility of applying method for given urban agglomeration
Review and critical rethinking of methods for studying spatial structure of St. Petersburg urban agglomeration, which developed in turbulent period between 2014 and 2022	Remote sensing data	5	5
	Data on buildings (including housing stock)	3	4
	Data on location of economic actors (legal persons and retail chains)	3	3
	Mobile network operators' data	5	2
	Road network data	4	5
Advantages and disadvantages of each group of methods are revealed	Remote sensing data	4	4
	Data on buildings (including housing stock)	4	4
	Data on location of economic actors (legal persons and retail chains)	4	3
	Mobile network operators' data	4	1
	Road network data	5	5
Owing to bibliographic analysis, limitations and possibilities for empirical content were identified (availability of specific data sources)	Remote sensing data	4	5
	Data on buildings (including housing stock)	4	4
	Data on location of economic actors (legal persons and retail chains)	4	2
	Mobile network operators' data	3	2
	Road network data	5	5
Final rating of applicability and usefulness of considered methods for St. Petersburg urban agglomeration	Remote sensing data	13	14
	Data on buildings (including housing stock)	11	12
	Data on location of economic actors (legal persons and retail chains)	11	8
	Mobile network operators' data	12	5
	Road network data	14	15

The designated groups of methods are extremely relevant when studying the St. Petersburg urban agglomeration (Table. 2), both individually and combined. Complete or partial testing shows the possibility of their use, and the scoring of the applicability and usefulness of the considered methods for the St. Petersburg urban agglomeration made it possible to understand the applicability here (see Table 1).

The trend of the use of new data and, accordingly, approaches and methods to urban research is obvious. The current level of development of information technology makes it possible to look at the spatial structure of urban agglomerations in a new way. The arsenal of these latest methods and data sources is generally quite broad, but in the context of the St. Petersburg urban agglomeration, some of these methods are applicable. This is generally due to the availability of data in the country and city, in particular with digitalization, on which the range of available data depends.

An undoubted advantage of the considered approaches and methods is the ability to consider the spatial structure of the city without reference to the ATD, because it overlaps or does not completely accommodate certain spatial phenomena in the city. It is also important to understand that the methods and approaches discussed are in demand in urban planning and administration. Data on the location of the population, retail facilities, recreation, etc., independent of ATD are actively used by entrepreneurs when making decisions about locating businesses.[11]

However, use of the methods described by the authors has a number of disadvantages. First, this concerns the information content and completeness of the data. For example, data on the housing stock of apartment buildings or the revenue of legal persons is still less informative for a researcher than simply data on the population or the wage fund provided by Rosstat.[12] At the same time, using mobile network operators'

[11] 2GIS Pro: visualizing data sets. https://vc.ru/services/557545-2gis-pro-vizualiziruem-massivy-dannyh. Accessed Decmeber 26, 2022.

[12] Federal State Statistics Service. www.gks.ru. Accessed July 18, 2022.

Table 2. Features of St. Petersburg urban agglomeration determining applicability of considered methods

Features of urban agglomeration	Applicable method	Rationale for method
Dominance in housing stock of apartment buildings	Data on buildings (including housing stock)	Difference between Federal State Statistics Service (Rosstat) data and data from housing and communal services reform website on volume of housing stock is insignificant
Dominance in residential construction of apartment buildings	Data on buildings (including housing stock)	According to Rosstat, residential buildings built by population using their own and borrowed funds account for, on average, less than 10% of total housing commissioning in St. Petersburg
Virtual absence of renovation	Data on buildings (including housing stock)	Due to lack of renovation, data on housing stock are suitable for studying dynamics of housing stock, because for the last half century there has been no (massive) change from one residential building to another
Development of online directory services, including archival	Data on location of economic actors (legal persons and retail chains)	It is possible to extract current (using 2GIS service) and archived (online version of Yellow Pages) retail data
Availability of large centers of business activity on regional and national scale	Data on location of economic actors (legal persons and retail chains)	Using services that aggregate data on legal persons (e.g., SPARK-Interfax database), it is possible to obtain spatial data on the location of business activity
Entering the coverage area of most space surveys	Remote sensing data	Possibility of using publicly available remote sensing data
Availability of access to geoanalytical data of mobile network operators from St. Petersburg authorities	Mobile network operators' data	Theoretical possibility of obtaining data for research purposes (by analogy with experience of Moscow researchers)

data, it is possible to obtain much more informative data about the nighttime and daytime population of the territory, and to see daily fluctuations in the urban space. However, for the most part, data from nonstatistical services are inferior in information content. In general, the identified problem may disappear in the future, because there has been a trend toward anonymized microdata from statistical services.[13] Accordingly, data from statistical services in general will be used by researchers similarly to the latest approaches and methods.

The most important disadvantage of the indicated methods is that they are not entirely suitable from the administrative viewpoint, because decisions by local authorities are made primarily at the ATD level. This feature in general is a problem in the development of urban agglomerations, because building intermunicipal cooperation is a separate difficulty (Shugrina, 2018). The problem of intermunicipal cooperation is actively considered by the state, as evidenced by the spatial development strategy,[14] draft federal law on urban agglomerations,[15] the emergence of horizontal interbudgetary transfers,[16] etc. Based on this, we can suggest that in the near future, the focus on ATD in decision-making at the municipal level will decrease and the considered modern approaches and methods will be increasingly relevant in administrative decisions.

[13]Rosstat will open access to microdata from post-Soviet population censuses in Russia in 2022. https://tass.ru/obschestvo/12876949. Accessed July 18, 2022.

[14]Spatial Development Strategy of the Russian Federation for the Period until 2025. Approved by Order no. 207-r of the Russian Federation Government of February 13, 2019.

[15]Draft Federal Law On Urban Agglomerations (prepared by the Ministry of Economic Development of Russia, text as of Aril 9, 2020). https://www.consultant.ru/cons/cgi/online.cgi?req=doc&base=PRJ&n=199079#ZgZo7RTWOz7suerC2.

[16]Putin signed a law changing the procedure for providing interbudgetary transfers. tass.ru/ekonomika/6729513. Accessed July 18, 2022.

Another disadvantage may be the well-known difficulty of visualization and quantitative calculations. For the most part, the new data used by modern researchers of urban space are a collection of point localized objects: enterprises, residential buildings, cellular subscribers, etc. Their depiction on maps using the common methods of cartograms or cartograms is not entirely appropriate, because the most important problem is obviating the ATD in general, but it is possible when correcting territorial units based on the dasymetric method (Petrov, 2012). Methods for depicting point phenomena and objects, in general, include: (1) so-called heat maps, where clustering of points occurs in groups and aggregation is carried out by territorial units (e.g., ATD or city blocks); (2) artificial regular grids of various shape (squares, hexagons, etc.); (3) derivatives of geometry and their areas (Voronoi polygons or Delaunay triangulations); (4) attribution of points through a distance matrix; (5) three-dimensional visualization (derived from aggregation maps and heat maps) (Kazakov, 2022). However, although the described visualization methods in general can be immediately perceived, the quantitative characteristics of the phenomena are easier to analyze using ATD.

In general, the identified shortcomings should not be considered critical and a reason for refusing to use the considered methods for studying urban agglomerations. Moreover, there is a trend towards minimizing these shortcomings. At the same time, the advantages are a significant argument for the use of new methods.

CONCLUSIONS

Contemporary studies of urban agglomerations are increasingly using new methods and data sources, which open up further possibilities. These methods and data sources have a number of advantages, but are associated with certain disadvantages, such as complexity of processing and interpretation, accessibility, relevance, etc.

Updating new methods and identified data sources in the context of studying the St. Petersburg urban agglomeration is extremely important to obtain more complete and in-depth knowledge of the modern urban agglomeration. The proposed updating of modern approaches and methods, especially in terms of the data used, as well as testing of some of them with a case study of the St. Petersburg urban agglomeration, significantly expands the arsenal of applicable tools for studying urban agglomerations both by the authors of this study and by other specialist followers. This makes it possible to scale and replicate research using other urban agglomerations in Russia, which contributes to generalization of the results and enrichment of knowledge in this geographic area.

Data on the road network proved the best in terms of usefulness and realism for studying the spatial structure of the St. Petersburg urban agglomeration. However, along with this, it was revealed that remote sensing methods and data on buildings, including housing stock, are also highly useful and realistic for our research. The chosen methods received scores close to the maximum, which indicates their importance for studying the spatial structure of the urban agglomeration. Thus, the analysis allows us to state that the use of data on the road network, remote sensing, and a building is the most efficient for studying the spatial structure of the St. Petersburg urban agglomeration.

Using proven methods, it is possible to improve the accuracy and reliability of the data that is used to analyze and predict various phenomena. Such methods can be especially useful when working with empirical data that has a complex structure or contains a large number of variables. When analyzing remote sensing and reforming housing and communal services, and other areas related to the administration and development of urban infrastructure, it is important to ensure that long time series and derived data can be adequately processed. Thoroughly validated methods also lead to significant improvements in reproducibility and data correlation, which becomes a key element for creating reliable predictive models and making informed decisions. As a result, this contributes to increased efficiency and accuracy of analysis, which is important in developing strategic documents, identifying trends, and making decisions in various areas related to the administration and development of the urban environment and infrastructure, creating innovative solutions, and improving the quality of life of urban residents. As a result, the use of proven methods makes data analysis more objective and accurate, which in turn helps to improve the understanding of the mechanisms underlying the studied processes and facilitates adoption of optimal strategic decisions.

Ensuring effective administration of urban agglomerations is an urgent problem in the modern world and in Russia. The benefits of using the latest research methods in this area are obvious. In particular, the use of automated transport dispatch systems and data on them when making management decisions at the local level can significantly improve the efficiency of urban infrastructure, reduce travel time and reduce the overall transport load.

However, it is worth mentioning the disadvantages of new methods for studying urban agglomerations, such as the complexity of visualization and quantitative assessment of data, as well as the reduced information content of most data in comparison with the data available from state statistical services. However, the impact of these shortcomings is gradually decreasing with the development of information technology and big data, improving the quality of public administration, as well as increasing the openness and diversity of this data.

In addition to these advantages, the use of the latest methods for studying urban agglomerations also contributes to the formation of a more accurate and detailed configuration of urban infrastructure, which can be useful for planning urban development, improving population mobility, and reducing negative impacts on the environment. In addition, modern research methods can help identify and analyze trends and dynamics of change in urban spatial and economic structures and agents, which in turn contributes to a deeper and more comprehensive understanding of the processes occurring in urban agglomerations. Thus, use of the latest methods for studying urban agglomerations is not only relevant, but also necessary for the efficient and sustainable development of cities in the modern world.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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