INTEGRAL ASSESSMENT OF STABILITY OF SOCIAL-ECOLOGICAL-ECONOMIC SYSTEM AGAINST CHANGES IN ITS FUNCTIONING CONDITIONS

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ABSTRACT

The relevance of the research is conditioned by the need to develop the theory and practice of integral assessment of the state and emergent properties of complicated natural and social systems, with the use of modern methods of evaluation. The article deals with assessment of stability of the social-ecological-economic system (SEES), being its integrative (complex, emergent) property influencing the "quality of life" of the population. The authors, analyzing a regional SEES, characterize it by the ability to retain its properties and mode parameters in case of external influence on the system or its intra-system changes affecting the "quality of life" of the population. Tver region of the Russian Federation was taken as a model object. To assess the stability, the authors devised the following scenarios of impact on each of the subsystems of a particular regional SEES: 1 - hypothetical aggravation of the ecological situation in the region by 10, 20, 30%; 2 - hypothetical aggravation of the economic situation in the region by 10, 20, 30%; 3 - hypothetical aggravation of social conditions in the region by 10, 20, 30%; 4 - hypothetical aggravation in all subsystems simultaneously by 10, 20, 30%. Further, in the scenarios 5 – 8, twofold aggravation of the situation takes place - alternately in all of the above subsystems and in all subsystems simultaneously. The integral indicators of quality of life of the population were calculated for all 8 scenarios - for the first (within the subsystems) and second (between the subsystems) levels of convolution of the indicators. The results of assessment of the environmental quality and the quality of social life are presented for the years 2003 and 2013. At the first stage, the linear character of changes, with equal weighting of the estimation parameters within the three subsystems (environmental, economic, social) and between them was taken into account. The ecological subsystem included 8 evaluation parameters; the economic subsystem - 5; the social subsystem - 5. These parameters were selected from the website of the Russian Federal State Statistics Service ("The Russian Regions" reports). The major objective of the research was identification of situations in which SEES, upon assigned impact on it, will not be able to maintain its properties and mode settings and will shift to another class, both in individual subsystems and within the system as a whole. The condition of the system and the "quality of life" of the population was assessed for 5 classes (I-high; II-above the average; III-average; IV-below the average; V-low), specific for it in 2013. All the changes in the scenarios were realized against the background of 2013.

Keywords: integral assessment, stability, quality of life

INTRODUCTION

In the recent years the interest in the problem of formation of an objective system of indicators of public well-being and sustainable development has been shown by governments of many European countries, the PRC, the USA, Japan.

The relevance of the research is conditioned by the need to develop the theory and practice of integral assessment of the state and emergent properties of complicated natural and social systems, with the use of modern methods of evaluation.

The article deals with assessment of stability of the social-ecological-economic system (SEES), being its emergent property. The conditional formula of such system is presented by us thus: socio-system = biocenoses + physico-geographic environment (biotopes) + population + economy + culture + politics [1].

Let us dwell on the key point of our previous publications: a multi-criterion assessment of the state of the system reveals incomparability of the obtained assessments or ambiguities in the assessment of the state of an SEES. A measure of proximity to the "benchmark" by an aggregate of assessment criteria for a number of years reflects the researcher's idea of the degree of the well-being of the SEES. These ideas depend on axiological provisions incorporated into the methodology and the axiometric ideas on the assessment scales of the assessment criteria. A stable system is a system that retains its properties and mode parameters in case of external or internal influence on it. One can also consider the well-being of an SEES and high or low quality of life of the population in SEES's of different scales. But even here, stability, as an emergent property of the system as a whole, can form the axiological bases of assessment of another complex property, in our case, of its well-being. In this case a situation arises when "stability" and "well-being" in a number of publications are considered almost as synonyms, or a term "health of a system" is introduced, for example. A stable system is considered in the first turn a "healthy", or "good" one [2], and if the stability is impaired, such system loses its initial (healthy) status.

MATERIALS AND METHODS

The paper characterizes the state of a regional SEES through the system's ability to retain its properties and mode parameters in case of external influence on the system or of internal, intra- systemic changes characterizing the quality of life of the region's population. Proceeding from the definitions of life quality, the basic objective of integral assessment may be the identification of an aggregate of natural, social, and economic conditions assuring to a greater or lesser degree human health, personal and public, and his/her needs, i.e. conformity of a healthy person's life environment to his/her needs [3].

Tver region of the Russian Federation was taken as a model object to an analysis of SEES stability. The common basis for constructing of integral indicators is described by us in a sufficiently large amount of publications, including the papers [2, 3].

Let us consider the following scenarios of impact on each of the SEES subsystems: - hypothetical aggravation of the ecological situation in the region by 30%; 2 - hypothetical aggravation of the economic situation in the region by 30%; 3 - aggravation of social conditions in the region by 30%; 4 - hypothetical aggravation of the situation in all subsystems simultaneously by 30%. Further, in the scenarios 5 - 8 , multiple aggravation of the situation takes place alternately in all of the above subsystems and in all subsystems simultaneously. Let us calculate the integral indicators of quality of life of the population for all 8 scenarios - for the first (within the subsystems) and second (between the subsystems) levels of convolution of the indicators. Let us present the results of assessment of the environmental quality and the quality of social life for the years 2003 and 2013. At this stage let us take into account the linear character of changes with equal weighting of the parameters within the three subsystems (environmental, economic, social) and between them, in the analysis let us consider only the results of the options with 30% and twofold aggravation of the situation within the units and between the units against the background of 2013.

Let us include into the ecological subsystem 8 estimation parameters: 1- emissions of pollutants into the atmospheric air from stationary sources (ths tons); 2- entrapment of atmospheric pollutants from stationary sources (ths tons); 3- use of fresh water (mln cubic meters); 4- volume of circulating and subsequently utilized water (mln cubic meters); 5- forest regeneration (ths hectares); 6- fertilizer application per one hectare of agricultural crops in agricultural entities (tons); 7- discharge of contaminated drain waters into surface water bodies (mln cubic meters); 8- generation of production and consumption waste (ths tons) (table 1).

Table 1. Scenarios for aggravation of the ecological situation and the environmental quality in the region.

Unit	Estimation parameters	Relation	2003	2013	Aggravation of situation of 2013 by 30%	Rated value of aggravation by 30%	Twofold aggravation of situation of 2013	Twofold rated value of aggravation of situation
Ecolo -gical	1. Emissions of pollutants into atmospheric air from stationary sources (ths tons)	Direct	51	60	78	0,031	120	0,048
	2 Entrapment of atmospheric pollutants from stationary sources (ths tons)	Reverse	20	19	14,6	0,998	9,5	0,999
	3. Use of fresh water (mln cubic meters)	Reverse	1283	1399	1076	0,838	700	0,894
	4. Volume of circulating and subsequently utilized water (mln cubic meters)	Reverse	2154	6382	4909	0,535	3191	0,697
	5. Forest regeneration (ths hectares)	Reverse	13,9	11,1	8,5	0.958	5,55	0.972
	6. Fertilizer application per one hectare of agricultural crops in agricultural entities (tons)	Direct	9,4	7,3	9,5	0,063	14,6	0,097
	7, Discharge of contaminated drain waters into surface water bodies (mln cubic meters)	Direct	77	90	117	0,078	180	0,120
	8. Generation of production and consumption waste (ths tons)	Direct	595	1064	1383	0,001	2128	0.001
	Integral indicator for ecological unit / class of quality of people's life		**0,45 (III)**	**0,41 (III)**		**0,44 (III)**		**0,48 (III)**

Into the economic subsystem let us include 5 estimation parameters: 1- population numbers (assessment by end of year; ths persons); 2- number of unemployed (ths persons); 3- per capita monetary income of population per month (rubles); 4- population numbers with monetary incomes below living wage (in % of total population); 5- number of enterprises and organizations (pcs.) (table 2).

Table 2. Scenarios for aggravation of the economic situation in the region.

Unit	Estimation parameters	Relation	2003	2013	Aggravation of situation of 2013 by 30%	Rated value of aggravation by 30%	Twofold aggravation of situation of 2013	Twofold rated value of aggravation of situation
Econo-mic	1 Population numbers (assessment by end of year; ths persons)	Reverse	1444	1325	1019	0,920	662,5	0,949
	2 Number of unemployed (ths persons)	Direct	50,9	38	49.4	0,299	76	0,461
	3. Per capita monetary income of population (per month**;** rubles;)	Reverse	3021	19106	14697	0,801	9553	0,881
	4. Population numbers with monetary incomes below living wage (in % of total population of the constituent entity)	Direct	39,0	11,8	15,34	0,170	23,6	0,262
	5 Number of enterprises and organizations	Reverse	42708	35614	27395	0.978	17807	0,986
	Integral indicator for economic unit		**0,72 (IV *m*)**	**0,59 (III-IV)**		**0,63 (IV *l*)**		**0,71 (IV *m*)**

Note. There are specified in the table: *l* is closer to the left border of the class; *m* is middle of the class; *r* is closer to the right border of the class.

Into the social subsystem let us include 5 estimation parameters: 1- life expectancy at birth (number of years, all population); 2- number of registered crimes per 100,000 people; 3- number of visits of museums per 1000 people; 4- number of hospital beds total, ths; 5- number of preschool educational institutions (table 3).

Table 3. Scenarios for aggravation of the social conditions in the region.

Unit	Estimation parameters	Relation	2003	2013	Aggravation of situation of 2013 by 30%	Rated value of aggravation by 30%	Twofold aggravation of situation of 2013	Twofold rated value of aggravation of situation
Social	1. Life expectancy at birth (number of years, all population)	Reverse	61,53	68,13	52,4	0,931	34,1	1,000
	2. Number of registered crimes per 100,000 people	Direct	1970	1515	1969,5	0,657	3030	1,000
	3. Number of visits of museums per 1000 people	Reverse	343	342	263	0.812	171	0,878
	4 Number of hospital beds total, ths	Reverse	18,5	13,3	10,2	0,915	6,65	0,945
	5. Number of preschool educational institutions	Reverse	645	487	374,6	0,822	243,5	0.884
	Integral indicator for social unit		**0,75 (IV)**	**0,70 (IV)**		**0,83 (Vl)**		**0,94 (V *r*)**

Note. There are specified in the table: l is closer to the left border of the class; m is middle of the class; r is closer to the right border of the class.

Let us take all indicators from Rosstat website ("Regions of Russia" compilations) for 2003 and 2013. The basis objective of the research will be convolution of the indicators at the first and second levels and identification of situations in which SEES fails to retain its properties and mode parameters at the prescribed hypothetical influence on it in individual subsystems and the system as a whole. The state of the system and quality of life of population in the region was estimated for 5 classes (I - high; II – above average; III - average; IV – below average; V - low) in which it was in 2013. The proximity of the integral indicator to 0.0 evidences high quality of life of population, the proximity to 1.0 evidences low quality.

The analysis of the obtained results has allowed the following basic conclusions to be drawn:

1. In 2003 quality of people's life in the region at the second level of convolution was characterized by the value 0.64 of the consolidated indicator (IV class middle); in 2013 – 0.57 (border of classes III-IV). The change in quality of people's life, as follows from the estimates, was mostly influenced by the economy (the integral indicator for the subsystem was reduced by 18%). The contribution of the social subsystem amounted to 6.7%, of the ecological one 8.9%. In general, from 2003 to 2013 the improvement of the social and ecological conditions was identified.

2. When planning scenarios of aggravation of the ecological situation at the first stage of convolution, the multidirectionality of the parameters was taken into account upon the prescribing of the characteristics of the ecological subsystems (4 characteristics have a direct relation to the assessment of life quality and 4 have a reverse relation). The borders of the classes of the integral indicator of the ecological subsystem for class III: 0.37-0.56; for class IV: 0.56- 0.77. The aggravation of the ecological situation only (only the parameters of the ecological subsystem) by 30% in all 8 parameters has not changed the class of the ecological state of the system. The integral indicator of the ecological subsystem has grown by 7.3% (it was 0.41, it has become 0.44, table 1).

At the second level of convolution (table 4), by the value of the consolidated indicator, the state of SEES and life of population transferred from a borderline situation between classes III-IV in 2013 to class IV (0.58). The change is generally insignificant (1.8%), but it characterizes the transition of the system into a more senior class and therefore should be mentioned, the system in general at 30% of hypothetical influence expressed in a change of the parameters of the ecological subsystem was unable fully its properties and mode parameters and thus was susceptible to the ecological situation. These calculations have confirmed the conclusion obtained by us earlier, in the North West of the Russian Federation, that an improvement of the environmental quality by less than 30% does not result in changing the class of people's life quality by a consolidated indicator [3].

The twofold aggravation of the ecological situation only by all 8 parameters (table 1) changes the value of the integral indicator of the ecological subsystem by 17% (0.48, class III; it was 0.41, class III) and brings life quality in this subsystem closer to class IV, class interval being 0.56-0.77). By the value of the consolidated indicator of life quality the absolute value is noted to have increased by 3.5%. The value of the consolidated indicator is characterized by class IV (0.59 left border of class IV, it was

0.57, the middle of the class). The borders of class IV for the consolidated indicator: 0.56-0.79 (table 4).

Table 4. Generalization of the results on the hypothetical reduction in quality of people's life in Tver region in relation to 2013

Aggravation of situation in % /Units	Ecological	Economic	Social
	30% reduction	30% reduction	30% reduction
For unit (level 1 of convolution)	7,3	6,8	18,6
For consolidated assessment (level 2 of convolution)	1,8	1,8	7,0
	twofold reduction	twofold reduction	twofold reduction
For unit (level 1 of convolution)	17	20	34,3
For consolidated assessment (level 2 of convolution)	3,5	7,0	21

3. When planning the scenarios of aggravation of the economic situation only, the multidirectionality of parameters upon the prescribing of the characteristics was also taken into account (2 characteristics have a direct relation to the assessment of life quality and 3 have a reverse relation).

The aggravation of the economic situation only by 30% in all 5 parameters has changed the value of the integral indicator of the economic subsystem by 6.8% (it was 0.59- the border of class III-IV, it has become 0.63 – class IV, closer to the left border, table 2), however, by the value of the consolidated indicator the class of life quality has changed insignificantly, by 1.8% (0.57 in 2013 and 0.58 at 30% aggravation).

The twofold aggravation of the economic situation only in all 5 parameters of the economic subsystem has brought about an increase in the integral indicator of the unit by 20% (0.71, class IV; it was 0.59) with the width of the class interval 0.59-0.81. This has not changed the class of the integral indicator, but has brought the life quality estimated by the economic subsystem closer to class V. By the value of the consolidated indicator, in this case, life quality has aggravated by 7% and was characterized by the value of the consolidated indicator 0.61 (class IV), it was 0.57 (the border of classes III-IV) with the width of the interval of the consolidated indicator of class IV 0.56-0.79.

4. When planning scenarios of aggravation of the situation in the social sphere only, the multidirectionality of the parameters upon the prescribing of the characteristics was also taken into account (1 characteristic has a direct relation to the assessment of life quality and 4 have a reverse relation).

The aggravation of the situation in the social sphere only by 30% in all 5 parameters (table 3) has changed the value of the integral indicator of the subsystem by 18.6% (it was 0.70 - class IV, it has become 0.83 – class V, closer to the left border with the width of the interval of class V 0.80-1.00), however, at the value of the consolidated indicator, life quality has changed insignificantly, by 7% (0.57 in 2013 and 0.61 at 30% aggravation of the social conditions) (table 4).

The twofold aggravation of the situation in the social sphere only in all 5 parameters

(table 3) changes the class of the integral indicator of the social subsystem by 34.3% (0.94, class V, it was 0.70). By the value of the consolidated indicator the quality of people's life has gone down by 21% (0.69, class IV, it was 0.57 – the border of classes III-IV) with the width of the interval of the consolidated indicator of class IV 0.56-0.79.

In general, one can observe that the most sensitive subsystem was the system of social conditions. For it the highest increase of the influence effect has been noted, both on separate subsystems and in general on the socio-ecological-economic system (a consolidated assessment). With small negative changes the ecological and economic parameters have almost the same changes, both on the first level of convolution and on the second. It is noticeable that after the 30% aggravation the consolidated assessment is influenced more by the economic factors.

5. Of interest also is the simultaneous taking into account of possible reduction in life quality in all subsystems simultaneously. For this, the consolidated indicator of life quality was calculated with 30% aggravation of the conditions in all subsystems simultaneously compared to 2013. In this case the consolidated indicator is equal to 0.63 (IV*m*). Prior to the changes it was 0.57 (the border of classes III-IV). In percentage terms the changes amount to 10.5%. In virtue of the prescribed linear nature of the changes in the characteristics at first approximation this value corresponds to the total of the percentages of the changes by separate subsystems: 1.8+1.8+7.0.

With the twofold reduction in life quality in all subsystems simultaneously we obtain the value of the consolidated indicator 0.71 (IV*r*). It was 0.57 (the border of classes III-IV). In percentage terms the changes have amounted to 24%. Thus, with the twofold reduction in the parameters we obtain an almost linear increase in the consolidated indicator and transition of life quality from the borderline value between classes III and IV into class IV (closer to the border with class V) (table 4).

6. It follows from conclusions 1-5 that the hypothetical 30% change of the situation in one of the subsystems toward aggravation of life quality compared to 2013 (table 4) brings about an increase in the consolidated indicator for the ecological subsystem by 7.3%, for the social subsystem by 18.6%, for the economic subsystem by 6.8%. By the value of the consolidated indicator with 30% change of the situation in all subsystems simultaneously there is 10.5% increase in the consolidated indicator. This increase causes reduction in life quality by about half of the class.

The twofold change of the situation in one of the subsystems toward aggravation of life quality compared to 2013 (table 4) results in an increase in the consolidated indicator in the ecological subsystem by 17%, in the social subsystem by 34%, in the economic subsystem by 20%. By the value of the consolidated indicator with the twofold change of the situation in all subsystems simultaneously there is 24% increase in the consolidated indicator. This increase causes reduction in life quality by about one class.

CONCLUSION

The results of the integral assessment have been analyzed. The quantitative characteristics of the state of the region in 2003 and 2013 have been obtained. In a series of experiments the influences have been identified under which a system

transitions into another state class and therewith loses stability. The authors are aware that the taking into account of the non-linear nature of changes and of the uneven weightage of the estimation parameters within subsystems (ecological, economic, social) and between them can change the obtained results. As our experience has shown, however, these changes will not result in any strong differences or fundamental changes.

In the same with one can calculate a change in the integral indicator by time for different years or by space in the basis of natural data or the Rosstat data. In more complex examples taking into account disparate weightiness of parameters within subsystems and between them, the non-linear nature of relations; incomplete, inaccurate, and non-numerical information on the assessment priorities, also multilevel convolutions of information are introduced. The weighting factors are specified on the basis on information deficiency models. The comparison of the state of the systems on the integral basis enables also quantitative assessment of spatio-temporal particulars of their dynamics and the degree of their transformation. As the "admissible limit" value of the consolidated indicator a value can be recommended obtained on the basis of the "convolution" of admissible limit (critical) values of the initial parameters on the borders of the classes, if they are known.

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