

MODELING AND FORECAST OF SOCIO-ECONOMIC PROCESSES

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Assessing Population's Quality of Life on the Basis of Intelligent Algorithms and Dynamic Modeling*



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Abstract. The article deals with the issues of research, modeling and management of society as a societal system. The authors propose a methodology for studying society based on the system composition of the main structures of activities organization, as well as the integration of general scientific laws and approaches. The peculiarity of the methodology is that society is represented as system integrity and a unity of economic, political, social, spiritual, and cultural sub-systems. Improving population's quality of life is considered a criterion for society's development and, at the same time, the effectiveness of its management. The paper proposes the models for assessing the quality of life as an integral indicator of the society's quality of functioning and development, which allow evaluating this indicator, studying

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its structure, and the dynamics of its changes. An algorithm for managing the functioning quality of the societal system, based on the assessment of the integral index, is developed. A special feature of the algorithm is the complex application of data mining and dynamic modeling methods. The algorithm includes two main stages. At the first stage, data mining is performed on the quality of the system functioning in the selected area in the regional context. The results of the analysis allow identifying the clusters of regions and determining their characteristic features. The second stage involves developing the integral index structure and a dynamic model for assessing the functioning quality of the societal system on the basis of the integral index calculation, producing control actions in the form of changes in the volume of investments taking into account the characteristics of the constructed clusters. The authors consider the case of the developed algorithm implementation for quality management of social infrastructure in the regions of the Russian Federation, which allowed determining the recommended change in the level of investment in social infrastructure development by the regional clusters.

Key words: societal system, quality of life, integral index, management algorithm, sampling, principal component method, regional clusters, dynamic model, social infrastructure quality.

Introduction

The current stage of civilization development is characterized by a high degree of dynamism, instability and uncertainty, the acceleration of mutual influence and interdependence of the world's regions, and the globalization processes strengthening [1]. Global community is now in fundamentally new conditions that can define our era as an era of change, planetary vulnerability, and emerging new conditions for humanity existence. Global transformations and technological development led to the formation of a new world order, where the leading positions will be occupied by the countries that have moved to a post-industrial society [2]. The principal difference between this society and the previous socio-economic formations is that the main goal of development is to improve the quality of human life based on technological progress and fundamental science [3].

Under these conditions, there is an increasing need to study society as an organized system integrity, as a societal system, which is understood as a system of phenomena and processes considered at the level of society as a whole [4, 5].

The analysis of social systems features has shown that society as a whole and its individual spheres of life are complex dynamic objects that can be considered in statics at certain (fixed) moments of time, and in dynamics at continuous changes in time. Social statics reflects the conditions and laws of society functioning, and social dynamics describes the laws of society's development and changes [6].

Modeling the dynamics of social systems is one of the most difficult scientific tasks. This is caused by the presence of a large number of system parameters, the dynamic instability of social processes, its multi-level and multi-scale (micro- and macro-processes), weak formalizability of parameters and structures, the need of taking many factors into account, the weak predictability of the system behavior, and other reasons.

The purpose of this paper is to study society as a complex dynamic system, which involves developing a conceptual framework for research, a set of models and algorithms to support decision-making in society management. The scientific novelty and

significance of the proposed approach to society studying is in the methodology of research, modeling and management of society, which allows studying the features of its functioning and development and working out recommendations for its management.

Methodology of research, modeling and management of society as a societal system

The proposed methodology includes the following main components:

- the concept of the societal system models building, which is based on the system composition of the main structures of activities organization, as well as the integration of general scientific approaches and laws [7];
- a set of models (system, cognitive, dynamic, simulation) of the societal system, its sub-systems, an integral index of the quality of the system and its components functioning;

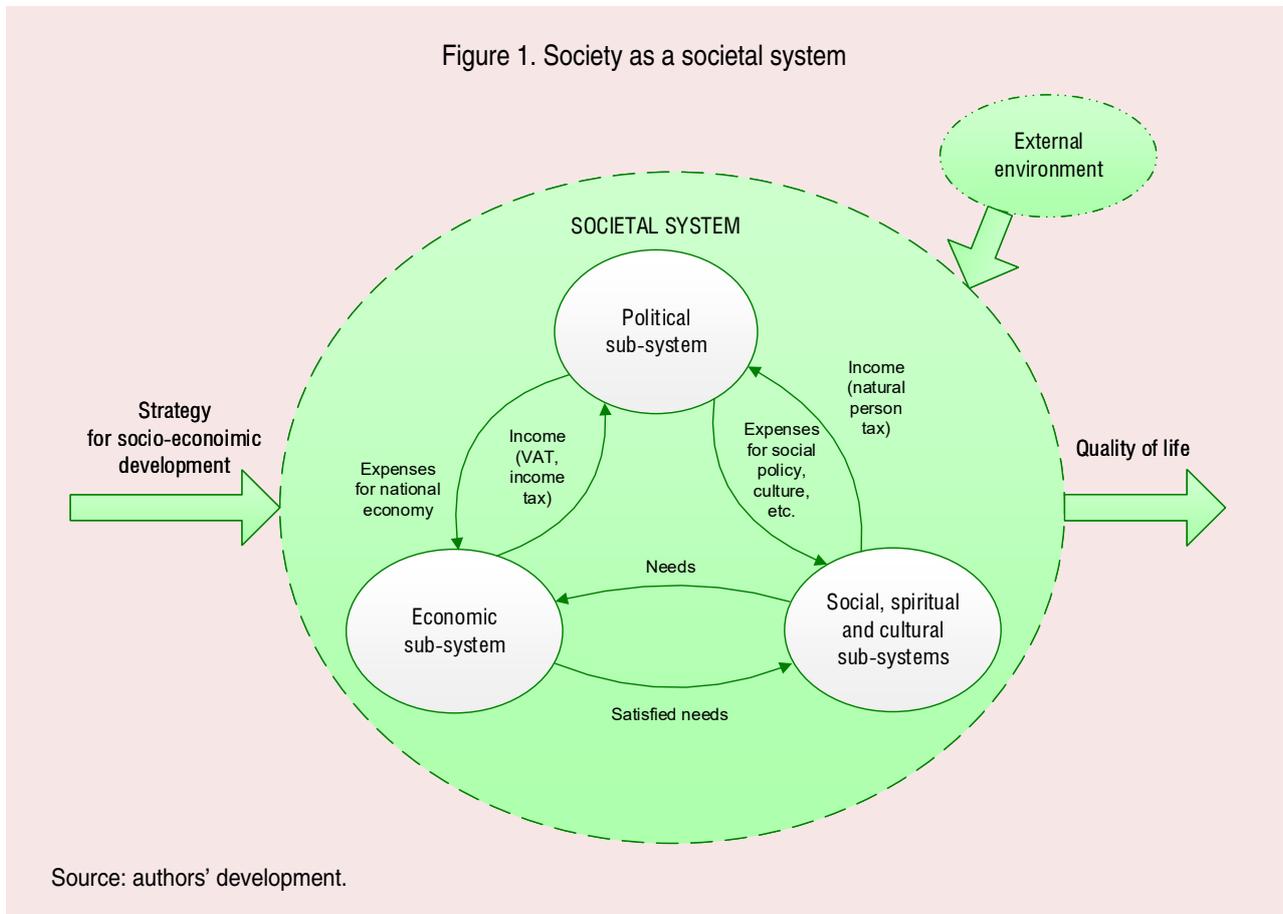
- intelligent decision support algorithms for managing the societal system.

When studying society’s properties, the authors followed a structural and functional approach [8], according to which society is considered a societal system capable of self-organization and representation of a unity of economic, political, social, spiritual, and cultural sub-systems (*Fig. 1*).

Each sub-system performs its own functions, and all of them are closely related to each other and interact giving the system a new quality that is not reducible to the properties of its individual sub-systems. Such an integral property is, for example, the property of society to develop in conditions of uncertainty.

The quality of life indicator, based on which the government determines the policy of resource allocation, is considered the main

Figure 1. Society as a societal system



Source: authors' development.

indicator of society's functioning and development. Improvement of the population's quality of life is the most important strategic task of public administration. The quality of life indicator serves as a criterion for the society's socio-economic development and a criterion for the efficiency of public administration bodies [9].

Quality of life assessment models

The concept of quality of life is used in various sciences: medicine, philosophy, sociology, economics, geography, and others, and it is interdisciplinary. Each science interprets this concept in its own way. Along with the variety of definitions of quality of life, there is a large number of methods for measuring it [10–15]. There are two main approaches to assessing the quality of life: an objective approach based on the analysis of statistical data, and a subjective approach based on the sociological surveys results processing [9, 16]. In international practice, a combined approach is also common, according to which objective and subjective indicators are considered equivalent [17].

The quality of life indicator is integral, it is a complex system consisting of many elements and links between them. To study its structure, it is advisable to apply a systematic approach, according to which the integral indicator is sequentially decomposed into a set of inter-related components and presented as their hierarchy. The authors proposed a model of quality of life in the form of a hierarchy of triads [18]. Each level has a triad of interrelated private indicators forming a system indicator of the corresponding level. There are three levels: the bottom one characterizing the quality of life (J_1) and including components such as income and expenses, housing conditions, quality of food; the average one characterizing the quality life potential (J_2), and including such components

as level of education, quality of health, level of culture; the upper one characterizing the quality of living environment (J_3) and including components such as environmental quality, quality of social infrastructure and quality of working life. System indicators form an integral indicator of quality of life (Q).

To calculate the integral index, a weighted assessment is used, which is common in most existing methods for assessing the quality of life:

$$Q = \sum_{i=1}^3 \alpha_i J_i, \quad (1)$$

where α_i is the significance coefficient of the system indicator of the i level. The values of α_i coefficients are determined by expert analysis or based on statistical data, while $\sum_{i=1}^3 \alpha_i = 1$.

We have considered a different view on the formation of an integral index of quality of life, where this indicator is represented as a multi-connected multi-layer dynamic object, while maintaining the transition from vertical links in the hierarchical structure to horizontal ones. The peculiarity of this model is that each system and particular integral index has its own mechanism of self-organization, implemented in the form of the corresponding feedback coefficients. Based on this approach, a dynamic model for assessing the quality of life is developed, presented in the form of continuous nonlinear differential equations.

The dynamics of changes in the integral index is described by a differential equation as follows:

$$\dot{Q} = -Q + \alpha_1 J_1 + \alpha_2 J_2 + \alpha_3 J_3. \quad (2)$$

The dynamics of changes in system indicators is described by differential equations as follows:

$$\begin{cases} \dot{J}_1 = -A_1(z_1)J_1 + \lambda_{12}J_2 + \lambda_{13}J_3 + J_{10}, \\ \dot{J}_2 = -A_2(z_2)J_2 + \lambda_{21}J_1 + \lambda_{23}J_3 + J_{20}, \\ \dot{J}_3 = -A_3(z_3)J_3 + \lambda_{31}J_1 + \lambda_{32}J_2 + J_{30}, \end{cases} \quad (3)$$

where $J_{i0}, i = \overline{1,3}$ are the initial values of indicators; $J_i; \lambda_{ij}, i \neq j$ are the weight coefficients reflecting the mutual influence of J_i indicators. The values of λ_{ij} coefficients are determined by experts based on the analysis of statistical data; $A_i(z_i)$ are feedback coefficients of system integral indicators that depend on z_i administrative and legal control actions at the level of federal government structures.

The initial values of J_i indicators are defined as the weighted sum of x_{i1}, x_{i2}, x_{i3} particular indicators of i level:

$$J_{i0} = \beta_{i1}x_{i1} + \beta_{i2}x_{i2} + \beta_{i3}x_{i3}, \quad (4)$$

where β_{ij} are coefficients of significance of x_{i1}, x_{i2}, x_{i3} particular indicators. The values of β_{ij} coefficients are determined by expert analysis or based on statistical data, while $\sum_{j=1}^3 \beta_{ij} = 1$.

The x_{i1}, x_{i2}, x_{i3} particular indicators are calculated by solving a system of equations:

$$\begin{cases} \dot{x}_{i1} = -a_{i1}(z_{i1})x_{i1} + k_{12}x_{i2} + k_{13}x_{i3} + u_{i1}, \\ \dot{x}_{i2} = -a_{i2}(z_{i2})x_{i2} + k_{21}x_{i1} + k_{23}x_{i3} + u_{i2}, \\ \dot{x}_{i3} = -a_{i3}(z_{i3})x_{i3} + k_{31}x_{i1} + k_{32}x_{i2} + u_{i3}, \end{cases} \quad (5)$$

where $k_{ij}, i \neq j$ are the coefficients of mutual influence of x_{i1}, x_{i2}, x_{i3} particular indicators. Numerical values of k_{ij} coefficients are determined by expert analysis; $a_{ij}(z_{ij})$ are the coefficients of feedbacks of private integral indicators that depend on z_{ij} administrative and legal control actions at the level of regional management structures; u_{i1}, u_{i2}, u_{i3} are financial and economic control actions.

The proposed models of quality of life as an integral index of the quality of the societal system functioning and development allowed us to study the structure, evaluate this indicator and study the dynamics of its changes.

Algorithm for managing the quality of the societal system functioning

The algorithm developed by the authors is designed to work out recommendations for

managing the societal system based on an assessment of the integral index of its functioning quality. The algorithm includes two main stages (*Fig. 2*).

The first stage involves data mining on the functioning quality of the societal system in the regional context in the selected area. The second stage includes developing a dynamic model of quality assessment and recommendations for managing the societal system in the form of changes in the volume of investments. Let us look at these stages in more detail.

The first step of the algorithm includes the formation of the original sample of data on the quality of the societal system functioning in the selected area.

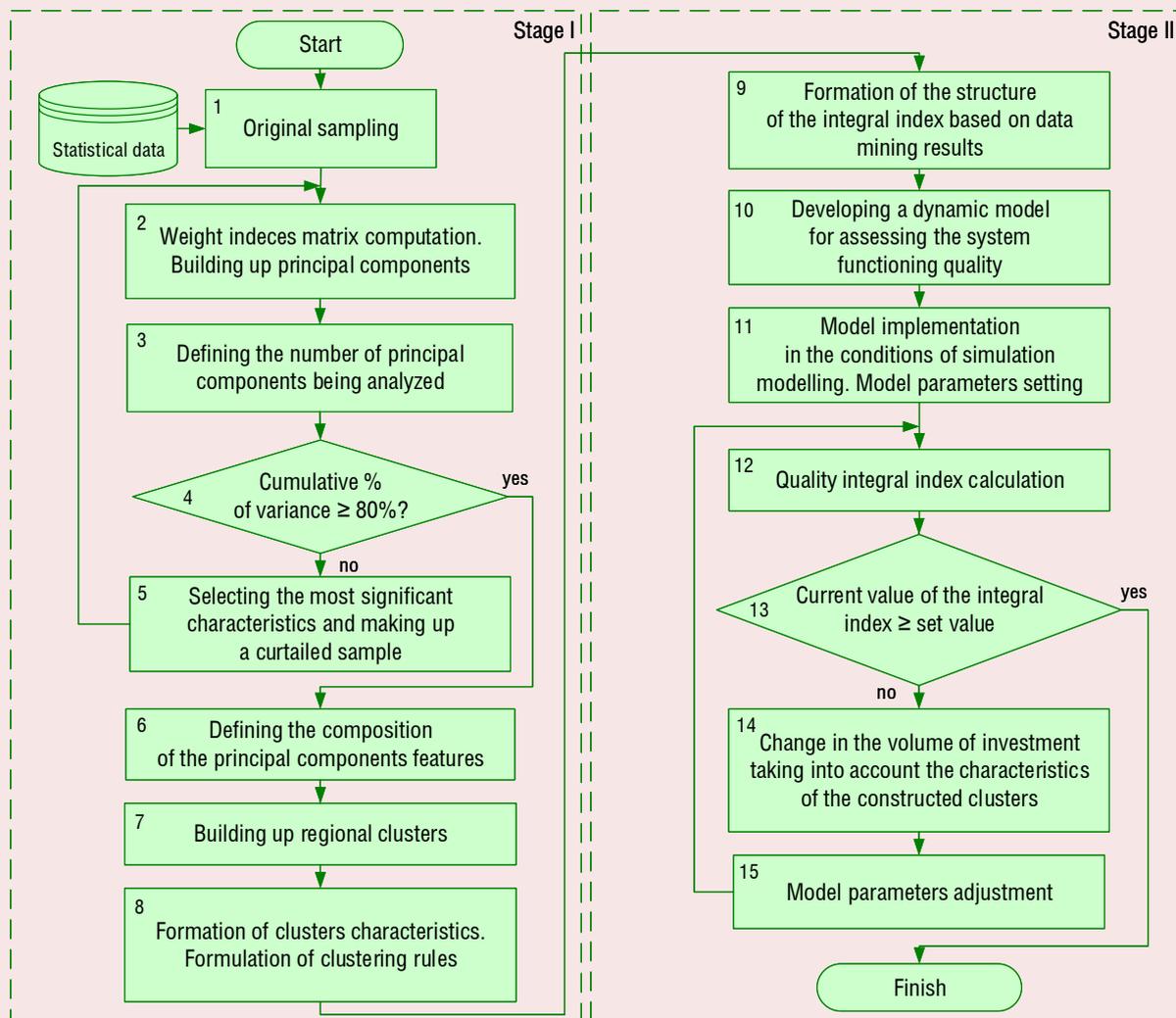
At the second step, a component analysis of the original sample is performed using the static data analysis package *StatGraphics*: a table of feature weights in the principal components is constructed; significant features with large modulo weight coefficients are identified; the composition of the main components is determined based on the information coefficients calculation.

The *StatGraphics* package was chosen due to its advantages, such as a combination of scientific methods for processing various types of data with the ability to create modern high-quality interactive graphics; extensive interaction with other software products (spreadsheets, databases); high-quality two-dimensional and three-dimensional graphics, and more. A comparative analysis of software products for static data analysis is given, for example, in [19].

The third step determines a number of principal components to be analyzed.

The fourth step involves checking up whether the required cumulative percentage of variance is reached. If this condition is not

Figure 2. Algorithm scheme of quality management of the societal system functioning



Source: authors' development.

met, then *the fifth step* is as follows: the weight coefficients of the features are analyzed and the most significant features having highest weight are selected. Next, a component analysis of the curtailed sample is performed (steps 2–4).

If the condition is met, then *the sixth step* includes determining the composition of the principal component features, based on the information coefficients calculating.

At *the seventh step*, the regional clusters are built.

At *the eighth step*, the clusters' characteristics, relative to the principal components and relative to the features, are formed. The rules of assigning regions to clusters are formulated.

On *the ninth step*, the structure of the integral index of quality of the societal system functioning based on the principal components and the composition of features is formed: a number of the subsystems and their elements are determined, and the coefficients of the relations between elements and subsystems are calculated.

A number of subsystems corresponds to a number of principal components being analyzed, and a number of subsystem elements corresponds to a number of features of corresponding components.

The values of the influence coefficients of i component of α_i on the integral index of the system functioning quality are calculated using the following formula:

$$\alpha_i = \frac{\Delta_i}{\Delta_\Sigma}, \quad (6)$$

where Δ_i is the percentage of variance of the i component; Δ_Σ is the cumulative percentage of variance for the constructed principal components.

The values of the coefficients of influence of j attribute on i component β_{ij} are calculated using the formula:

$$\beta_{ij} = \frac{w_{ij}}{\sum_{j=1}^m w_{ij}}, \quad (7)$$

where w_{ij} is weight coefficients of the features of i component, m is a number of features of i component.

At the *tenth step*, a dynamic model for assessing the quality of the societal system functioning, based on the calculation of an integral index, is developed. The model is presented in the form of continuous differential equations and is used for conducting experimental studies to assess the quality of the societal system functioning in different areas, as well as to study the dynamics of changes in the integral index under controlling and disturbing influences.

At the *eleventh step*, a simulation model based on the dynamic model is developed, and the model parameters are set. The model is implemented by means of the *MatLab Simulink* mathematical modeling package. The choice of this package is caused by the fact that it has a wide range of functions for plotting and visualizing results, the ability to develop a user

interface, as well as opportunities for dynamic modeling and development of control systems. A comparative analysis of software products for simulation modeling is given, for example, in [20].

At the *twelfth step*, an integral index of the system's functioning quality is calculated.

At the *thirteenth step*, the calculated (current) value of the integral index is compared with the specified (target) value and the deviation is calculated. If the deviation is greater than zero (the current value is greater than or equal to the target value), the algorithm terminates. If the deviation is less than zero, then the transition to the fourteenth step is performed, which involves changing the investment volume taking into account the characteristics of the built clusters.

At the *fifteenth step*, the model parameters are adjusted, and the transition to step 12 is performed.

It should be noted that the proposed algorithm does not limit the choice of tools for its implementation, and other tools available to the researcher can be used for statistical data analysis and dynamic modeling.

Social infrastructure quality management

Let us consider the application of the proposed algorithm for managing the quality of social infrastructure, based on the assessment of an integral index and working out recommendations by changing the volume of investments in social infrastructure development.

In modern conditions, infrastructure plays an important role in the formation of a single economic space, and it is considered a special social and market institution [21].

There are production and non-production (social) infrastructure. Social infrastructure in a broad sense refers to industries and economic activities that meet the needs of the population in maintaining health, getting education,

spending leisure time, etc. in order to form and accumulate social capital, reproduce intangible assets to support the country's global competitiveness [22]. In a narrow sense, social infrastructure includes health care, education, housing and communal services, social services, culture and sports, and employment organizations. Thus, the social infrastructure provides the necessary level and quality of life.

One of the most important problems in Russia today is the problem of financing social infrastructure. The main investor providing financial resources in social infrastructure development is the government. The analysis of theoretical and methodological approaches to assessing the effectiveness of public investment in infrastructure is given in [22]. The authors' works [23] devoted to the study of the impact of public investment on social infrastructure as the most powerful factor contributing to the growth of labor productivity, the creation of new jobs, and the equalization of the pace of regions' socio-economic development are particularly noted.

However, public funds are not enough for the social sphere development, and private investors need to be attracted. To this end, public-private partnership projects are being implemented, most of them are in the field of health and education, much less are in the field of tourism, culture, physical education, sports, and social services [24].

Given the complex territorial organization of the Russian Federation and its considerable territorial extent, it is advisable to consider the social infrastructure of the country as a whole and its regions. It should be noted that one of the key priorities of regional policy is balanced spatial development, and this task should be addressed at the federal and regional levels [25]. However, according to the authors of the study [26], there is currently no systematic approach

to development of infrastructure in Russia's regions: there is no clear plan for integrated development of territories, a unified assessment of the infrastructure state, investments are determined based on the current needs, the planning horizon does not exceed two or three years, and development strategies are often not implemented.

We prepared a sample of data describing the state of various areas of social infrastructure in the context of the Russian Federation's regions. The sample is based on data published by the Federal State Statistics Service of the Russian Federation¹. Initially, we considered twenty-two features that characterize the state of housing and communal services, education, health, culture and art, information communications, and retail trade.

A component analysis of the original sample was carried out; based on the results of the analysis, the most significant features for each area were selected, and a curtailed sample was formed. Then a component analysis of the curtailed sample was performed and four principal components (PC) were constructed. The weight coefficients of the indicators of the constructed principal components are presented in *table 1*.

The authors identified significant indicators having large modulo weight coefficients (they are highlighted in *tab. 1* in bold) and calculated the values of the information coefficients of the principal components, which made it possible to determine their composition. The first principal component includes the following indicators: coverage of children by preschool education, number of organizations of secondary vocational education, number of hospital beds, capacity of outpatient clinics, number of museums, number of gyms.

¹ *Regions of Russia. Socio-Economic Indicators. 2017. Stat. Coll. Rosstat. M., 2017. 1402 p.*

Table 1. Weight coefficients of the principal components' features

Indicator	Weight coefficients			
	PC1	PC2	PC3	PC4
Total area of residential premises, on average per inhabitant	0.146	-0.321	-0.398	0.224
Volume of public services per capita	0.218	-0.438	0.145	0.021
Coverage of children by preschool education	0.336	-0.277	-0.232	-0.018
Number of comprehensive educational organizations	0.288	0.400	0.122	-0.097
Number of organizations of secondary vocational education	0.415	0.157	0.112	0.075
Number of organizations of higher education	-0.103	-0.195	0.383	0.505
Number of hospital beds	0.363	-0.014	0.163	0.089
Capacity of outpatient clinics	0.358	-0.137	-0.004	0.153
Number of theaters	-0.011	0.103	0.422	0.543
Number of museums	0.385	0.111	0.102	-0.071
Number of flat sports facilities	0.016	-0.001	-0.469	0.437
Number of gyms	0.379	0.150	-0.068	-0.101
Population using the Internet	0.005	-0.293	0.377	-0.338
Retail trade turnover per capita	0.015	-0.506	0.104	-0.182

All indicators have positive coefficients. The second principal component includes two indicators with negative coefficients (volume of public services per capita and retail trade turnover per capita) and one indicator with a positive coefficient (number of comprehensive educational organizations). The third principal component included two indicators with negative coefficients (total area of residential premises, on average per inhabitant and number of flat sports facilities), and one indicator with a positive coefficient (population using the Internet). The fourth main component includes two indicators with

positive coefficients: number of organizations of higher education and number of theatres. The signs of the coefficients are taken into account when making recommendations for changing the volume of investments in infrastructure development.

The authors constructed two-dimensional and three-dimensional scattering diagrams of principal components. After its analysis, 9 regional clusters with different levels of social infrastructure development were identified. The clusters characteristics relative to the principal components are shown in *table 2*.

Table 2. Clusters characteristics relative to the principal components

Development level	Cluster number	PC1	PC2	PC3	PC4
Most developed infrastructure	4	low	low	high	average
	5	high	average	high	average
	9	high	low	high	high
Medium developed infrastructure	1	average	average	low	low
	2	average	average	average	low
	7	low	low	average	low
Least developed infrastructure	3	low	average	high	low
	6	average	high	high	average
	8	low	high	high	low

Source: compiled by the authors based on the results of the analysis of the location of clusters in the space of principal components.

The regional clusters with most advanced infrastructure include Moscow, St. Petersburg, Nenets AO, Chukotka AO, Kamchatka Krai, Jewish AO, Sakhalin Oblast, Magadan Oblast, and others.

The clusters with medium-developed infrastructure include the Republic of Bashkortostan, Sverdlovsk Oblast, Chelyabinsk Oblast, Bryansk Oblast, Kaluga Oblast, Astrakhan Oblast, Volgograd Oblast, Novosibirsk Oblast, and others.

The clusters with the least developed infrastructure include Murmansk Oblast, Tula Oblast, Republic of Kalmykia, Altai Republic, Zabaykalsky Krai, Dagestan, Ingushetia, and other.

It should be noted that, when determining the level of infrastructure development, the signs of the indicators' weight coefficients, included in the principal components, are taken into account. Thus, the first and fourth principal components include indicators that have only positive coefficients, so the higher their values, the higher the level of infrastructure development. And the second and third principal components include indicators that have negative coefficients: "Volume of public services", "Retail trade turnover", "Total area of residential premises, on average per inhabitant" and "Sports flat structures". Therefore, the lower the values of these indicators are, the higher the level of infrastructure development is.

Based on the constructed principal components and the composition of their indicators, the structure of the integral index of social infrastructure quality is formed. A number of subsystems corresponds to a number of principal components, and it is equal to four, a number of subsystems elements is equal to a number of indicators included in the corresponding principal component. Thus,

for the first principal component, a number of indicators is six, for the second and third principal components – three, for the fourth principal component – two.

The integral index of social infrastructure quality I_s is calculated similarly to the integral index of the quality of life as a weighted sum of the components K_i :

$$I_s = \sum_{i=1}^4 \alpha_i K_i, \quad (8)$$

where α_i coefficients are found by the formula (6).

The dynamics of changes in the integral index I_s is described by a differential equation as follows:

$$\dot{I}_s = -I_s + \alpha_1 K_1 + \alpha_2 K_2 + \alpha_3 K_3. \quad (9)$$

The dynamics of changes in K_i components is described by differential equations as follows:

$$\begin{cases} \dot{K}_1 = -\lambda_{11}K_1 + \lambda_{12}K_2 + \lambda_{13}K_3 + \lambda_{14}K_4 + K_{10}, \\ \dot{K}_2 = -\lambda_{22}K_2 + \lambda_{21}K_1 + \lambda_{23}K_3 + \lambda_{24}K_4 + K_{20}, \\ \dot{K}_3 = -\lambda_{33}K_3 + \lambda_{31}K_1 + \lambda_{32}K_2 + \lambda_{34}K_4 + K_{30}, \\ \dot{K}_4 = -\lambda_{44}K_4 + \lambda_{41}K_1 + \lambda_{42}K_2 + \lambda_{43}K_3 + K_{40}, \end{cases} \quad (10)$$

where $K_{i0}, i = \overline{1,4}$ are the initial value of K_i components; $\lambda_{ij}, i \neq j$ are the weight coefficients reflecting the mutual influence of K_i components. The values of λ_{ij} coefficients are determined by expert analysis based on statistical data.

The initial values of K_i components are defined as the weighted sum of the indicators values included in the corresponding principal component:

$$K_{10} = \beta_{11}x_{11} + \beta_{12}x_{12} + \beta_{13}x_{13} + \beta_{14}x_{14} + \beta_{15}x_{15} + \beta_{16}x_{16}, \quad (11)$$

$$K_{20} = \beta_{21}x_{21} + \beta_{22}x_{22} + \beta_{23}x_{23}, \quad (12)$$

$$K_{30} = \beta_{31}x_{31} + \beta_{32}x_{32} + \beta_{33}x_{33}, \quad (13)$$

$$K_{40} = \beta_{41}x_{41} + \beta_{42}x_{42}, \quad (14)$$

where β_{ij} coefficients are calculated by the formula (7).

The dynamics of indicators' changes $x_{1j}, j = \overline{1,6}$ for the first principal component is described by the differential equations as follows:

$$\begin{cases} \dot{x}_{11} = -x_{11} + k_{112}x_{12} + k_{113}x_{13} + k_{114}x_{14} + k_{115}x_{15} + k_{116}x_{16} + u_{11}, \\ \dot{x}_{12} = -x_{12} + k_{121}x_{11} + k_{123}x_{13} + k_{124}x_{14} + k_{125}x_{15} + k_{126}x_{16} + u_{12}, \\ \dot{x}_{13} = -x_{13} + k_{131}x_{11} + k_{132}x_{12} + k_{134}x_{14} + k_{135}x_{15} + k_{136}x_{16} + u_{13}, \\ \dot{x}_{14} = -x_{14} + k_{141}x_{11} + k_{142}x_{12} + k_{143}x_{13} + k_{145}x_{15} + k_{146}x_{16} + u_{14}, \\ \dot{x}_{15} = -x_{15} + k_{151}x_{11} + k_{152}x_{12} + k_{153}x_{13} + k_{154}x_{14} + k_{156}x_{16} + u_{15}, \\ \dot{x}_{16} = -x_{16} + k_{161}x_{11} + k_{162}x_{12} + k_{163}x_{13} + k_{164}x_{14} + k_{165}x_{15} + u_{16}, \end{cases} \quad (15)$$

The dynamics of indicators' changes $x_{2j}, j = \overline{1,3}$ for the second principal component is described by the differential equations as follows:

$$\begin{cases} \dot{x}_{21} = -x_{21} + k_{212}x_{22} + k_{213}x_{23} + u_{21}, \\ \dot{x}_{22} = -x_{22} + k_{221}x_{21} + k_{223}x_{23} + u_{22}, \\ \dot{x}_{23} = -x_{23} + k_{231}x_{21} + k_{232}x_{22} + u_{23}, \end{cases} \quad (16)$$

The dynamics of indicators' changes $x_{3j}, j = \overline{1,3}$ for the third principal component is described by the differential equations as follows:

$$\begin{cases} \dot{x}_{31} = -x_{31} + k_{312}x_{32} + k_{313}x_{33} + u_{31}, \\ \dot{x}_{32} = -x_{32} + k_{321}x_{31} + k_{323}x_{33} + u_{32}, \\ \dot{x}_{33} = -x_{33} + k_{331}x_{31} + k_{332}x_{32} + u_{33}, \end{cases} \quad (17)$$

The dynamics of indicators' changes $x_{4j}, j = \overline{1,2}$ for the fourth principal component is described by the differential equations as follows:

$$\begin{cases} \dot{x}_{41} = -x_{41} + k_{412}x_{42} + u_{41}, \\ \dot{x}_{42} = -x_{42} + k_{421}x_{41} + u_{42}, \end{cases} \quad (18)$$

where k_{ijl} are weight coefficients reflecting the mutual influence of indicators. Numerical values of k_{ijl} coefficients are determined by expert analysis

based on statistical data; u_{ij} are the financial and economic control effects (investment volume).

Based on the clusters' characteristics relative to the principal components, given in table 2, we developed recommendations for changing the volume of investment (U_i) in social infrastructure by regional clusters (Tab. 3). The up arrow "↑" indicates the need to increase investment in the relevant areas. For example, for cluster 8, the PC1 value is "low", therefore, to increase the level of development of social infrastructure for cluster 8, it is necessary to increase the amount of investment in those areas (indicators) that are included in the specified component. The signs of the weight coefficients of the indicators included in the principal components are taken into account. For example, for cluster 7, the PC2 value is "low", but it includes indicators with a negative sign, and a low sign of the indicator means a high level of development in this area, so no additional investment is required.

It should be noted that no additional investment was planned for the regional clusters with the most developed infrastructure.

The volume of investment in social infrastructure in the regions of the Russian Federation for 2016 and 2017 is compared, and the relative changes in the values of investment in different areas by cluster are calculated. Taking into account the recommended changes in investment volume for regional clusters and

Table 3. The recommended change in investment volume

Cluster no.	recommended change in investment volume			
	U_1	U_2	U_3	U_4
Cluster 8	↑	↑	↑	↑
Cluster 6		↑	↑	
Cluster 3	↑		↑	↑
Cluster 7	↑			↑
Cluster 2		↑	↑	
Cluster 1				↑

Table 4. Assessment of social infrastructure quality

Experiment no.	$\Delta U_1, \%$	$\Delta U_2, \%$	$\Delta U_3, \%$	$\Delta U_4, \%$	I_s	$\Delta I_s, \%$
Basic experiment	-	-	-	-	1.123	-
Experiment 1 (for cluster 8)	0.45	0.39	0.64	0.1	1.526	36
Experiment 2 (for cluster 6)	-	0.23	0.11	-	1.298	15
Experiment 3 (for cluster 3)	0.01		0.08	0.1	1.239	10.3
Experiment 4 (for cluster 7)	0.06			0.1	1.199	6.7
Experiment 5 (for cluster 2)		0.13	0.06		1.192	6.1
Experiment 6 (for cluster 1)				0.1	1.137	1.2

calculated relative changes in investment volume, the quality of social infrastructure is estimated (*Table 4*).

The research results showed that the increase of investments in social infrastructure development improved its quality, while the highest quality growth $\Delta I_s = 36\%$ was achieved in cluster 8, which includes such regions as the Republic of Dagestan, the Republic of Ingushetia, and the lowest growth $\Delta I_s = 1.2\%$ is in cluster 1, which includes, for example, the Republic of Bashkortostan and the Sverdlovsk Oblast. For the regions in cluster 6 (e.g., Altai Republic, Zabaykalsky Krai) the quality of social infrastructure increased by 15%; for the regions in cluster 3 (for example, Murmansk Oblast, Tula Oblast) by 10.3%; for the regions in cluster 7 (e.g., Astrakhan Oblast, Volgograd Oblast) by 6.7%; for the regions in cluster 2 (for example, Bryansk Oblast, Kaluga Oblast) by 6.1%.

Thus, the developed algorithm made it possible to build regional clusters characterized by different levels of social infrastructure development, assess the quality of social infrastructure based on the calculation of an integral index, and develop control actions in the form of recommended changes in the

volume of investments in the development of social infrastructure by the regional clusters.

Conclusion

The proposed methodology of research, modeling, and management of society considers it a societal system, which is an organized system integrity and a unity of economic, political, social, spiritual, and cultural sub-systems. As a criterion for society development, the integral index of the quality of life is studied that is also a criterion for the effectiveness of public administration bodies. We developed the models of life quality which allow studying the structure of the integral index from the standpoint of a systematic approach and presenting it as a hierarchy of triads of the interrelated components, presenting the integral index as a multi-layered and a multi-connected object having the property of self-organization, and developing a dynamic model for evaluating the integral index. An algorithm for managing the quality of the societal system functioning on the basis of the evaluation of an integral index, based on the usage of data mining and dynamic modeling methods, is proposed. The authors considered the application of the algorithm for managing the social infrastructure quality in the Russian regions, which made it possible

to build regional clusters which have different level of social infrastructure development, to work out the structure of an integral index and a dynamic model for assessing the quality of social infrastructure, and to formulate control actions in the form of recommended changes in the volume of investments, taking into account the characteristics of the constructed clusters. Developed recommendations may be used by federal and regional authorities while developing strategic documents aimed at improving population's quality of life.

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