Information & Analytical Support of Innovation Processes Management Digitalisation at the Regional Level

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Summary
The problem of interaction of RIS elements and modeling of their impact on sustainable development of the region today is practically not considered in terms of model tools for providing solutions at the main stages of strategic management in the complex. The aim of the work is to develop and test economic and mathematical models of the regional innovation system (RIS). The proposed set of developed economic and mathematical models is designed to expand the theoretical and methodological base and identify factors of regional development of regions, including key indicators of RIS, explore their relationship in two interconnected systems «RIS →Regional economy» and «Sustainable regional development→RIS» and to develop a forecast for the development of the regional economic system taking into account the innovation factor.
Key words:
regional innovation system, model, analysis.

1. Introduction

In the conditions of formation of economy of knowledge the actual task is development of methods of strategic planning of innovative development of region; development of models for the development of innovation infrastructure in the region, evaluation and forecasting of the results of innovation policy, the distinctive feature of which is to ensure coherence and coordination of actions of all actors in innovation. At the same time, one of the main problems is modeling the relationship of elements of the regional innovation system (RIS) and modeling their impact on socio-economic development of the region.

RIS is a promising and relevant subject of research, as it is now becoming increasingly important to ensure the competitiveness of the regional economy. Various indicators can be used to characterize RIS, among which are the following: the number of organizations performing research and development; number of personnel engaged in research and development; volume of innovative products. However, the presence of a certain number of organizations or qualified personnel does not mean that their actions are aimed at the development of the region. That is why there is a need for a more thorough study of the interaction of RIS. There are some areas of research related to the development of methodological framework and instrumental environment to support RIS strategic decision-making. But they provide only some stages of strategic management of RIS, such as:

– evaluation of individual projects and selection of optimal innovation structures for the implementation of an innovation project (for example, an intelligent information support system for innovation activities based on a multi-agent approach) [1–4];

– development of integrated (generalized) indicators of IP assessment of regions, countries (for example, European Innovation Scoreboard methodology, "Innovation Barometer"; generalized indicator of innovative development of the economic system based on resource and functional indices that determine innovation potential and innovation activity systems and many others);

– methods of analysis and planning of regional development on certain aspects of RIS development (information, financial, personnel, infrastructure criteria, etc.), e.g. regression [5].

Thus, the problem of interaction of RIS elements and modeling of their impact on sustainable development of the region today is practically not considered in terms of model tools for providing solutions at the main stages of strategic management in the complex.

This raises the problem of creating strategic decision-making models, ie models that allow interpreting and analyzing available information about the external and internal environment of RIS, establishing relationships between development factors, monitoring the region's progress towards strategic development guidelines. Models that help people make informed decisions that support the decision-making process.

Based on the existing methodologies of strategic planning, it is concluded that the least developed in terms of

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decision-making models are methods of RIS assessment at the stages of monitoring, prioritization, analysis and control of the region's innovation strategy.

New factors of socio-economic processes make relevant issues of analytical support of public administration [6-7]. In the previous researches of the authors the current trends of social transformations are considered [8-9], which should also be taken into account in the work of civil servants.

The aim of the work is to develop and test economic and mathematical models of the regional innovation system (RIS).

Achieving this goal determined the formulation and solution of the following tasks:

– analyze the main approaches to RIS modeling;

– on the basis of a set of economic and mathematical models to identify factors of regional development, including the main economic indicators of RIS;

– to develop a mathematical model to assess the importance of the RIS factor in the economic growth of regions;

– perform an analysis of the dynamics of RIS indicators and develop a methodology for constructing a classification of regions on indicators of innovation, including the identification of integrated indicators of innovation in the regions;

– to develop an algorithm for the functioning of the decision support system for the development of RIS.

3. Main issues of RIS research

To achieve the goal of the study it is necessary to build a variable model of the impact of a set of innovation processes, which are generalized in the work called RIS, on regional economic development.

The set of developed economic and mathematical models will expand the theoretical and methodological base and identify factors of regional development of regions, including key indicators of RIS, explore their relationship in two interconnected systems «RIS → Regional economy» and «Sustainable regional development → RIS» and to develop a forecast for the development of the regional economic system taking into account the innovation factor.

The scheme of the study is shown in Fig. 1.

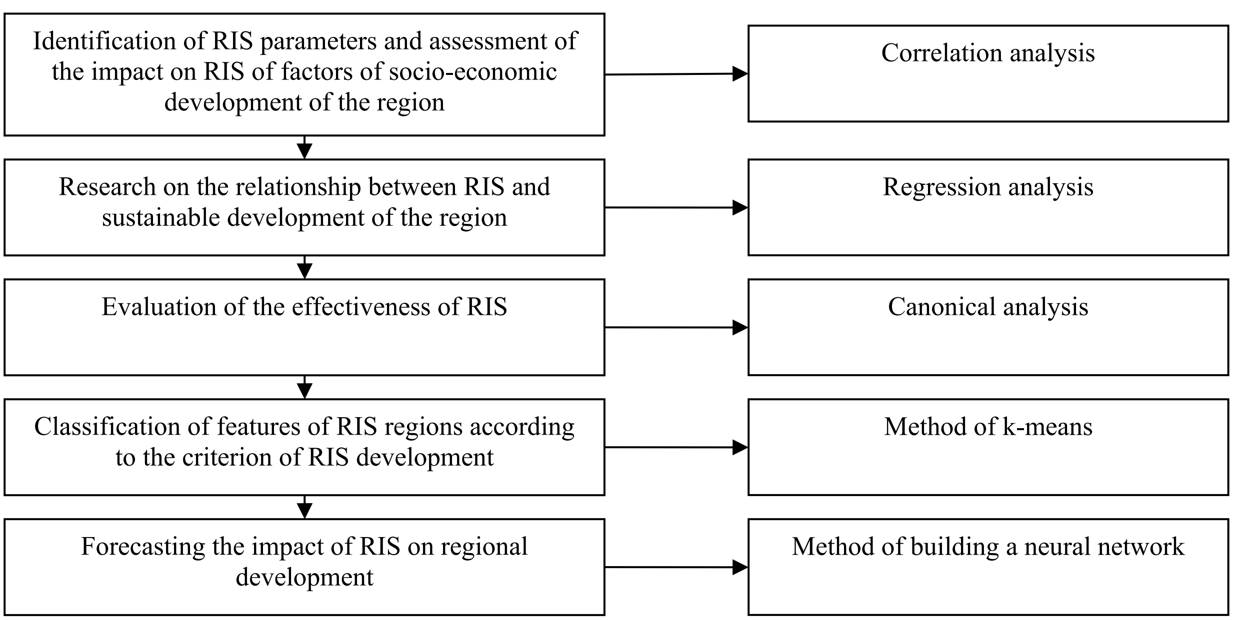

Fig. 1 Scheme of RIS study

The practical significance of the developed model lies in the possibility of its application for forecasting, planning and programming of the economy of the regions, the development of measures to improve innovation, both individual regions and the country as a whole.

Correlation analysis was chosen to determine the degree of importance of RIS components and its impact on the functioning of the regional innovation system.

To assess RIS, it is advisable to choose the development of regression models using criteria to analyze the probability of the parameters of the obtained equations and determine the degree of their adequacy to real processes.

Canonical analysis should be used to further investigate the effectiveness of RIS. This method is the most effective for the purposes of real research due to the fact that it allows to identify relationships between sets of variables, in our case – between the «inputs» and «outputs» of RIS. Comparative analysis of RIS, in particular, the identification of problem areas of development, requires finding homogeneous groups of regions in terms of economic development, which is possible only with the analysis of factor conditions of RIS. Such classification or typology of regions characterized by a set of socio-economic indicators is the task of the used multidimensional statistical analysis.

For the implementation of simulation modeling, the methodology of formalization of information systems and construction of a neural network was used in order to develop a forecast of the development of the most important components of RIS.

For the purposes of this study, the identification of input data for the construction of the RIS model was based on three approaches:

– use of official statistics, which contain data on the basic factors of RIS and the results of its operation;

– the use of G. Linkvist's theoretical model, which considers the relationship of RIS in the context of other closely related phenomena through the calculation of individual indicators;

– calculation of integrated indicators that characterize the processes in RIS and allow to determine the degree of influence of specific factors on individual results of RIS operation.

3. Information system to support RIS strategic decisions designing stages

The purpose of creating an information system to support RIS strategic decisions is to develop a universal tool that provides complete and reliable information on the processes of analysis, planning and forecasting of RIS to justify decisions at the stages of data analysis, selection of development alternatives, assessment of consequences.

RIS is the union of a set of subsystems, ie formally:

$$S=\cup Si \quad (1)$$

and the development of RIS in general is determined by the innovative development of each of its subsystems.

Acording to research [10] the process of RIS management, as a process of long-term planning of its development begins with the forecasting of the development of scientific and technical sphere for a certain period of time $[t_1, t_2]$.

Sustainable development of the region formulates requirements for development indicators, and hence the quality of functioning of the RIS management system as a degree of compliance with these requirements. At this stage, the general forecast of RIS development for a certain period of time.

Based on this, more specific forecasts are made in the areas of innovation development, which relate to various aspects of the functioning of RIS and are conducted by experts in the field of selected aspects of innovation development. At this stage, the main role is played by the forecast of requirements for the values of RIS indicators. Such a forecast should be made for each subsystem taking into account the criteria of sustainable development.

Then possible directions of its innovative development are formed, which should provide an increase in the level of innovative development of the business entity as a whole. This stage corresponds to the stage of defining goals in the scheme of decision-making technology. The concept of development of states of these objects has to be developed here. Indicators of innovative development of each subsystem of the economic entity are, as a rule, integral in nature and are a system of primary indicators of innovative development $\{x_{im}\}$, with each primary indicator xim characterizes a certain aspect of development. Thus, the chosen direction of innovative development of RIS, aimed at increasing its level, is determined in the space $X_{i1}\times X_{i2}\times\ldots$ Xim variables $x_{i1}, x_{i2},\ldots, x_{im}$, ie as a point in (xi1, xi2,…, xim) in m-dimensional space of the states of innovative development of the element S_i.

The priority of variables $x_{i1}, x_{i2},\ldots, x_{im}$, (indicators of innovative development of the element of economic entity S_i), which describes the state of its innovative development is determined by the weight values of these indicators $w_{i1}, w_{i2},\ldots$, wim, which are determined in terms of their impact on innovation. development of this element of the business entity. The states and levels of innovative development of all elements of the economic entity S as a whole are similarly described. Implementation of this stage requires the involvement of experts.

Then the preliminary development of action plans aimed at increasing the level of innovative development of the business entity. The forecast of possible final levels of innovative development of elements of economic entity Si is made, the estimation of cost characteristics of the supposed actions directed on innovative development of element Si is given also.

At the next stage the priority of development of elements of economic entity Si is established, distribution of active means and allocations on elements or aspects of innovative development of RIS is made.

Further planning of active and supporting operations is carried out. Efficiency functions for different types of tools on Si objects are built.

At the next stage a set of active means of operations is formed. At the stage, the necessary calculations and analysis of the expected level of innovative development of subsystems of element S as a result of operations in accordance with their plans developed and the distribution of active assets. If the result of operations is considered effective, development of the innovation sphere is transferred to next stage. Otherwise, in stage, the distribution of allocations is adjusted.

At the next stage the adjustment of the plans of active operations and efficiency functions of different types of tools for each of the operations. Then return to stage, where on the basis of the corrected actions again the formation of complexes of active means of operations. Next, you need to make the transition to appropriate stage and the cycle continues. This cycle continues until a variant of the action plan aimed at innovative development of the economic entity is obtained, which provides the desired effect, which means the set of resulting transformations Δxim, values of xim, which characterize the state of each aspect of S_i subject S.

At the next stage the analysis of the developed options for the development of element S and clarification of existing economic opportunities. If, in the opinion of the expert, there is no option among the developed plans that would be considered effective enough to achieve the set goals, then actions are taken to find additional allocations. If these attempts do not succeed, then there is a transition to stage 5 and the subsequent repetition of all stages, thus there is a new attempt to improve the target effect of the developed plan options by increasing the total appropriations, or moving to stage, on which a new variant of possible innovative development of the subsystem is formed, which can lead to an increase in the level of RIS development. The whole described cycle of formation of the plan of the actions directed on innovative development of the subsystem which is realizing the new concept of its development at new volumes of financing is repeated.

This iterative process continues until an acceptable variant of innovative development of subsystem S is found.

The last stage includes the preparation of documents on the adopted version of the action plan aimed at the development of RIS.

3. Information and analytical system in the field of RIS

Information and analytical system in the field of RIS should include the following main components [11]:

1. Database – set of facts about RIS (elemental composition, achieved indicators of innovation).

2. Base of models – tools for substantiation and decision-making in conditions of uncertainty at the stages of data analysis (current state of the regional innovation system), selection of alternatives for innovative development of the region, as well as assessment and forecasting the consequences of decisions. One of the most important stages in creating decision-making models is the stage of constructing membership functions that describe the semantics of the basic values of the variables used in the model. To choose the methods of constructing membership functions, the following requirements for the method must be formulated:

– to create a model, it should be possible to formalize the information received from various actors in the decision-making process;

– the model should take into account the specifics of the factor of innovative development of the region, described by vague concepts.

3. Software subsystem that provides interaction between the user of the system, the database and the reference version. It manages the creation, storage and recovery of models on a model basis and integrates them with the data in the database.

A feature of the RIS monitoring system is the greater incompleteness and uncertainty of the conceptual framework, compared to current management systems. Therefore, the standard means of relational databases are inconvenient to describe the model of this system. To build the layout of the information system, you can use the approach of evolutionary construction of the data model, based on the metadata management system.

The proposed model of metadata is substantiated in the framework of classification theory, according to which any classification system has a dual nature (duality principle), namely – "outer side" (taxonomy, in our case Subjects) and "inner side" (meronomy, in in our case Properties). In addition, the model uses the conclusions of the theory of measurements, in particular, the values (Values) can be of three types: along with quantitative scales, ordinal scales are introduced, as well as scales of names.

From the user's point of view, the system should include the following main functional modules:

1. Monitoring of the state of RIS. The main function of this module is to provide the user with the ability to add, edit, delete individual groups of RIS elements, their subgroups, specific to each subgroup of indicators of innovation development, as well as filling the database with real facts;

2. Module for the formation of fuzzy expert assessments of the patterns of development of RIS, the relationship of individual strategic factors, elements of RIS;

3. Module of strategic analysis in view of opportunities and threats posed by the external environment of RIS, as well as taking into account the strengths and weaknesses of the region and the potential of RIS development;

4. A module that allows for an integrated assessment of the innovative development of the region, as well as to monitor the consequences of strategic decisions on RIS;

5. Scenario analysis module – a solution search program (direct calculation of the system) when setting all input values of RIS;

6. Uncertainty estimation module for estimating random changes of coefficients and inputs of models in order to study them for stability and sensitivity;

7. Global optimization module for finding solutions characteristic of this RIS model as approximately globally optimal, which can be selected as initial approximations for the next iterative step;

8. Module of sequential improvement and approximate-optimal synthesis of control for the implementation of iterative improvement of approximate solutions of RIS.

3. Innovation and Investment Processes Impact Simulation Model Case

The formation of RIS occurs in most cases through innovation and investment processes with multiple impacts [12]. Investment attractiveness of the region and innovation activity in the region, as well as investment potential and investment risks of the complex are neurons of the first layer of the network, investment climate of the region and investment attractiveness of the complex are second level neurons, and innovation status of the complex is a third level neuron.

The calculation of the model involves first determining the state of the neurons of each layer of the network one by one and then estimating the final output of the network using the activation function.

The current state of each neuron is defined as the weighted sum of the input parameters and the magnitude of the connection (weight) of each parameter and neuron:

$$S = \sum_{i=1}^{n} X_i \cdot V_i \qquad (2)$$

S – current state of the neuron;

X_i – value of parameter i;

V_i – weight of input parameter i.

To find the weighted sum of the input parameters of the neuron, other functions can be used, the appearance of which is determined by the properties of the neural network necessary for the researcher.

When using a multilevel neural network, the current state of higher-level neurons will depend on the state of lower-level neurons, and the magnitude of the connection between them will also be calculated according to the formula.

For example, the investment attractiveness of the region as a neuron of the first layer of the network will be formed by partial indicators, which act as input parameters:

$$SD = S = f(X_j, V_j) \qquad (3)$$

SD – sustainable development of the region;

S – assessment of the state of sustainable development of the region as a neuron of the first layer of the network; X – partial indicators of the region (input parameters of RIS); V is the weight of the indicator ш of RIS

Then the neurons of the first layer of the network (neurons of a lower level) will affect RIS as a neuron of the second layer of the network (neuron of a higher level), taking into account the magnitude of the connection between them (Fig. 2):

$$I = S_{ip}^{2} = f\left(S_k^1, V_k^1\right) = \sum_{k=1}^{2} S_k^1 \cdot V_k^1 \qquad (4)$$

S – assessment of the state of neurons of the first level of the region;

V – the magnitude of the connection of neurons of the first and second level – the weights of the elements of RIS.

The final output of the neural network is determined by the activation function, which integrates the interaction of all neurons and calculated depending on the function of the state of neurons:

$$F = f(S) \quad (5)$$

F – neural network activation function;

S – neuronal status assessment function.

Different types of activation functions are used in neural network models, the type of which is also determined by the tasks of each specific study and the necessary properties of the neural network.

Thus, the integrated estimation of RIS can be obtained as the calculated value of the activation function of the neural network (Fig. 2).

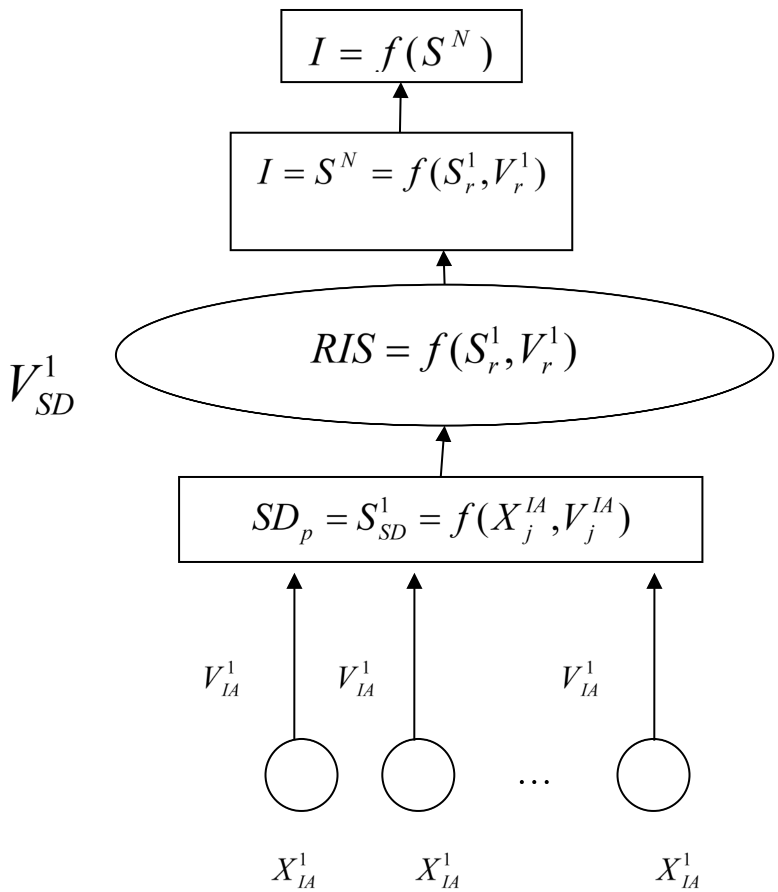

Fig. 2 RIS assessment model based on neural network:

Designation: IA – innovation activity of the region; RIS – state of RIS; X – input parameters of the neural network (economic, social and environmental indicators that form the corresponding characteristics), and = 1,…, I; V is the magnitude of the connection between the input parameters and the neurons of the network, as well as neurons of different layers; S – function of the current state of neurons, for neurons of the first layer – taking into account the influence of input parameters, for neurons of the second and third layers – taking into account the influence of neurons of the lower layer

The proposed model of RIS assessment can be used to study the investment processes of other objects of complex nature – other intersectoral complexes, as well as enterprises. The use of the proposed neural network model will assess the investment status of RIS and adjust the mechanisms for managing investment activities in the region in order to attract additional investment in RIS.

To clarify the parameters of model, we use a neural network generated by NeuroPro 0.25 neurosimulator, whose main functions are to assess the significance of the studied network parameters, which we use to refine the parameters of the RIS model. With the help of NeuroPro 0.25 tool, 10 networks of different configurations (single and two-layer) were built, trained and researched, taking into account the requirements of the neurosimulator and the basic theoretical principles of neural networks.As it is impossible to carry out the analysis on the example of

Sumy region due to low indicators of some indicators, the experiment was carried out on the data of Ukraine.

The results of the calculations allowed to clarify the parameters of the RIS model. According to the calculations, the set of indicators that determine the RIS is represented by variables that coincide with the results of previous calculations (numbers have been changed for convenience):

X_1 – the number of staff engaged in research and development;

X_2 – the number of new technologies created;

X_3 – research and development costs

X_4 – the number of research organizations.

The method of constructing predictive variants of RIS development using a trained neural network has the following characteristics:

– uses a trained network;

– is aimed at building predictive options for the development of RIS.

The results of the calculation of the parameters of the RIS model are given in table. 1.

Table 1: The results of neural network calculation of the RIS model

№	*Rating significance*	*Configuration*	*Characteristics of activation function*	*Number of teaching cycles*	*Average testing error*
1	**Network 1**				
		2-4-1	0,1	9	0,06
	X_1=0,801				
	X_2=0,915				
	X_3=0,902				
	X_4=0,880				
2	**Network 2**				
		2-4-1	0,2	11	0,08
	X_1=0,711				
	X_2=0,689				
	X_3=0,923				
	X_4=0,391				
3	**Network 3**				
		2-4-1	0,3	12	0,07
	X_1=0,631				
	X_2=0,549				
	X_3=0,903				
	X_4=0,710				

The technique is carried out in stages, includes the following operations:

Stage 1: check the predictive ability; preparation of data in the form of a control set of values that take into account possible options for economic development – options for growth and decline in production in the economy; survey of the trained network and obtaining forecast values;

Stage 2: analysis and research of the obtained forecast variants of RIS development;

Stage 3: interpretation of the obtained results.

As a result, forecast options for the development of RIS are formed; analysis and research of models reveals quantitative, qualitative characteristics.

The network, trained to predict RIS variants, has the following characteristics:

– significance of indicators: X_1=0,801, X_2=0,915, X_3=0,902, X_4=0,880;

– configuration: 2-4-1; the input layer includes 4 neurons, the intermediate layer consists of 9 neurons; output neuron – 1;

– activation function – sigmoid;

– learning algorithm – reverse error propagation, number of learning cycles – 9, average testing error – 0.06.

To build a predictive model, we anticipate possible combinations of RIC factors, prepare data in the form of a control set of values for a trained neural network, obtain by surveying the network predicted values of Y.

Based on the survey data of the trained network, we determine the growth options of RIS development (Table 2).

In the table 2 the "best" options for development are shown; the best one is the one that does not predict a decline in individual RIS indicators and an increase in the resulting indicator.

Table 2: Forecast options for the development of RIS

№	X_1	X_2	X_3	X_4	Y
1	0,801	0,915	0,902	0,880	1,11
2	0,711	0,689	0,923	0,391	1,05
3	0,631	0,549	0,903	0,710	1,09

The variants of production growth obtained on the basis of the forecast model can be used to make management decisions.

Thus, the proposed technology helps to increase the potential of forecasting by:

– identification of significant factors of production growth in the region's economy;

– definition of promising industries ("growth points");

– tracking structural changes in the region's economy.

5. Conclusion

The study of the features of RIS modeling allowed to make the following conclusions.

The analysis showed that the most important task at this time is to increase the innovation potential in regions with its low level, as innovation potential is the most important factor in ensuring the competitiveness and development of the regional economy. Its solution is possible, first of all, by increasing the attractiveness of innovation in these regions, as well as the introduction of new promising production technologies, new product development and economic policy aimed at activating endogenous factors of development.

The application of mathematical methods in the regional economy has a long tradition. Many modeling approaches, such as optimization models and intersectoral balance models, have become classic to date. Econometric models are rightly considered to be the main tool of regional economic modeling today. With their help in the work the connections and formed models of interrelations of RIS indicators with various groups of factors, both for regions, and for national economy as a whole are revealed.

As a result of the system analysis of RIS development on the example of Sumy region and interrelations between elements of the system and its external environment, and also according to a technique of construction of econometric models the complex of models of forecasting of RIS development was developed.

Building a model adequate to RIS, objectively helps to identify the main trends in its development. The vague classification corresponds to the implicit division of regions into groups according to innovation potential, which provides an opportunity to implement a new approach to typological regression.

In the process of research, a neural network was developed and trained, which is used as an element of artificial intelligence and is designed to provide analytical support for decision-making.

For a visual representation of RIS, its structure, main components, sequence of data processing in the system, to present its information support developed system models: structural-functional scheme (model), technological scheme, which reflects the relationship between modules and sequence of management data processing; the information model of the system is presented in the form of a logical model.

A methodology for assessing the investment status of RIS has been developed, which takes into account significant factors that shape regional and sectoral innovation characteristics. The method is based on the use of two methodological approaches to the calculation of the integrated indicator RIS: based on a multifactor function based on the hierarchy of characteristics, and a mathematical model of the neural network that takes into account the relationship and interaction of factors shaping RIS characteristics.

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