Подход к организации поддержки принятия решений при разработке стратегий инновационного развития регионов с применением адаптивно-имитационной модели

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Аннотация

Рассмотрены вопросы формирования системы поддержки принятия решений в области управления региональным развитием. Представленный обзор существующих подходов в данной области свидетельствует с одной стороны об их многообразии, а с другой позволяет сделать вывод о необходимости решения ряда методологических и практических вопросов поддержки принятия решений в части инновационного развития регионов. Исходя из этого целью исследования являлась разработка концепции системы поддержки принятия решений для обоснования параметров инновационной стратегии развития региона на основе применения адаптивных механизмов согласования интересов экономических агентов.

Методология проведения исследования базируется на синтезе различных подходов в рамках интегрирования в структуру адаптивных имитационных моделей проблемно-ориентированных баз знаний с механизмом логического вывода, а также интеллектуальных технологий обработки слабоструктурированной информации, используемых для поиска решений в процессе формирования и корректировки параметров управления инновационным развитием региона. Результатом исследования является теоретическое обоснование разработки проблемно-ориентированной СППР, включая описание взаимосвязанных этапов, определяющих основные конструктивные особенности данного инструментария.

В рамках проведенного исследования предложена концептуальная схема реализации системы поддержки принятия решений в области управления инновационным развитием региона, описаны ключевые функциональные блоки предлагаемого инструментария, а также определено место инструментария в структуре системы управления региональным развитием, показаны возможности его использования при формировании прогнозно-плановых оценок развития региона, а также оценке эффективности применения альтернативных управляющих воздействий.

На наш взгляд, предложенный инструментарий позволит расширить возможности применения методов теории управления и поддержки принятия решения, интеллектуальных информационных технологий, экономико-математических методов, современных технологий компьютерного имитационного моделирования для задач стратегического планирования развития социально-экономических систем макро- и мезоуровня. С практической точки зрения инструментарий может быть интересен для органов государственного управления при решении задач в области разработки стратегий инновационного развития регионов России, формировании среднесрочных прогнозов и обосновании параметров социальной, экономической и бюджетной политики.

Ключевые слова: поддержка принятия решений; инновационное развитие; имитационное моделирование; адаптивное моделирование; региональное управление; прогнозирование и планирование.

Approach to the organization of decision support in the formulation of innovative regional development strategies applying adaptive-simulation model

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ABSTRACT

The issues of formation of the decision support system in the field of regional development management have been considered. The presented review of the existing approaches in this field testifies on the one hand to their diversity, and on the other hand, it allows us to draw a conclusion about the need to solute a number of methodological and practical issues of decision support in terms of innovative development of regions. On this basis, the goal of the research is to develop the concept of a decision support system to substantiate the parameters of the innovative strategy of regional development based on adaptive mechanisms for coordinating the interests of economic agents.

The research methodology is based on the synthesis of different approaches in the framework of integration into the structure of adaptive simulation models of problem-oriented knowledge bases, as well as intelligent technologies for processing semistructured information, using to find decisions in the process of formation and adjustment of parameters of management of innovative development of the region. The result of the study is a theoretical justification for the development of problem-oriented DSS, including a description of the interrelated stages, determining the main design features of this toolkit.

As a part of the study, a conceptual scheme of implementation of the decision support system in the field of management of regional innovative development has been proposed, the key functional blocks of the proposed tools have been described, the place of existing tools in the structure of the regional development management system has been determined, the possibilities of its use in the formation of forecast-planned assessments of regional development, as well as the evaluation of the effectiveness of alternative management actions, have been shown.

In our opinion, the proposed tools will expand the possibilities of applying the management theory and decision support methods, intelligent information technology, economic and mathematical methods, modern computer simulation technologies for strategic planning of socio-economic systems of macro- and meso-level. In practice, the tools can be interesting for public authorities to solve problems in the formulation of innovative regional development strategies for the Russian regions, the formation of medium-term forecasts and the justification of the parameters of social, economic and budgetary policy.

Keywords: decision support; innovative development; simulation modelling; adaptive modelling; regional management; forecasting and planning.

The regional economy is a complex, multidimensional and multifunction system. It is formed by a large number of elements and complex interactions, that permeate all socially important spheres of activity. Economic efficiency directly determines the stability and sustainability of regional development as a whole. It stands to reason, that strategy formulation for innovative development of systems on this scale requires a comprehensive and integrated justification. This justification determines the managed nature of system development with clearly defined targets. The implementation of effective economic policies requires a wide application of scientific-based management tools, first of all, the tools for developing and justifying the parameters of innovative regional development, that determine the possibility of accelerated economic growth with the simultaneous balanced development of the economy sectors and social sphere [19].

In recent decades, a study on the economic and mathematical model development and tools for planning innovative development has been actively conducted. These methods someway allow solving the problem of managed strategic development. Currently, there is a set of software package to solve a number of forecasting problems of regional socio-economic development [22]. At the same time, most of the modern domestic applied software is based on the planned economic model. They are often not equal to the current market conditions of management. The socio-economic and financial aspects of regional development modelling also need to be substantially improved. Moreover, the existing approaches model the inertial mechanisms of development. They are not focused on the decision of topical problems of regional development, first of all, ensuring accelerated economic growth through the transition to a new innovation-oriented model of the economy.

In this regard, the current model tools require significant improvement at the cost of the strengthening of the simulation components. Simulation modelling allows forming different scenarios of regional development, taking into account the objective possibilities and limitations of the regions. In the end, the scenarios will ensure the development of the specific mechanisms and conditions for achieving socially significant development priorities.

Methods

Analysis of the current state of research implies a comprehensive consideration of approaches to the strategic management of regional development, the theory of innovative economy, as well as decision support systems. In addition, the issues of designing economic and mathematical models used in these areas should be highlighted separately.

The selected areas, each separately have a fairly extensive scientific base. The foundations of the theory of innovative economy were formed in the early twentieth century by the Austrian economist J. Sympetrum who gave the definition and classification of innovations. The attention is paid to the innovative processes in the studies of Kondratiev waves, diffusion innovations by K. Freeman, etc. To date, the leading scientific and technical countries of the world formed a post-industrial society in which the sector of the innovative economy has become dominant (F. Fukuyama, J. Naisbitt, etc.).

The techno-economic paradigm is deserving of special mention. It considers as interdependence with the issues of innovative development of the economy (S. Yu. Glazyev, D. S. Lviv, K. Peres, Yu. V. Yakovets, etc.). It is to be noted, that the studies carried out in this direction, are largely qualitative analysis and diagnosis of innovation processes. At the same time, these studies are not always focused on the quantitative assessment of the interaction of innovation and territorial socio-economic development and, in particular, the formation of appropriate strategic forecasts and development plans.

Today it has become clear, that from a technological point of view, the decision of this problem requires the development of specialized decision support tools, including DSS class systems (ERP, OLAP, Data Mining, CRM, etc.) [25]. But again, most of the existing projects aimed at solving the problems of the microeconomic level, in particular, ensuring the activities of individual corporations — from enterprise resource planning and project management to support decision-making in terms of working with semi-structured information. At the macroeconomic level, including the development of regional innovation strategies, such systems were practically not used. At the same time, existing individual studies in this area, for example, the information and analysis DSS for management of innovative activity in the region, DSS on the strategy of innovative development of the region and so forth, do not fully reflect such a significant property of the regional system as the adaptability of behavior of the main economic actors [17; 9; 1]. There are also a number of studies, that are purely theoretical and/or sectoral in nature and couldn't be applied in real practice of management at the macro level [2].

In the field of economic and mathematical modelling of the regional processes and systems the various directions, in particular models of economic balance; the models based on the use of probabilistic and statistical methods; models of system dynamics and other models of simulation type; the models based on the use of different intellectual information technologies also include. However, in most cases, the present models combine different approaches. Among the foreign models based

on balance and econometric methods, such as the Wharton model, the Long-term Interindustry Forecasting Tool, the Brookings Model of the US economy, the model of the US fiscal policy can be identified [23].

Model software complexes "SIRENA" and "SIRENA-2" (Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences), model complex "POLIGON-2" (Novosibirsk State University), the model "Russian Interindustry Model" (Institute of Economic Forecasting, RAS), "Model of intersectoral relations" (Institute of Economics and Scientific and Technological Progress Forecasting of the Academy of Sciences of the Soviet Union), CGE model, "RUSEC", "Econometric model of Russian economy", "CGE model of social and economic system of Russia with the built-in neural networks" (Central Economics and Mathematics Institute, RAS), "Model of the Russian North region" (Syktyvkar State University), model "Gubernator", "The agent-based model of Moscow" (Central Economics and Mathematics Institute, RAS) and so on, should be distinguished among domestic models [14]. Many enterprise information systems, including widely used in the actual practice of the regional management information and analytical complex "Prognoz" (Prognoz, JSC) are also based on simulation models [13].

In addition, the presented models in many cases do not indicate the features of regional innovative developments of the regions, because they do not contain a description of the parameters of innovative activity as a managed adaptive process [4; 20]. A lot of models based on, in particular, econometric equations lose their predictive capability in the context of changes in the economic structure. This is due to the lack of adaptive properties of the regional system elements. In this regard, these models are not (and in most cases couldn't be) the basis for the formation of decision support systems. Thus, despite a vast number of the researches on the issue, a number of questions remain unresolved. The issues related to methodological and technical feasibility considerations of the decision support systems, especially with regard to the modelling of innovative development of the complex social and economic systems at the regional level and the use of adaptive mechanisms of coordination of the economic agents' interests.

The methodological problems in strategic planning at the regional level discussed above, justify the need for the development of flexible and adaptive management tools. IT should enable, on one hand, to take into account fundamental changes of the engagement principles of the actors as a matter of innovation economy, on the other hand, to quickly assess the consequences of decisions. On this basis, the qualitative development of the methodological and instrumental base of the newly emerging system for managing innovative development of the regional systems through the integration of such methods as strategic management, economic and statistical analysis and mathematical modelling, decision support theory and simulation, as well as the use of modern high-performance computing and information technology within a common tool.

In our view, this synthesis of different approaches can be implemented within the scope of decision support systems based on adaptive simulation models [15]. In addition, the domain knowledge base with inferential mechanism, and the intelligent technologies of the processing of semi-structured information used to find decisions in the process of formation and adjustment of the parameters of innovative development management of the region will be integrated into the structure of simulation models.

In general, the theoretical justification for the development of such a problem-oriented DSS should include the implementation of several consistently interrelated stages, that determine the main design features.

As part of the concept phase of research, it is necessary to clearly formulate the basic principles and requirements for the development of decision support tools in relation to the formulation strategies for regional innovative development. It is also necessary to form a common methodology of the study, to justify the approaches, methods, and technologies, that will be used in the development of decision support tools, as well as to formulate the concept of the implementation of adaptive control schemes and the simulation model of the regional economic system [12]. The methodology of the study should define a systems perspective on the regional economic system with the allocation of the place, role and relationships of social, economic and innovative processes in a common reproductive circuit. These processes formalized on the basis of an adaptive-simulation model as the structural core of the decision support system.

At the stage of the design and mathematical description of the simulation model embedding of structural elements and functional relationships should be carried out. These relationships are necessary for the formulation of innovative development strategies of regional economic systems. It is important to develop consistently logical, information and mathematical models for the entire set of economic agents of the regional economic system on the basis of the proposed methodology and approach. In addition, it is necessary to develop and integrate into the general contour the subsystem of management focused on the decision of a problem of innovative development, and to carry out system integration of all functional blocks and subsystems.

The engineering stage of the control subsystem should include the development of an indicative planning model and the substantiation of a set of regulators and control parameters in order to develop strategies for economic growth based on the factors of innovative development. The model of the substantiation of a set of regulators and control parameters for the formulation of innovative development strategies will allow integrating the algorithms of goal-setting and regulation in a unified information environment. At the same time, the development of the algorithm for the classification of macroeconomic situations based on the use of fuzzy logic methods and making changes to the basic indicative plan will allow developing regulatory effects [5; 16]. It is necessary to ensure the achievability of planned values in case of mutual adaptation of the objectives of the economic subsystem and the control subsystem. The formation of such a mechanism should involve a combination of the characteristics of the economic agent's behaviour and the rules of decision-making by regional authorities in the implementation of the innovation development strategy.

At the stage of designing the software of the decision support system, it is necessary to integrate systematically the developed models and algorithms into a common tool. And, in particular, it includes the statistical databases, software and user interface, a control module with the ability to design scenario maps, graphical output system and display the results of experimental and scenario calculations, etc.

At the stage of methodological support of DSS, it is also necessary to develop a methodology for substantiating innovative development strategies using an adaptive simulation model. Substantial, it includes the procedure for the development of an indicative plan, the development of the regulatory impact parameters and the implementation of simulation experiments. This methodology will allow coordinating the resources and interests of the economic agents and the management subsystem in the general methodological and calculation base. It will provide the possibility of system modelling of innovative development strategies.

Finally, at the stage of practical testing of DSS, it is necessary to carry out a set of experimental and scenario calculations using an adaptive simulation model to justify the choice of the most preferred strategy for innovative development in the medium term.

It is important, that the basic principle of the study at all stages is implementing a systems approach. It is determined whether to consider all key elements and relationships of the regional system, that form the basis of innovative development, as well as the description of their main properties and determining factors of innovative development. As part of the proposed approach, the principles of adaptability and consistency of decision-making processes by both economic agents and the regional management system in the implementation of state economic policy measures is fundamental.

At the same time, in contrast to the existing information analysis systems, the proposed tools to support management decision-making for the development will be based on the adaptive-simulation model focused on the formulation of the innovative development strategy of the economy. This class of model allows a holistic reflection of the adaptive agent's behaviour and the management subsystem in the implementation of strategies. It is characterized by the presence of integrated circuits of the subject interaction for different macroeconomic situations and allows to adapt their resource strategies in the formation of mutually agreed development goals.

Results

Among the tasks facing the DSS for managing innovative regional development are:
• collecting and storing different information both a structured and unstructured;
• analysis of data on the current state and development of the regional system and its components using a problem-oriented database with the inference mechanism;
• forecasting of macroeconomic conditions based on the adaptive simulation model;
• forming the recommendations on the adjustment of the parameters for managing innovative regional development.

At the same time, in view of the specifics of the management object, the features of its functioning and development, and taking into account the goals and tasks of the developed DSS, it would be useful to choose a specific simulation model structure as its core [11]. It implements the ability to adapt the behaviour of the different economic agents to both changes of macro environmental and behaviour of other agents. In addition, it should be noted, that the characteristics of an agent, the rules of decision-making have a significant impact. Agent rules can be based not only on "own experience" but also include the rules identified in the analysis of the behaviour of other agents. The use of adaptive simulation model of the region contributes to the decision of such tasks. The logical structure of adaptive simulation model, in our opinion, must integrate into a common hierarchically organized structure three key levels — economic agents, regional authorities, macro environment.

The strategy of economic agent behaviour in this model is a set of conditions and corresponding rules of behaviour. Thus, the situational nature of decision-making is taken into account. It must be noted, that both "internal" conditions (including the state of the economic agent,

the volume of available reserves, the needs of the economic agent) and "external" conditions (including the possibility of obtaining resources from other economic agents and the external environment, changes in macroeconomic indicators) are considered. Changing conditions allow leading not only to quantitative but also to qualitative changes in the functioning of the economic agent. The adaptive-simulation model structure allows obtaining balanced forecast-planned estimates of the regional development indicators. With that, by itself, the simulation model doesn't allow to perform all the functions of the DSS. It requires a set of special blocks that expand its capabilities. The composition and relationship between the blocks are shown in Figure 1.

The starting point is the formation of the input data array. The data-input block provides the maintenance of the database at the actual state. It is to be noted, that information should be updated in DSS periodically, in other words, the objective condition of effective functioning of the system is the organization of the monitoring procedure. Monitoring allows to review the consequences of implemented management decisions and improves the base of rules and precedents. In this context, the importance of the work should be taken into account. The database stores information about the regional socio and economic system, and also about the significant characteristic of the external environment.

The reflection of the heterogeneous information relating to different objects bearing in mind the changes in their characteristics over time is necessary to take into account. Modern information technologies in data processing and data mining would be useful to work with a large array. The data storage can be based on the conception of OLAP and Data Mining. Analysis of literature sources revealed, that using Data Mining allow detecting the hidden patterns in the large volume of information [3; 24].

Concurrently, the problem statement is carried out to be the decision-maker (the block of the formulating task). The need for such block is preceded by, on the one hand, the diversity of the practical tasks and applications of DSS, ranging from the analysis of retrospective information to proposing alternative decisions in the planning of innovative development. On the other hand, it preceded by the need to enter not only reporting data but also exogenous parameters of the model, as well as the choice of development strategy. A set of the exogenous model parameters include the scenario parameters of the macro environment, the controlled parameters, and also other indicators, that are used in the calculations, but are not modelled within the framework of the tool. The block of the formulating strategies is used for the formation of the general strategy of social and economic development of the region. For that, a number of parameters of the model
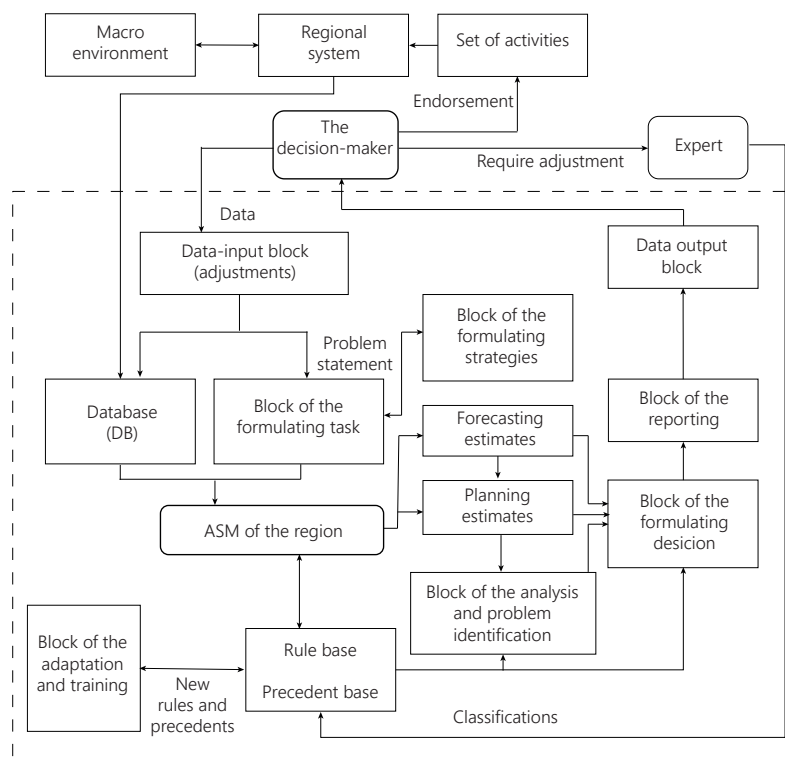
Compiled by the authors on the materials of the study / *Составлено авторами по материалам исследования*

Figure 1. The scheme of DSS organization on the basis of the adaptive simulation model
Рис. 1. Схема организации СППР на базе адаптивно-имитационной модели

determine before the experiment to choose the priorities in the development. In particular, socially oriented, investment-oriented, innovative, complex and other strategies may be identified. Thus, the data-input block is an interface for entering statistical information, controlled and scenario parameters [18].

A set of the above data will be the input information for the adaptive simulation model of the regional system. In this article, we will not dwell on the internal structure of the adaptive model and algorithms for calculating the totals. However, it should be noted, that simulation involves the possibility not only to select the rules of behavior from the existing rule base, but also to adjust the base. Depending on research objectives, this model allows to solve problems as forecasting (forecasting of development of socio and economic system without the use of control algorithms) and planning (taking into account management settings).

At the same time, the problem statement of forming the parameters of innovative development of the region imposes certain requirements on the procedure of the model experiments. Particularly, the determination of the indicator of innovative development of the region is necessary [21; 6]. The researchers note, that in solving this problem the following requirements can be proposed:
• aggregation of a set of multi-dimensional and multi-directional criteria from the point of view of dynamics;
• taking into account the weights of the criteria, the degree of their importance in the integrated assessment;
• formalization of fuzzy concepts for effective analysis of qualitative information as well as clear quantitative data;
• linking the integral indicator with the target priorities of the strategic development of the region, etc. [8].

Forecast and planned estimates are transferred to the block of analysis and problem identification. Various types of analysis (including structural analysis, dynamics analysis, etc.) are carried out within this block. This allows identifying both the problems themselves and the causes of their occurrence. The use of the precedent base allows considering the accumulated experience in the process of developing decisions to new tasks. The basic definition is precedent as a structured representation of the accumulated experience in the form of data and knowledge, that provides its subsequent automated processing with the use of specialized software [7]. The generalized structure of the precedent includes two main components: the identifying part (characterizes the experience), the training part (describes the decisions and their characteristics). On the basis of the data obtained, a set of alternative decisions is formed. They are evaluated according to predetermined criteria.

One of the most important components of DSS is the block of the formulating decision. It is supposed a clas-

sification of situations and comparison with an available base of precedents for a choice of possible ways of the decision within this block. For this purpose, it is advisable to use the methods of fuzzy logic theory. Such an approach allows to monitor the gradual changes in the properties of a management object and also use quality characteristics. However, fuzzy variables are also best suited for planning factors over time, when their future evaluation is difficult. Here, the most important stage is constructing fuzzy set adjectives. These functions describe the semantics of the used basic values of fuzzy and linguistic variables. There ae several methods for constructing membership functions. However, it is necessary to take into account such a feature as the presence of heterogeneous sources of information (enterprises, population, public organizations, state and municipal authorities, etc.) for the development of decision support tools in the field of strategic management of regional development. In addition, the choice of decisions should take into account the specifics of innovative development.

The final phase is the formation of a report on the results of modelling and proposed decisions to the identified problems. It is reasonable to use ready templates of unified reports. Such reports allow the decision-maker to navigate quickly the data received. However, should understand that DSS is only a tool, that allows preparing a decision, but it does not replace the decision-maker for which it has a responsibility [10]. In this regard, an assessment of the data obtained. If the proposed decision is approved, a measure (a set of measures) is developed on its basis. The implementation of the measure leads to a change in the state of the regional system. If the proposed decision is not approved, the databases of rules and precedents will be adjusted with the assistance of the relevant experts and the DSS will be restart.

It is to be noted, that for the decision-maker in the framework of its practical activities the use of DSS should not be associated with the direct setting of individual parameters of the economic and mathematical model, the conduct of mathematical calculations or the study of the features of the mathematical tool of fuzzy logic. Interaction with the system is carried out through the input and output blocks of information through the user graphical interface, and all the internal work of the system is hidden from a user.

In addition to these functional blocks and adaptive simulation model for the use of DSS will also require the development of methodological support for the practical use of the tool, including:
• the methodology of collection and processing of data on the state of the regional socio and economic system;

• the methodology of the experiment with a simulation model of socio and economic development of the region;
• the methodology of the formation of management decisions based on the use of DSS.

In general, the proposed DSS can become a universal tool to provide the DSS with the information necessary for decision-making on the retrospective, current and future state of the regional system, allowing to analyze and identify possible ways to solve the existing problems.

Discussion

This study revealed, that different approaches both to the management of regional development and to the modelling of macroeconomic processes are available today. Nevertheless, the presented models often do not reflect the specificities of innovative development of the regions. The existing approaches have both advantages and disadvantages. However, separately, these approaches are not able to solve fully the problems, that the transition to an innovation economy poses. As a direction of development, the conceptual scheme of DSS in the field of management of innovative development of the region is developed. The stages, that determine the main design features, are identified. The place of the adaptive simulation model in the structure of DSS is determined, based on its capabilities in the formation of estimates of the development of the region and the effectiveness of certain management actions. The description of the key functional blocks of the system and the procedure of the decision formation are also given.

The theoretical importance of research are the developed tools expand the possibility of sharing the methods of management theory, decision support, economic and mathematical methods, computer modelling technologies in solving problems of development management of the territorial socio and economic systems. In addition, software tools are of practical importance. The developed design of the DSS can be used by public authorities to calculate the parameters of the medium-term development of the regions of Russia for the development of social, economic and budgetary policy.

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