

The Concept of Application of Adaptive Simulation Models in the Formulation of Regional Development Strategy

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Abstract—The article deals with the formulation of the regional development strategy. An approach to the justification of the parameters of the economic and mathematical model of the regional system is proposed. This model can be used to predict the socio-economic development of the region. The generalized scheme of the formation of adaptive behavior of the economic agent within the framework of the developed model are offered. The functional scheme of adaptive simulation model of the region is described. This scheme includes blocks of the assessment of a situation, the description of dynamic processes, formation of the balance ratios, the description of certain areas of the life of society, the monitoring, etc. The algorithms for the development of the model core tools and the formation of the regional development strategy are proposed. The preparatory stage, stage of the economic and mathematical model of the parameters of regional management development, stage of the algorithms of determination of the parameters of regional management development, stage of an integration of the received models are identified in the framework of the development of the model core tools. Eight key stages are identified as part of the development of the algorithms for the formation of the regional development strategy. The place of the proposed model tools is determined at each stage.

Keywords—economic and mathematical modeling, region, economic agent, functional scheme, regional development strategies, algorithm of formation strategy, adaptive simulation model.

I. INTRODUCTION

Effective management of the progressive development of the regional socio-economic systems requires fundamental understanding of the occurrences and existing interactions, analysis of the current situation and trends in the system parameters. Despite the experience, practical difficulties remain in this field. These difficulties are caused by the nonconcurrency of objectives by levels, horizons and subjects of management, low level of consistency of implemented economic policy, lack of clarity of the system of analysis and use of information, as well as lack of methodological development of the strategic planning issues [1–3]. One of the most perspective directions in this field is the use of modern technologies based on simulation modeling, which allow to assess the consequence of many different interesting effects. Despite the presence of a significant amount of works on this subject [4], a number of issues relating to both methodological and practical aspects of the formalization of

adaptive mechanisms for congruence of the economic agents (EA) [5] interests remains unresolved.

II. OPERATIONAL CONCEPT OF ADAPTIVE SIMULATION MODEL OF THE REGION

The development of tools of complex justification of the medium-term development strategies of the region is based on understanding as a complicated open socio-economic system in which various economic agents interact. In this regard, the regional socio-economic system (RECS) is modeled as a multilevel [6] and multidimensional system, the most important elements of which, as well as the economic mechanisms that link them, are characterized by special mathematical models (Fig. 1). The adaptive-simulation model (ASM) of the region is proposed to be used as the core of tools. The concept of model construction is based on the gradual adaptation of both behavior of the economic agents and control action to the change of various factors. At the same time, the results of adaptation are factors affecting at the functioning of other economic agents.

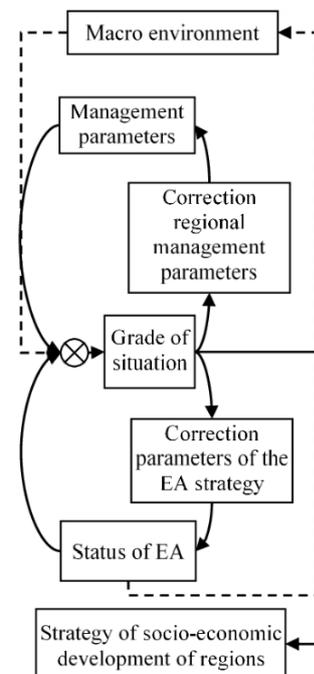


Fig. 1. The aggregated scheme of functioning of ASM of the region

The ASM of the region is a complex of models of functioning of the economic agents which are a part of RSES and interrelations of these agents among with each other and the external environment of the region. By the economic agents we mean the subjects of economic relations, taking part in the production, distribution, exchange and consumption of economic goods [7]. An economic agent is guided by the relevant role interests and makes decisions according to limited set of indicators of macroeconomic environment. In additional point is that the agent has certain expectations [8].

A distinctive feature of the developed model is availability of the decision-making mechanisms by the economic agents in various situations, which reflect the adaptive nature behaviour pattern of the economic agents. Interaction of economic agents within the framework of this approach is a change in the parameter value of some economic agents in response to changing the parameters of other economic agents or the external environment. Behavior of economic agents is formed in the framework of income and expenditure strategy. It is a set of rules of the application of resources in various situations. In general, this approach consists with the idea presented in [9]. Revenue strategy determines agent behavior in obtaining financial resources of the agents. Expenditure strategy determines the use of these resources.

The mechanism of adaptive behavior of the economic agent is a closed contour, which links the factors of behavior, the strategies of economic agents and the results. Four groups of factors are identified: scenario conditions (the parameters set by the macro-environment and not formed in the model itself), the regulators (the parameters set by the management model and representing the regulatory impact), the parameters of other economic agents (the parameters of other economic agents that are essential for this economic agent, included in this system), the parameters of the economic agent (significant for decision-making parameters of this economic agent). The result of functioning of the economic agent is an input parameter for other economic agents and in some cases is transferred to other levels of the model. An iterative mechanism is used to ensure mutual adaptation of the agents. Similar methods are considered by researchers in the framework of the evaluation of the resource base of regional development [10–12].

The generalized scheme of formation of adaptive behavior of the economic agent in the framework of the developed ASM implies a consistent analysis of all adaptable indicators of the economic agents and includes the following sequence of aggregated stages:

- 1) For the i -th indicator ($\forall i=1;ik$), the values of the influencing factors are determined, as well as the value of this indicator;
- 2) Based on the obtained data, the situation class for the i -th indicator from a set of previously defined classes is determined;
- 3) If the class situation means the change of the parameter, then the value of the i -th indicator corrects by the value λ (increase or decrease);
- 4) New data are submitted to the input of the economic and mathematical model, and it is recalculated;

5) At the end of the recalculation, counter i takes the value l and returns to the first stage;

6) If the situation class does not imply changes, then the value of the i -th indicator remains unchanged. If the i -th indicator was the last one to be adapted, then the matching algorithm is completed, and data about the parameters of the socio-economic system are transferred to the management level. If this indicator was not the last (i.e. $i < ik$), then the transition to the next indicator $i=i+1$ and return to the first step takes place;

7) Thus, the presented algorithm provides a consistent adaptation of all interacting economic agents in all parameters that require adaptation.

III. FUNCTIONAL FRAMEWORK OF THE MODEL

Development ASM of the region based on the proposed modeling concept implies the formation of two circuits of the adaptation mechanism (adaptation of behavior of the economic agents and adaptation of the control subsystem) as shown in Fig. 2.

The management model within the framework of the developed functional scheme describes regional management. It includes three key blocks – the block of correcting targets, the block of correcting control action, the block of determining the rules of adaptation of the control system. The block of correcting targets is meant to formation and correcting the parameters of the indicative plan. It is based on the application of fuzzy logic methods implemented within the framework of the fuzzy inference module. The block correcting of control action provides the formation of the control parameters based on behavior in the ASM of the region. The basis of a choice of the behavior strategy is the classification of situations defined by the line of the indicative plan, observed values of the indicative plan and resource capabilities of the management system. Thus, the general correcting of the parameters of the control system is set by means of feedback based on changes in the parameters of the model of the economic agents functioning at the regional system.

The impact of the management system on the functioning of economic agents is realized through a system of parameters.

IV. ALGORITHM FOR THE DEVELOPMENT ASM OF THE REGION

Algorithm for the development of the model core of the tools for justification of the medium-term development strategies of the region includes a number of aggregated stages:

1) *The preparatory stage.*

The preliminary substage. The goals and objectives of the use of tools justification of the medium-term development strategies of the region, its purpose, limitations are determined. The boundaries of modeling, forecasting, and planning, granularity, and assumptions are determined.

The internal architecture of the tools for justification of the medium-term development strategies of the region, and the class of the used model [13], and the structure of the model, and other internal parameters of the tools, and the

development of the concept of formulation an adaptive-simulation model of the region are determined.

Databases are formed. The structure and amount of data required to develop the model are determined. Data are requested, obtained, sorted, and the initial information base is formed.

2) *The economic and mathematical model of the economic agents functioning is developed.* This stage involves the analysis of data and identification of dependencies, the structural analysis of processes, the formation of rules of economic agents' behavior, the construction of information and logical model of the regional socio-economic system. The formalization of a complex real process is carried out by decomposing into

subprocesses that perform certain functions and have functional connection. Thus, the information-logical scheme of the ASM of the region is formed. The next step is the mathematical formalization and verification of the adequacy of the interrelationships.

3) The algorithms of determination of the parameters of regional management development based on the selection of a preferred development strategy with application of methods of fuzzy logic is developed;

4) There is an integration of the received models of functioning of the economic agents in the regional system and the models of determination of the parameters of the regional

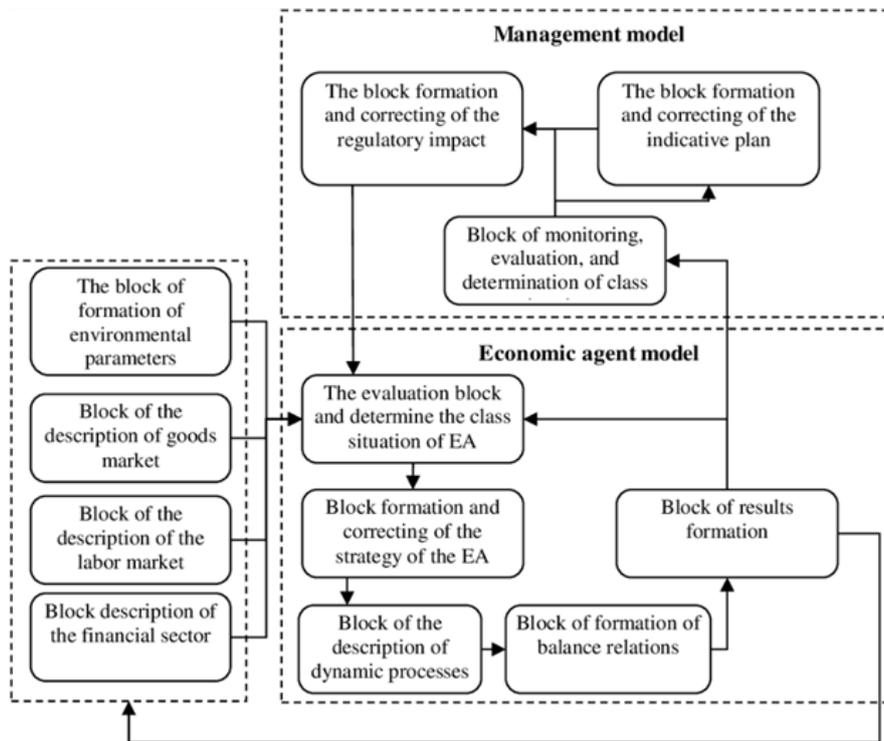


Fig. 2. Functional scheme of the regional model

management development taking into account mutual adaptation of these levels.

V. INTEGRATION THE ASM OF THE REGION IN THE PROCESS OF FORMATION OF THE REGIONAL DEVELOPMENT STRATEGY

The subsequent use of the ASM of the region assumes possibility of correcting the tools, which to some extent is a continuation of the development stage and, accordingly, implies a partial repetition of the algorithm presented above. In general, the process of determining the parameters of the regional development strategy with the use of the proposed approach is based on the formation of the forecast of territorial socio-economic development in the conditions of adaptive behavior of stakeholders and, accordingly, the integration of the ASM of the regional system into the existing algorithm of the formation of the regional development strategy. This process includes the following steps.

1) *The preparatory stage includes a number of substages: the formulation problem, the organizational support, the information collection, the preliminary analysis.* Substage of the formulation problem involves developing requirements of the strategy, the determination of the action, the determination of key parameters (including the period of implementation of the strategy, the level of detail of activities, breadth of coverage living environment, etc.). Further, the collection and analysis of data on the state and development trends of the regional system, as well as the influencing factors are carried out.

2) *The analytical stage is necessary to determine the current state and development trends of the regional socio-economic system.* Within the framework of this stage, the possibilities of the region in various fields, including natural resource, production, human resources, financial and other potentials are analyzed [14]. It involves structural analysis,

comparative analysis, SWOT analysis, study of the dynamics of indicators, analysis of the individual spheres of society, analysis of the competitive advantages, identification of the key problems and threats to development [15]. Based on the obtained results, the problems of regional development, i.e. the deterioration of the situation (the discrepancy of some parameter to the normative value) or the presence of unused potential for the development of the region are identified.

The integration of the proposed ASM of the region into the strategy development procedure implies, in particular, formation at the analytical stage of the basic version of the forecast of changes in the main macroeconomic parameters of the region while maintaining the initial values of the vector of control actions.

3) *Scenario-target stage involves formation of the benchmarks of development of the regional system in the future.* That is the criteria for the target state of the system are determined. The stage includes three major components –determination of priority areas of the development, formation (correcting) of the indicative plan, determination of the parameters of the control actions (formation and correcting of the vector of the control action).

Immediate quantitative determination of target parameters is expressed in formation of the indicative plan of the regional development. The indicative plan represents a set values of indicators at the end of the strategy implementation, as well as intermediate values at the end of each time interval.

Within the framework of the scenario-target stage, formulation of scenarios for the evolving situations, as well as the identification of priority areas for the development of the region, the formation of goals, the indicative plan, its correcting and resource capabilities of the management system are carried out.

4) *Regulatory stage.* A vector of the control actions is formed based on a set of target indicator values in the model. This vector focused on correcting the current values of the indicators in order to minimize the lag and maximize the achievement of each of the indicators.

From a practical perspective, to achieve the values of the regulators defined in the ASM, for each of the selected areas an interrelated set of measures is formed to ensure the correcting of the control parameters. It should be noted that the development strategy defines only an integrated action plan and, as against development programs and other documents of a lower level, should not be a set of business plans of individual measures. On the other hand, as a document of a higher level, the strategy of regional development should cover a wide range of areas, including improving the competitiveness of the economy in various spheres of the production, improving infrastructure, improving the level and quality of life.

For the purpose of implementation of the developed set of measures at this stage, the volumes, sources and terms of formation of resource support are determined. First of all, it is meant to determine the volume and sources of financial resources necessary for the implementation of the strategy.

5) *Stage of assessment of the parameters of social and economic system.* At this stage, the parameters of the regional system development are determined. The correcting of controlled parameters of the economic agents and the formation of the vectors of output parameters of the economic agents is carried out. A set of monitored indicators is formed and transferred to the management level.

The expected effect is estimated based on the results of forecasting changes in the key parameters of socio-economic development of the region. The result of modeling is a set of development pathway of the regional system with specific values of the main parameters at certain stages of development, as well as a list of impacts that need to be implemented to achieve this goal.

On the basis of the obtained results, projects of social and economic development of the region for the medium term are formed. At the same time, the use of the simulation model allows to coordinate actions of different authorities. The importance of this objective is noted by a lot of domestic and foreign experts [16,17]. The implementation of these projects will lead to changes in socio-economic situation, control of which is carried out during the monitoring. Thus, the analysis of the decision consequences can be implemented at the stage of their development, which will improve the efficiency of the management.

The estimation of RSES parameters is based on a complex of simulation experiments. This stage includes determining the input and output coordinates of the economic agents, achieving a dynamic balance between supply and demand in the market of goods and the labor market, the monitoring of the indicators, and the transferring their values to the level of management. Based on the results of calculations, the forecast of parameters is formed in each of the periods.

6) *The institutional and management stage is the development of the management system and the implementation of the strategy.* The organizational and role structure is formed, the main processes of management are distinguished, and areas of responsibility and authority are delimited. The possibility and mechanism of subsequent adjustment of the strategy is determined.

7) *Final stage.* The final stage of the development of the regional development strategy is coordination and approval by the relevant public authorities (representative agency of constituent territory of the Russian Federation). At the same time, public hearings may be held. It seems appropriate to carry out intermediate coordination of certain parameters of the strategy at different stages of development. This stage is organizational and does not involve the active involvement of the developed ASM of the region.

8) *Monitoring and correcting stage.* During the implementation of the strategy, changes in the values of the selected indicators are monitored. Depending on the specifics of the management tasks, and the characteristics of the parameters, the frequency of updates may be different. The analysis of compliance of benchmarks and values of

indicators obtained as a result of the monitoring, the procedure of which can also be described with the use of model complexes, is carried out. In the presence of deviations, the priority is to identify their causes. For this purpose, causation and incidence of events and phenomena that influenced the state of the managed object are considered. The next step is to analyze the possible consequences of such deviations. If there is a “positive” deviation, the measures are developed to consolidate the result [18]. First problem in case of detection of “negative” deviation is getting the return indicators in the area of allowable values, i.e. reduction to the normative values. Such correcting requires changes in the parameters of the adaptive simulation model. At the stage of correcting, the initial parameters of the system state are revised, and a set of stages presented above is performed. Recalculation of the strategy parameters in terms of the indicators and expected results seems appropriate to be carried out yearly.

Thus, the proposed tools to justify of the medium-term development strategies of the region based on adaptive simulation modeling can be used at most stages of the process of developing medium-term strategies for regional development.

The allocated functionality determines the place of the ASM in the management process at the regional level and defines this model as an auxiliary tool in the development of the strategy. It does not replace the activities of specialists but increases the effectiveness of this activity.

VI. CONCLUSION

In the framework of the study the following results were obtained:

- The generalized scheme of the formation of adaptive behavior of the economic agent within the framework of the developed ASM is proposed;
- The functional scheme of the ASM of the region is proposed;
- The algorithm for the development of the model core tools for justification of strategies at medium-term development of the region is proposed;
- The algorithm for the formation of the forecast of social and economic development of the territory in the conditions of adaptive behavior of stakeholders is proposed.

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