APPLICATION OF SCENARIO METHODS IN MULTI-ACTOR MANAGEMENT OF REGIONAL DEVELOPMENT

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Abstract. This paper considers the application of scenario methods in multi-actor regional management to investigate and assess challenges in improving the effectiveness of managerial decision-making for sustainable and coordinated development under uncertainty and the impact of various destructive factors. The object of this study is an information and analytical support system for regional management. The aim of this study is to apply the scenario approach in order to form and justify a set of effectiveness assessment criteria for multi-actor regional management scenarios. The criteria are formed by analyzing the results of simulation modeling, encompassing both the event-level scenario descriptions and their closeness to given parameters of a target scenario. Using the mathematical apparatus of signed directed graphs, a comprehensive scenario-event simulation model of multi-actor regional management is developed. This model is intended to analyze and assess various management strategies with multiple actors, as well as to forecast the consequences of implementing these strategies. Based on the conducted research using the scenario-event model, scenarios of regional dynamics and their individual components are obtained. These scenarios are employed to identify key trends and factors influencing the stability and effectiveness of regional system management under growing external and internal threats. According to the scenario analysis results (the event-by-event encoding of event sequences and closeness to target parameters), the preferred management strategy based on the scenario analysis and situation forecasting in a rapidly changing environment is to shift the decision center to the state, possessing the greatest number of capabilities and influence mechanisms. This strategy shall be implemented on the principles of multi-actor management, relying on the coordination of actors to reduce the impact of external destructive effects from potential and existing adversaries and maintain socio-economic processes and stability in the region. When selecting a management strategy, one should keep in mind that incentive mechanisms for economic actors contribute to the prevention of conflicts and a uniform distribution of existing management capabilities and resources within the regional system.

Keywords: multi-actor management, simulation modeling, scenario analysis, regional security, effectiveness assessment, event encoding.

INTRODUCTION

In the context of modern regional development, an effective management strategy has become a key factor in ensuring stability (sustainability) and security. Due to its unique systemic nature, the concept of multi-actor regional management represents a complex system that integrates economic, political, legal, organizational and managerial, socio-demographic, and scientific and technical spheres [1]. This concept characterizes a cooperative form of regional management: strategic decisions are made jointly by several actors (primarily the state and the private sector). Its topicality is of increased significance in current conditions, where regional development tasks have become complex, and the environment exhibits intensive dynamics and uncertainty. Most approaches to studying the problems of strategic regional management fall within the realm of systems analysis, which includes an assessment of external conditions, regional specifics, and prospects for expanding management capabilities [2, 3]. From an applied perspective, the main problems are the absence of the following elements:

– clear scenario criteria and methods for defining management strategies,

– assessments for the effectiveness of management strategies, and

– a formalized representation of scenario models, methods, and algorithms to model multi-actor management processes.

These problems complicate the processes of coordinating and redistributing control actions between various regional actors, as well as forecasting and assessing their consequences. Conventional modeling methods (linear programming and balance models) assume complete information about a complex system, therefore proving inefficient in a complex and adaptive environment. Contemporary challenges, such as uncertainty, risks, external threats, and destructive impacts, require a shift toward hybrid models (e.g., scenario planning), which account for data incompleteness and the nonlinearity of processes.

Within the theory of scenario planning and forecasting, a scenario is rarely treated as a formalized sequence of unique events, which significantly limits the possibilities for an objective assessment of its effectiveness. This approach is particularly necessary in multistage scenario models, which reveal paradoxical dynamics of deviations: the initial deviations from a target scenario may be temporarily compensated for by stabilizing mechanisms, but in the final stages, even minor accumulated errors possibly cause qualitative changes in the evolution trajectory of both individual key factors and the entire system. The absence of formalized criteria and methodologies for event-by-event scenario assessment makes data interpretations subjective and hinders the process of making well-justified decisions based on scenario modeling. Let us define the key concepts.

A *state* is a set of current values of factor parameters that are significant for a system.

An *event* is a change in the state of one or more factors; a transition between states is supposed to be instantaneous.

An *object's behavior scenario* is a model of changes in the current conditions due to the emergence and development of a particular situation (a sequence of events) defined in a discrete time space with a given time step.

The aim of this paper is to form and justify a set of effectiveness assessment criteria for scenarios obtained through simulation modeling of multi-actor regional management processes, based on an analysis of their event-by-event representation and closeness (similarity) to the specified parameters of a target scenario. To achieve this aim, we solve the following tasks:

– identify possible criteria for assessing the effectiveness of multi-actor regional management scenarios;

– form a system for assessing the similarity of given scenarios to target ones under fixed management strategies;

– perform scenario simulation modeling of the strategies under consideration;

– analyze the results based on scenario-event identification and pairwise comparison of the generated scenarios with the target one.

1. SCENARIO METHODS FOR REGIONAL MANAGEMENT

1.1. The Organizational Structure of Regional Management

The organizational structure of regional management is a complex system of interaction between several actors making managerial decisions at various hierarchical levels. Based on their permanent and situational socioeconomic and organizational links, it is intended to achieve the common goals of the actors. This system involves stable socioeconomic links and situational factors determined by the strategic tasks, methods, tools, resources, and capabilities of each actor [4, 5].

Below, we focus on public actors (represented at the level of the state as a decision center and at the level of regional authorities) and private actors (in the form of private businesses), as well as their relationships and interaction during management and goal achievement. In the process of making managerial decisions at the regional level, geographically determined links are of particular significance: those between economic clusters, infrastructure systems, natural resources, and demographic groups. These links are not direct but reciprocal. At the regional level, the effect of such feedback is most pronounced due to limited resources, the heterogeneity of territories, and the high interdependence between industries and the population. Regional management requires a systematic approach considering the territory's internal social and economic features and its interaction with external levels (federal, interregional, and global).

Such an analysis aims at identifying the key goals, interests, vulnerabilities, and capabilities of management, which is fundamental to form a comprehensive and strategically justified concept.

The application of forecasting methods within a systems approach facilitates the development of preventive strategies oriented to minimize potential threats and risks.

Integrating this approach into management ensures forming a complex and adaptive decision system capable of effectively responding to changes in external and internal conditions.

Let us describe the capabilities and interests of actors in detail (Table 1), based on an analysis of the state-level strategic documents [6–9], including national projects, regional socio-economic development strategies, and public-private partnership (PPP) documents [10, 11]. Here, we identify the interests of the state and private business (strategic goals, development priorities, expectations from PPPs) and their capabilities (the resource and institutional bases of both parties, as well as their organizational potential to participate in regional development). This approach clearly associates strategic goals with available management capabilities and allows passing to interaction mechanisms between the state and private actors in achieving regional management goals.

Note that the list below does not claim to be exhaustive. We deliberately limit the analysis to the most relevant factors that directly influence the objectives of this study and significantly contribute to management dynamics.

1.2. Regional Security Management Based on Scenario Methods

Regional management is carried out at three levels: strategic, tactical, and operational.

Strategic management is the process of establishing the long-term goals and tasks of an organization and making fundamental decisions, possibly including restructuring or optimizing a current system. This level of management is intended to analyze external and internal factors influencing a regional system and elaborate long-term plans and development strategies.

Table 1

The interests and capabilities of the state and private business

	State	Private business
Interests	• Updating the strategic regional management system. • Developing the regional transportation, energy, and social infrastructure. • Optimizing the management of state-owned natural resources and land reserves. • Applying innovations in management and industry to enhance the region’s competitiveness. • Reducing risks in regional projects, informing the business community, and increasing revenue from state assets. • Improving the quality of life for the population, enhancing the quality of education, and creating jobs. • Maintaining economic, political, and social stability	• Concluding long-term contracts for the operation of state-owned objects and facilities, generating stable income, and ensuring a return on investment. • Participating in key infrastructure projects to expand business operations. • Coordinating regional development plans with state programs and collaborating with reliable partners, with the state acting as a guarantor. • Attracting budgetary funds for joint investments and sharing risks with the state. • Participating in security projects to support stable business development
Capabilities	• Establishing a legal environment and state policy (creating a favorable legal and legislative framework, including tax incentives, preferential treatment, and subsidies, which are important for economic growth). • Managing state property (applying state mechanisms for the redistribution of property, such as the transfer of assets for management and lease, which are important for the effective use of assets and attraction of private investment). • Maintaining institutions and the social sphere (developing social agencies, business support centers, and skill programs). • Maintaining regional security (federal and regional authorities, as well as armed forces for local security, which is essential for stable development). • Maintaining interregional cooperation (developing interregional links to promote economic integration and the exchange of experience and resources). • Supporting science and innovation (implementing the results of cutting-edge scientific research, innovations, and modern management methods)	• Attracting private investment, bank funding, and project funding. • Implementing innovations, developing new technologies and business models, and improving project lifecycle management using skills and expertise. • Creating jobs and training new specialists. • Influencing the region’s social and economic processes and participating in the formation of its priorities. • Maintaining flexibility in decision-making, collaborating with other companies in clusters and industry consortia. • Providing state guarantees of business support under uncertainty and active disruptive impacts

Tactical management focuses on implementing particular control actions for achieving the established strategic goals. At this level, operational planning and resource coordination are carried out to solve short- and medium-term tasks, thereby ensuring steady progress toward strategic landmarks.

Operational management deals with current and urgent problems arising within a regional system. This level of management is characterized by a high degree of adaptability and flexibility, as it requires a prompt response to changes in internal and external conditions.

In this paper, regional management is viewed as a complex set of control methods, principles, and tools for a targeted and systematic influence of multiple actors on social and economic processes and other aspects of regional development. This system coordinates the control of various actors in pursuit of strategic goals for stability (sustainability) and security. Important tasks include improving the quality of life for the population and ensuring political stability and regional security.

Figure 1 presents the block diagram of multi-actor management based on scenario methods. The diagram describes the management process carried out by several actors: considering the goals, available control apparatus, and existing resources, the actors ensure regional security by determining their capabilities and developing scenario alternatives based on forecasting the consequences of their control actions, in order to select the most effective management option for the controlled object.

Strategic management is a purposeful systemic transformation process for the managerial potential of actors based on coordinating and optimizing three interrelated subsystems: goal-setting, resource provision, and control apparatus. Its essence lies in the transition from a reactive response model to a proactive strategy for shaping the evolution trajectory. The development of scenario methods for regional management at the strategic level has two main tasks:

– ensuring the security of the controlled object,

– identifying and activating new management capabilities adapted to current conditions and the environment.

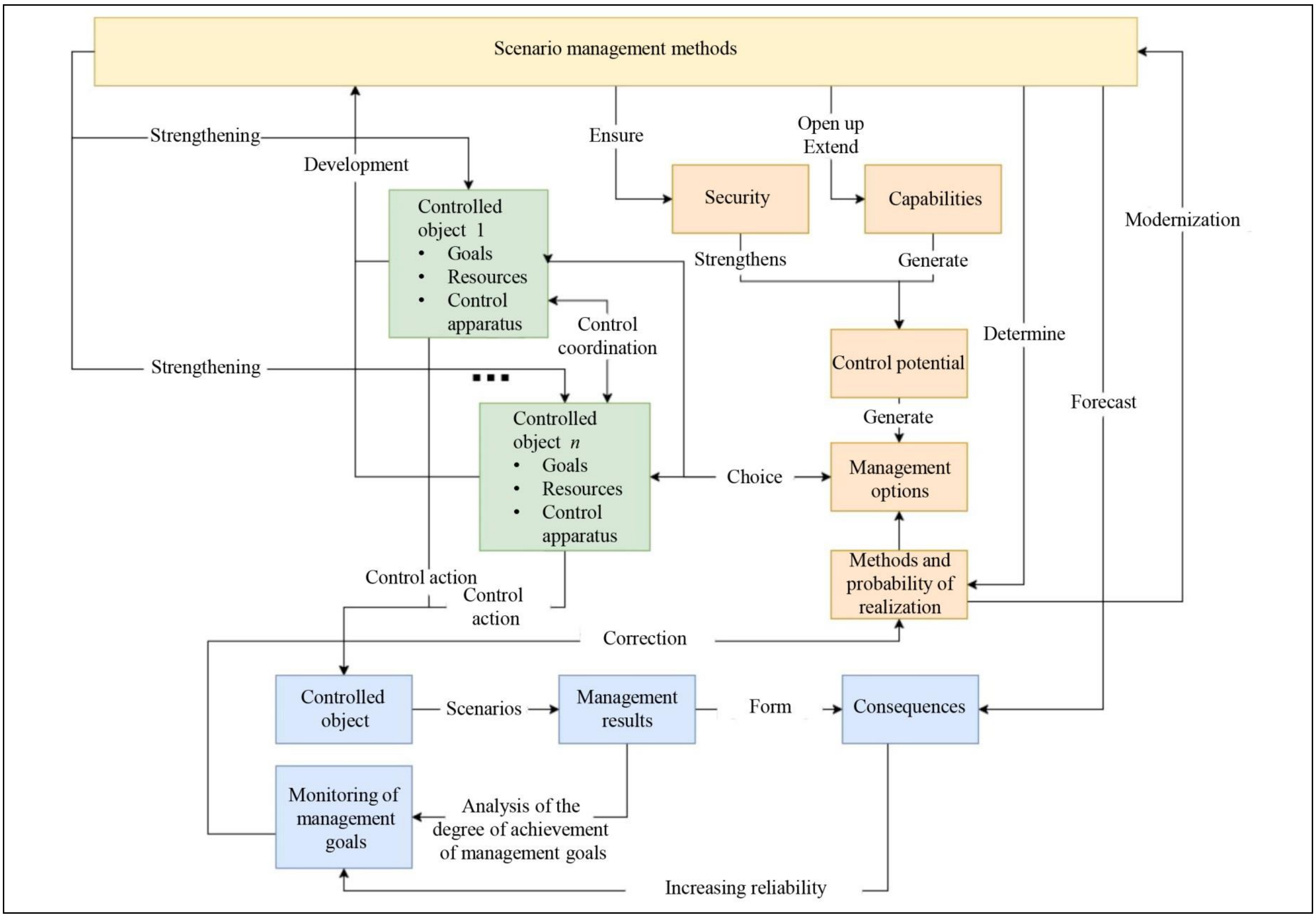


Fig. 1. The structural diagram of multi-actor management based on scenario methods.

Thus, managerial potential is formed—a systemic characteristic reflecting the aggregate capability of actors to influence the controlled object to varying degrees, select management options, and assess the implementability of these options by determining available control methods and the probability of their successful implementation. After assessing management options, forecasting the results of their implementation, and analyzing possible situation scenarios, an actor decides on the optimal option. The final choice is based on comparing the expected effectiveness of each scenario in terms of achieving management goals.

The diagram also illustrates the interrelated nature of management processes: the current information on the results of control actions is supplied to the goal monitoring unit, which implements the feedback function:

– tracks the actual implementation of managerial decisions,

– identifies deviations from planned indicators,

– and serves as the basis for correcting management methods.

The consequences of control actions (the planned ones and those that actually arise during implementation) are analyzed to verify the reliability of monitoring procedures and enhance the justifiability of managerial decisions. Thus, a closed control loop is formed. This loop ensures the continuous improvement of the management system through:

– promptly adapting the methods to changing conditions,

– gradually improving the accuracy of forecasting, and

– and reducing uncertainty during decision-making.

1.3. Effectiveness Indicators of Regional Management

For an objective and accurate analysis of the effectiveness of regional management, especially in the context of interaction between the state and the private sector, a system of regional development criteria (indicators) is needed to reflect the country's key goals and priorities. Such criteria should cover various aspects, including national security, economic modernization, social support improvement, and infrastructure development. By analyzing the strategic documents [6–8, 12] and several relevant studies and related literature [1, 3, 13–15], we identify the following indicators to develop a scenario simulation model of multi-actor regional management:

- **Social and economic development**: an increase in gross regional product (GRP), growth in the volume of exports and investments, a decrease in the unemployment rate, population growth, and a reduction in migration.
- **The quality of social infrastructure**: accessibility of healthcare, housing, and social and legal support.
- **The region's investment appeal**: improving the region's profitability.
- **Goal-setting and strategic planning**: the effectiveness of the administrative and institutional apparatus, and the existence of a development strategy, plans, and indicators.
- **Regional infrastructure development**: the condition of roads, water supply, and energy supply.
- **The regional level of satisfaction with the work of public authorities**: the level of trust in public authorities, support in the media.
- **The quality of managerial decisions**: justifiability, timeliness, and effectiveness.
- **The level of innovation**: adoption of new technologies, development of science and education.
- **Regional security**: preparedness for emergencies, adaptability to changes, and flexibility in budgetary and management policies.

In the author's view, these factors comprehensively influence the region's stability and development and should be used to construct a scenario model of regional security. They cover key spheres determining the region's ability to withstand threats and adapt to changes. Note that all indicators in a scenario model are considered only in qualitative terms: only the type of their dynamics (increase, decrease, fluctuations, etc.) is important for forming scenario events. Consequently, the dynamics of factors from statistical data on regional development indicators and expert data can both be used for modeling. The model below is used without reference to a particular region to illustrate the applicability of the scenario approach in regional management. In future studies of particular regions, no doubt, one should use existing statistical data and additional parameters of the model's factor dynamics, including the rate of change in their characteristics. Let us briefly describe the model's factors in the context of this study.

Economic growth underlies the sustainable development of a region, creating a resource base for addressing social issues, enhancing the region's investment attractiveness, and updating critical infrastructure facilities.

The quality of social infrastructure affects the population's standard of living; insufficient quality may cause social tension and reduce trust in public authorities.

Investment attractiveness determines the interest of actors in the region's development and the level of capital inflows. Traditionally, gross regional product (GRP) per capita, household income levels, and return on business assets are commonly used regional profitability indicators. In this paper, the profitability factor is considered in qualitative terms (the direction of its change): an increase in profitability promotes the long-term growth of the region's investment attractiveness and reduces its dependence on external factors and destructive impacts. Thus, the region's profitability is treated as a qualitative parameter whose dynamics influence, directly or indirectly, the formation of events in simulation scenarios.

Goal-setting and strategic planning reflect the degree of effectiveness in managerial decision-making. The weak development of institutional mechanisms may cause the inefficient use of resources and increase strategic planning risks.

The development of regional infrastructure is the foundation of the social and economic development of a region. Insufficient or deteriorated infrastructure limits the region's capabilities to attract investment and satisfy the needs of the population. Here, we analyze only the qualitative impact of this factor on the region's development—specifically, as a change in its condition. An increase or decrease in the value of this indicator (depending on funding) has a positive or negative effect on the region's development prospects.

The level of innovation is a source factor for enhancing the region's competitiveness and reducing its dependence on other regions, thereby contributing to economic diversification. In the paper, this factor demonstrates the development of science (the creation of new technologies and management methods) and educational programs for training qualified personnel; and the introduction of new technologies into manufacturing and agriculture to improve their efficiency.

Regional security reflects the capability of regional authorities to counter external and internal threats and challenges, including emergencies, destructive impacts of potential and existing adversaries, and flexible responses to changes in the economic, social, and political environment.

Finally, we emphasize that the above list of factors is of fundamental nature. However, when considering particular regional conditions, one may need to expand this list by additional factors and features.

1.4. Scenario Simulation Modeling in the Management of Regional Systems

Among the tools for developing and analyzing alternative scenarios for the functioning of complex socioeconomic systems at the regional level, simulation modeling plays a significant role. Based on computer modeling and simulation, this method enables an in-depth analysis of the dynamics of ongoing processes and the identification of potential risks and sources of uncertainty; it serves as a foundation for making well-justified managerial decisions and ensuring the sustainable development of regional systems in a rapidly changing environment.

Simulation models have a complex structure, including sets of endogenous and exogenous factors and their relationships. Endogenous factors represent the internal processes and characteristics of a regional system, while exogenous ones reflect external impacts from potential and existing adversaries, political conditions, social changes, and other factors. The relationships between these elements allow simulating the system's evolution and forecasting its behavior in various scenarios.

In the simulation modeling of regional development, a key element is analysis based on formalized methods for building models and generating scenarios of their behavior under various conditions. Scenario models help forecast the consequences of different managerial decisions, identify external and internal threats, and mitigate risks [16–18].

The scenario approach to multi-actor management under consideration involves several actors as an additional resource. The ability to determine their exclusive or cooperative participation in a changing environment allows developing complex regional management strategies. The problem-solving procedure includes two main stages as follows.

1. Identifying an appropriate actor that possesses the necessary resources and potential to form and implement control actions for a secure or target scenario in the current or forecasted situation. This stage is a major aspect of the strategic analysis and planning discussed in the paper.

2. Identifying particular control actions for the selected actor to achieve the target scenario.

The proposed strategies must be elaborated by analyzing current risks and factors of uncertainty in order to minimize (or completely neutralize) potential threats and achieve the target scenario for the situation's development [16, 19].

As part of this study, we carried out the scenario simulation of regional security management with several strategies; the control loop included an algorithm for assessing the effectiveness of scenarios by their comparison with a target counterpart. For this purpose, we applied *Polyus*, a special program-analytical complex (PAC) for simulation modeling with a Russian-language interface developed at the Trapeznikov Institute of Control Sciences, the Russian Academy of Sciences.

Figure 2 presents the block diagram of the scenario simulation procedure for regional management.

Based on the modeling data, we developed a set of the following criteria for assessing the effectiveness of the scenarios associated with the management strategies:

– the degree of coordination between the control actions of different actors;

– the degree of relevance to the ultimate management goals (closeness to target parameters);

– the degree of deviation from a target trajectory (the degree of similarity to a target (secure) scenario);

– resource and time constraints.

2. REGIONAL SECURITY MANAGEMENT

2.1. Mathematical Formulation of the Problem

Let us define a set of regional actors: $Sm = \{Sm^j\},\ j = 1, N^{Sm}$.

To describe a regional system *S*, we introduce the following basic parameters:

– the vector of endogenous variables $y \in Y$, characterizing the state space of factors and states of the object *S*;

– the vector of exogenous variables $x \in X$, characterizing the state space of factors and states of the environment of the system *S*;

– the vector of controlled variables for each actor $Sm^j : u^j \in U^j \in U$;

– the vector of allocated resources for each actor $Sm^j : p^j \in P^j \in P$.

The extended state space $z = Y \cup X$ is the union of the state spaces of the factors and states of the object *S* and its environment.

To consider the possible evolution of the system *S* (the environment (situation) and/or the behavioral dynamics of the controlled object), in this paper, we use situation development alternatives described and analyzed via scenarios.

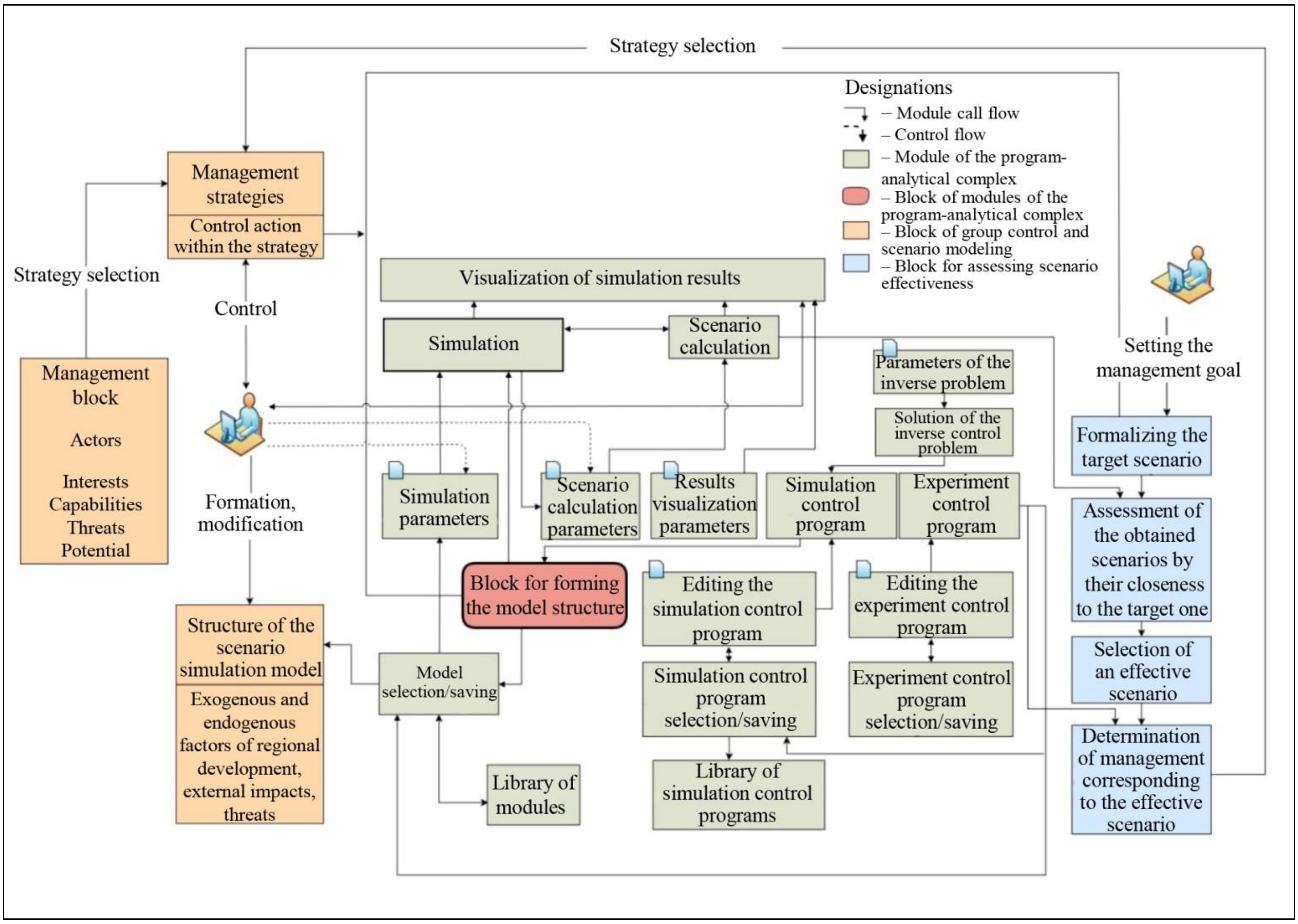


Fig. 2. The block diagram of scenario simulation modeling of regional management.

The simulation models proposed are based on a complex set of indicators and their relationships that adequately describes the state and dynamics of the regional system, including both the actors and controlled objects. This approach ensures the most accurate consideration of external factors influencing the functioning and development of the regional system, which significantly improves the accuracy and relevance of the simulation results.

Let $G(V, E)$ be the structure of the scenario simulation model of the system S, where V and E denote finite sets of factors (graph vertices) and relationships between them (graph edges), respectively.

We assign to each vertex a parameter, i.e., a variable characterizing its state at the ith simulation step: $v_i \in V$, $i = 1, 2, \ldots$

Within the scenario-event approach, the identified dynamics type of a given factor requiring the establishment (correction) of an indirect relationship during the simulation process will be treated as an *event*; accordingly, such a relationship will be called a *scenario-event relationship*. For brevity, factor dynamics will refer to the nature of a temporal dependence of changes in factor values during the simulation process.

Let events be defined through changes in the behavioral dynamics of a set of significant factors for situation analysis and management: $V^{(\mathrm{sig})} \subseteq V = \{v_n\}$, $n = 1, 2, \ldots, N$, where N is the number of factors (vertices) in the model G. Then an event at the ith step t_i is a function of the behavioral dynamics of the significant factors for the formation of this event: $E^{(\mathrm{sig})}(t_i) = f\left(FSc(v_n, t_i)\right)$, $v_n \in V^{(\mathrm{sig})}$, $n = 1, 2, \ldots, N$, $i = 1, 2, \ldots$

A scenario $FSc(v_n, t_i)$ is a type of prevailing dynamics (increase, decrease, fluctuations with bounded amplitude, constant value, divergent or convergent fluctuations) of a factor v on a given discrete-time interval Δt, measured in simulation steps. Essentially, a scenario is a variable reflecting the nature of temporal changes in a given factor of the scenario model; it takes integer values corresponding to a basic type of factor dynamics (Table 2) on a certain time interval of the simulation process. Therefore, for each nth factor, the corresponding identifier $FSc(v_n, t_i)$ of its current dynamics is determined during the simulation.

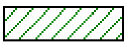
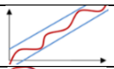
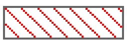
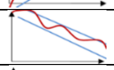
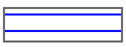
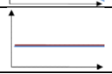
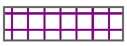
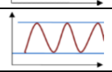
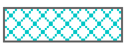
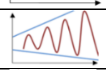
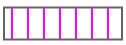
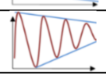
Let $Z = Z^{(\mathrm{nav})}(t) \cup Z^{(\mathrm{sec})}(t)$ be the set of extended states of system S in the state space z, where $Z^{(\mathrm{nav})}(t)$ and $Z^{(\mathrm{sec})}(t)$ are the sets of inadmissible and secure states, respectively, at a time instant t. We denote by $Z^{(\mathrm{tar})}(t) \subseteq Z^{(\mathrm{sec})}(t)$ the set of target (desired) states of system S.

Scenario management is based on a set of control capabilities, risks, and vulnerabilities influencing goal achievement, i.e., the system S being in the state $Z^{(\mathrm{tar})}(t)$ or $Z^{(\mathrm{sec})}(t)$.

In this paper, vulnerability is understood as the degree to which system S is exposed to destructive impacts causing a deviation from the management goal.

Table 2

The identifiers of factor dynamics

The value of scenario $FSc(v_n, t_i)$	Designation	The dynamics of model factors	The dynamics type of factor i	Default name
0		–	Not defined (not calculated)	Not defined
1			Increase	Increases
2			Decrease	Decreases
3			Constant value	Constant
4			Fluctuations with bounded amplitude	Stable state
5			Divergent fluctuations	Unstable
6			Convergent fluctuations	Stabilizes

Let a scenario $\mathfrak{R}(t)$ of the system's behavior be defined as a set of control-significant events $\left\{E^{(\text{sig})}(t_i)\right\}$, $i=0,1,\dots,N$, $t_0=0$, at discrete time instants on the set Z:

$$\mathfrak{R}(t)=\mathfrak{R}\left\{E^{(\text{sig})}(t_i)=f\left(Z(t)\right),\ (t-t_r)\le t_i\le t\right\},$$

where t_r is the depth of this scenario.

By analogy, we define a target scenario of the system's behavior as

$$\mathfrak{R}^{(\text{tar})}(t)=\mathfrak{R}\left\{E^{(\text{sig})}(t_i)=f\left(Z^{(\text{tar})}(t)\right),(t-t_r)\le t_i\le t\right\},$$

and a secure scenario as

$$\mathfrak{R}^{(\text{sec})}(t)=\mathfrak{R}\left\{E^{(\text{sig})}(t_i)=f\left(Z^{(\text{sec})}(t)\right),(t-t_r)\le t_i\le t\right\}.$$

For each ith actor and all uncontrollable factors $\zeta^j\in\Gamma^j$, it is necessary to determine a management strategy $Sm^j\in Sm$ and a control action $u^j\in U^j$ such that

$$\theta=\left(z,\zeta^j,u^j\right)M^{\Im j}\in Z^{(\text{tar})},\theta=\left(z,\zeta^j,u^j\right)M^{\Im j}\in Z^{(\text{sec})}:$$
$$\{u|\theta=\left(z,\zeta^j,u^j\right)\in Z^{(\text{tar})}\vee\theta\left(z,\zeta^j,u^j\right)\in Z^{(\text{sec})}\}$$

when implementing scenarios $\mathfrak{R}^{(\text{tar})}$ or $\mathfrak{R}^{(\text{sec})}$, where $\theta=Z\times S^{(\text{cs})}$ is a forecast of possible transitions of system S to the next state, and $M^{\Im}\subseteq Z$ is the set of possible events (states).

To assess the effectiveness of a selected strategy, the **problem** is to determine the closeness (similarity) of scenarios $\mathfrak{R}^{(\text{tar})}(t)$ and $\mathfrak{R}^j(t)$ based on the similarity of event sequences, where $\mathfrak{R}^j(t)$ is the jth scenario from the set of resulting scenarios.

2.2. Solution of the Problem

When assessing the effectiveness of scenarios, the following parameters (Fig. 3) are introduced to calculate scenario events [20]:

$p(t)$, the calculation or update period for factor dynamics (the simulation of decision processes) in simulation steps; this parameter specifies the frequency of event monitoring (event diagnosis during the simulation process, i.e., the detection and identification of the dynamics of factor values from a given subset; see the definitions above);

$k^{FSc}(t)$, the number of simulation steps considered to analyze factor dynamics; this parameter reflects the depth of event monitoring of the system;

$z^{FSc}(t)$, the number of modeling iterations required to simulate the time delay in the process of situation analysis and subsequent decision-making; this parameter represents the lag period of managerial response, expressed in simulation steps.

Thus, a pairwise comparison of resulting scenarios with a target one reduces to assessing the similarity of text strings (the identifiers of event types in a sequence) obtained by concatenating all values of $FSc(v_n,t_i)$. For example, consider a scenario represented by the text string $TSc=$ "1, 1, 1, 1, 1, 2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 1, 1, 1, 4, 4, …"; here, an event of type 1 occurs during the first five simulation steps, followed by an event of type 2 for the four steps and an event of type 3 for the six steps; then an event of type 1 repeats during the three steps, and so on.

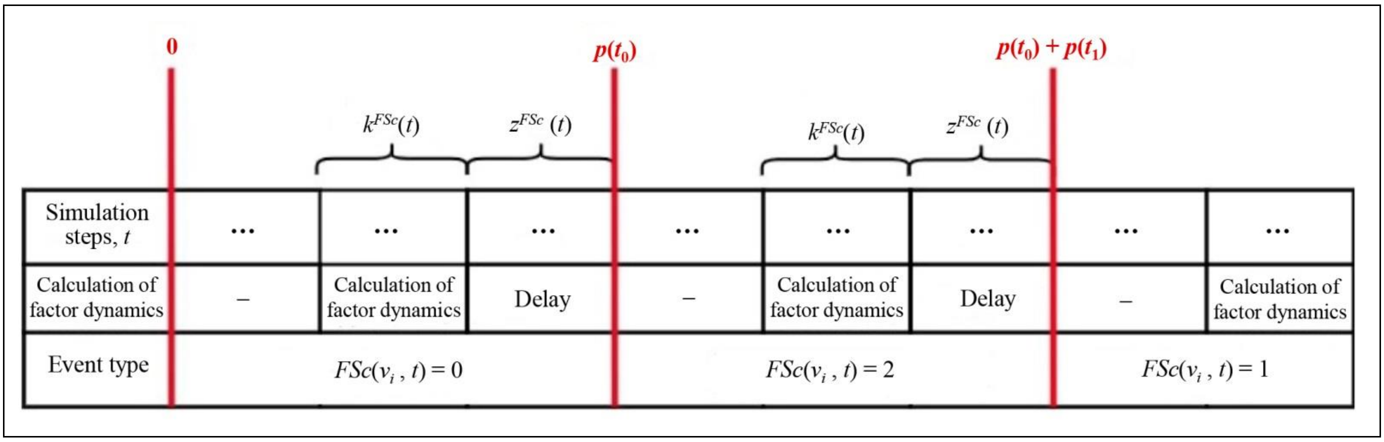


Fig. 3. The relationship between the calculation parameters of factor dynamics.

Event types are formed as follows. Suppose that in the entire set of factors, only five influence the formation of an event (the so-called significant factors). During simulation, the dynamics of these factors are continuously analyzed in accordance with Table 2. A new event is detected and assigned an appropriate identifier 0, 1, 2,…, if the dynamics type of at least one significant factor has changed.

For each scenario, we thereby obtain an array of strings with a sequential integer representation for the sets of types of (changing or unchanging) events. Figure 4 shows the algorithm for encoding scenarios into string representations and comparing them pairwise.

Let $\breve{\mathfrak{R}}$ be the set of all scenarios under consideration, i.e., the union of a target scenario (placed at the beginning of this set) and the set of alternative scenarios. Each element of the set $\breve{\mathfrak{R}}$ is an ordered sequence of significant events.

The event-by-event comparison procedure

1. Identifying significant events. Each significant event is assigned a unique integer identifier from Table 2. This identifier uniquely characterizes the event and ensures that all events of the set can be distinguished.

2. Generating the string representation of scenarios. For each scenario, a string is created by concatenating the identifiers in the order of event occurrence.

3. Constructing the array of unique events. An ordered array is formed from all unique events of the set $\breve{\mathfrak{R}}$ in accordance with the following rules:

– Events are added in the order of their first detection during the sequential analysis of scenarios.

– Each unique event is assigned an identifier (position in the array).

– The identifier is included in the string representation of the corresponding scenario.

4. Handling duplicate events. When detecting an event already present in the array, it is assigned the identifier *m* without being re-added to the array.

This algorithm ensures:

• a unified representation (all scenarios are described using integer event identifiers);

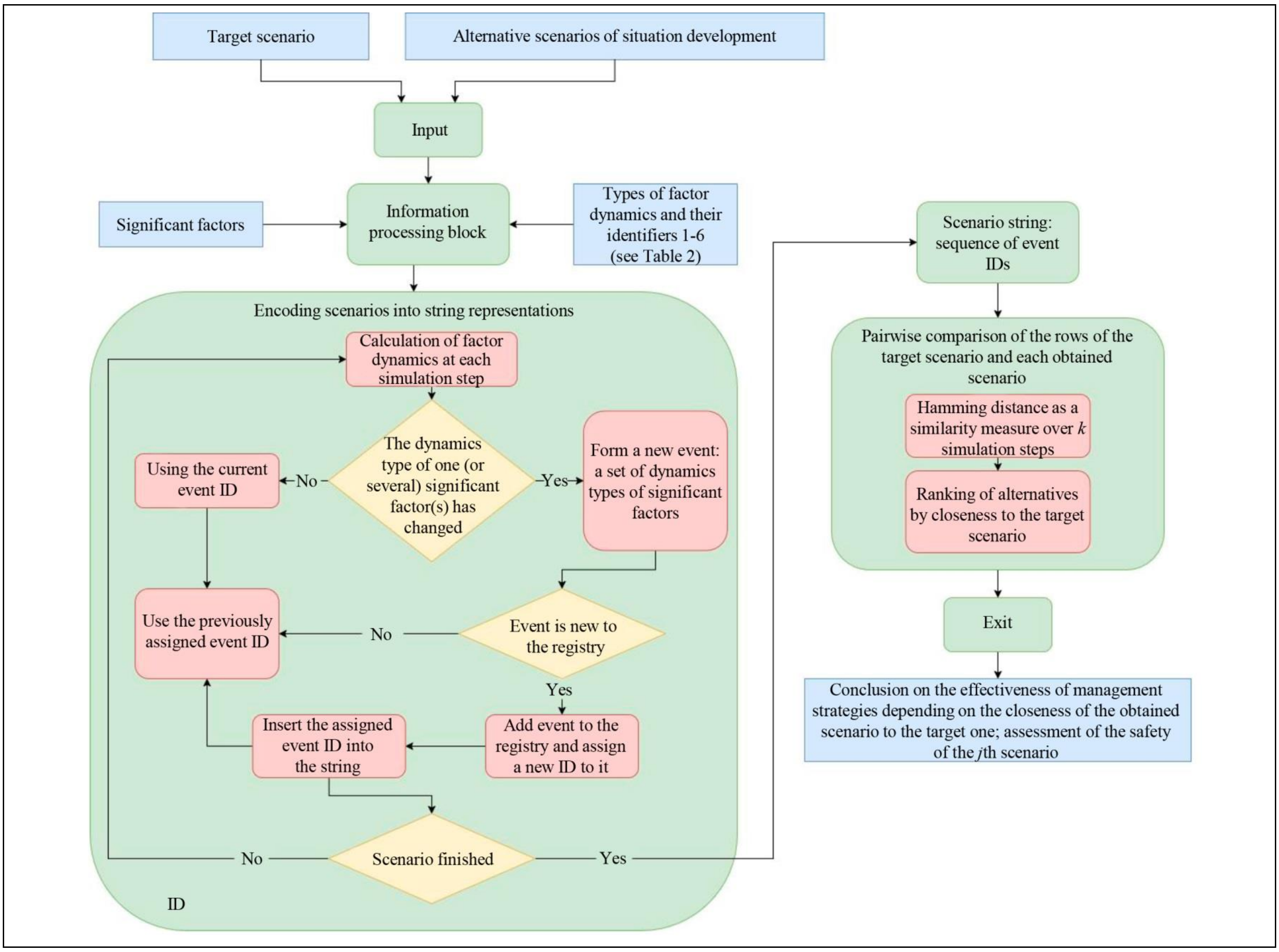


Fig. 4. The algorithm for encoding scenarios into string representations and comparing them pairwise.

• comparability at the event level (the emergence of the same identifiers in the string representations of different scenarios indicates the coincidence of the corresponding events);

• storage optimization (duplicate information is eliminated by reusing the identifiers of previously detected events).

Thus, the initial set of scenarios is transformed into a set of string representations suitable for formal comparison through the analysis of identifier sequences. Consequently, known similarity metrics of text strings can be used here. For example, the similarity of a generated scenario $\mathfrak{R}^j$ and a target one $\mathfrak{R}^{(\mathrm{tar})}$, represented as text strings on $[t_r - t]$ simulations steps, can be measured by the Hamming distance [21]. In this case, the similarity measure δ_H for K simulation steps is given by

$$\delta_H\left(\mathfrak{R}^{(\mathrm{tar})}, \mathfrak{R}^j\right) = 1 - \frac{d_H\left(\mathfrak{R}^{(\mathrm{tar})}, \mathfrak{R}^j, K\right)}{K},$$

$$d_H\left(\mathfrak{R}^{(\mathrm{tar})}, \mathfrak{R}^j, K\right) = \sum_{k=t-K}^{t} \theta\left(TSc^{(\mathrm{tar})0}(k), TSc^j(k)\right),$$

$$\theta\left(TSc^{(\mathrm{tar})}(k), TSc^j(k)\right) = \begin{cases} 0 \text{ if } TSc^{(\mathrm{tar})}(k) = TSc^j(k) \\ \quad 1 \text{ otherwise,} \end{cases}$$

where $TSc^{(\mathrm{tar})}(k)$ and $TSc^j(k)$ represent the event types of these scenarios at the kth step.

3. SCENARIO SIMULATION OF REGIONAL MANAGEMENT

3.1. Scenario Simulation of Multi-Actor Regional Management Processes under Threats

Some steps to assess the effectiveness of regional management with multiple actors were undertaken in the previous paper [22]. The most preferable strategies were identified by assessing the coordination of management processes between multiple actors and their closeness to target parameters (based on an analysis of the output data of scenario simulation and their correspondence to the target states of the model's factors). As established therein, public actors (the state and regional authorities) and private actors (businesses and entrepreneurs) possess unique tools and capabilities to influence the regional system, as well as both similar and differing interests in the management process. Based on the analysis, a mutually beneficial incentive system for regional security management was developed, and a scenario simulation model of regional development under the influence of external threats was created (Fig. 5).

In this figure, the influence domain of actors is shown in green; the main vulnerability domain, in red; and the target factors for maintaining regional security, in yellow.

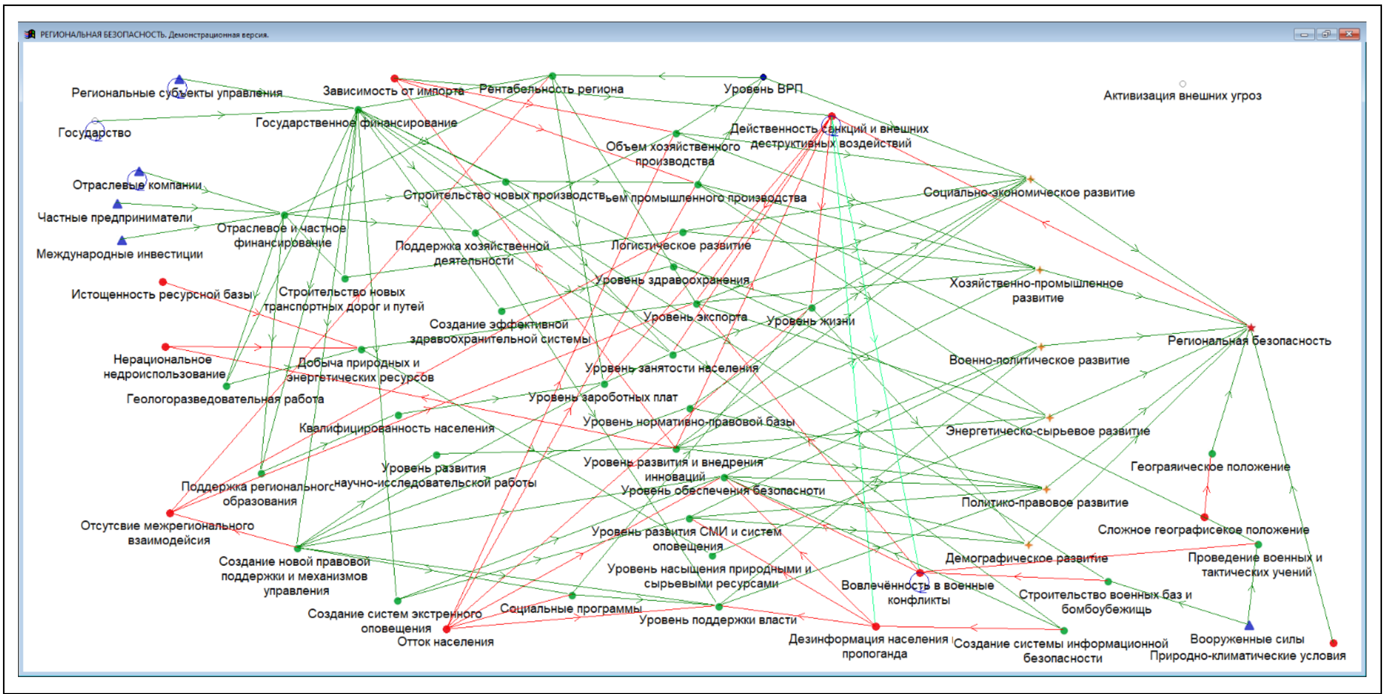


Fig. 5. The structure of the scenario simulation model of regional development.

In the cited study, the target factors, also representing the set of significant factors for situational analysis and management of the form $V^{(\mathrm{sig})} = \{v_1, v_{28}, v_{31}, v_{38}, v_{47}, v_{49}, v_{50}, v_{51}, v_{53}\}$, were as follows: "Regional Security"; "Regional Profitability"; "State Funding"; "Sectoral and Private Funding"; "The Effectiveness of Sanctions and Destructive Impacts"; "Public Disinformation and Propaganda"; "Population Outflow"; and "Dependence on Imports" (the region's level of dependence on foreign technologies, innovations, equipment, raw materials, components, etc.).

During the study, a series of scenario simulation experiments was conducted using a set of hypothetical management strategies, each with a different configuration of interactions between actors and specific impacts on key factors of the region's development. The effectiveness of all scenarios was assessed in terms of a single criterion: the closeness of the simulation results to predetermined target parameters. The results of the analysis are systematized in Tables 3 and 4.

The first scenario demonstrates a rapid-response strategy in which the public actor becomes the center of decision-making. Within this model, private actors take a disadvantageous position: as the "Regional Profitability" indicator decreases, they lose the motivation to achieve individual goals in the absence of an incentive system. In turn, they reduce resource participation in the region's development, thereby weakening the partnership between the state and the business sector. The result of this scenario is a decrease in the coordination of control actions between the actors.

The second scenario reflects a proactive management strategy based on forecasting potential threats and coordinated interaction between multiple actors. A key feature of this scenario is the shift from reactive measures to proactive management. Management coordination is achieved through the synchronization of control actions by public and private actors and the joint use of resources, as well as the development of uniform criteria for assessing threats and the effectiveness of measures. According to the analysis of the resulting dynamics of the model's key indicators [22], this strategy is effective: the evolution trajectory aligns with target parameters in terms of quantitative and qualitative indicators, and the system is stable to the simulated threats.

Table 3

Analysis of the simulation results for scenario 1

Factor	Type of dynamics		Match
	Target	Result	
Regional Security	$FSc(v_{12}) = 1$	$FSc(v_{12}) = 2$	–
Sectoral and Private Funding	$FSc(v_{28}) = 1$	$FSc(v_{28}) = 2$	–
Regional Profitability	$FSc(v_{31}) = 1$	$FSc(v_{31}) = 2$	–
State Funding	$FSc(v_{38}) \neq 2$	$FSc(v_{38}) = 1$	+
Public Disinformation and Propaganda	$FSc(v_{47}) = 2$	$FSc(v_{47}) = 1$	–
Dependence on Imports	$FSc(v_{49}) \neq 1$	$FSc(v_{49}) = 1$	–
Involvement in Military Conflicts	$FSc(v_{50}) \neq 1$	$FSc(v_{50}) = 1$	–
Population Outflow	$FSc(v_{50}) \neq 1$	$FSc(v_{50}) = 1$	–
The Effectiveness of Sanctions and Destructive Impacts	$FSc(v_{51}) = 2$	$FSc(v_{51}) = 1$	–

Table 4

Analysis of the simulation results for scenario 2

Factor	Type of Dynamics		Match
	Target	Result	
Regional Security	$FSc(v_{12}) = 1$	$FSc(v_{12}) = 1$	+
Sectoral and Private Funding	$FSc(v_{28}) = 1$	$FSc(v_{28}) = 1$	+
Regional Profitability	$FSc(v_{31}) = 1$	$FSc(v_{31}) = 1$	+
State Funding	$FSc(v_{38}) \neq 2$	$FSc(v_{38}) = 1$	+
Public Disinformation and Propaganda	$FSc(v_{47}) = 2$	$FSc(v_{47}) = 2$	+
Dependence on Imports	$FSc(v_{49}) \neq 1$	$FSc(v_{49}) = 2$	+
Involvement in Military Conflicts	$FSc(v_{50}) \neq 1$	$FSc(v_{50}) = 1$	–
Population Outflow	$FSc(v_{50}) \neq 1$	$FSc(v_{50}) = 2$	+
The Effectiveness of Sanctions and Destructive Impacts	$FSc(v_{51}) = 2$	$FSc(v_{51}) = 2$	+

In this paper, we analyze management scenarios based on the previous results. Here, the focus is on a comprehensive assessment of two key aspects:

– the closeness of a given scenario to a target one and its trajectory,

– the coordination (logical consistency) of all control actions (the goals of different actors shall match the overall development strategy, without contradictions in the decisions made).

The coordination between actors is assessed by systematically tracking their control actions for the model's target and associated factors.

The analysis methodology includes the following stages:

1. Recording control actions. All control actions for achieving a goal are tracked; for each impulse, the following elements are recorded:

– source (the actor),

– direction (the factor being influenced),

– intensity (the strength of influence),

– temporal parameters (the time instant and duration of influence).

2. Considering the mutual influence of control actions. Impulses from different actors are compared to identify:

– synergistic effects (the control actions with the same direction, which strengthen one another);

– neutralizing interactions (the oppositely directed influences that reduce the overall effect);

– conflicting signals (simultaneous influences on the same factor with different goals).

This stage is necessary to analyze the effectiveness of scenarios and, moreover, to verify the model and the signals supplied.

Here, it is possible to use well-known measures of the connectivity between a pair of scenarios implemented by two actors based on their coincidence with a target scenario. In particular, with the above encoding of scenarios as a sequence of event identifiers, the Sokal–Michener, Rogers–Tanimoto, Kulczynski, and other coefficients can be applied [21].

Closeness to a secure trajectory reflects, in qualitative terms, the deviation of a given scenario from the target trajectory, even in cases where the target parameters are formally achieved. Such a qualitative analysis allows judging factor dynamics not only by the final simulation result but also throughout the entire process. Therefore, it is possible:

– to assess the state of the controlled object or its subsystems at each simulation step,

– to perform an event-by-event analysis for each factor and the entire system.

Thus, critical states of the system can be identified, and their causes can be determined.

Figures 6 and 7 show the target scenario and the simulation results, respectively, in the factor dynamics notation for visualization and ease of understanding. Based on a similarity analysis of the event-by-event encoding of the event sequences in these scenarios and a qualitative analysis of the coordination of control actions during the simulation (as well as the time and resources for mitigating the simulated threats), we assessed the effectiveness of the obtained scenarios, see Table 5. The target parameters of management, determined during the analysis, are combined in Tables 3 and 4. The following requirements were imposed on the dynamics of key factors:

– The "Regional Security" factor shall demonstrate a stable increase.

– For several factors ("Dependence on Imports," "Involvement in Military Conflicts," and "Population Outflow"), any type of dynamics is permissible except for increase. (Decrease or stable state are considered to be admissible results of management.)

Table 5

The Effectiveness of different scenarios: an assessment

Effectiveness criteria	Scenario 1	Scenario 2
The coordination of actors	–	+
Closeness to target parameters ($\mathfrak{R}^{(\mathrm{tar})}$)	–	+
Closeness to a secure trajectory ($\mathfrak{R}^{(\mathrm{sec})}$)	–	–
Resource and time costs	–	+

To make the modeling methodology transparent, we give some clarifications: within a particular simulation, each factor had only two types of dynamics, i.e., increase or decrease (see the tables); however, during experiments with various management strategies, other types of dynamics were identified (not included in the final tables).

We emphasize that the above designations are not calculated values: they serve only to illustrate the type of factor dynamics, being introduced based on the tracked quantitative changes in the values of key factors.

According to the analysis results, even with coordination in multi-actor management and closeness to target parameters (falling within the range of target scenarios), there is a divergence between the obtained scenario and the secure one. This becomes evident during the even-by-event comparison of the scenarios: despite formal compliance with target indicators, the system deviates from the secure trajectory.

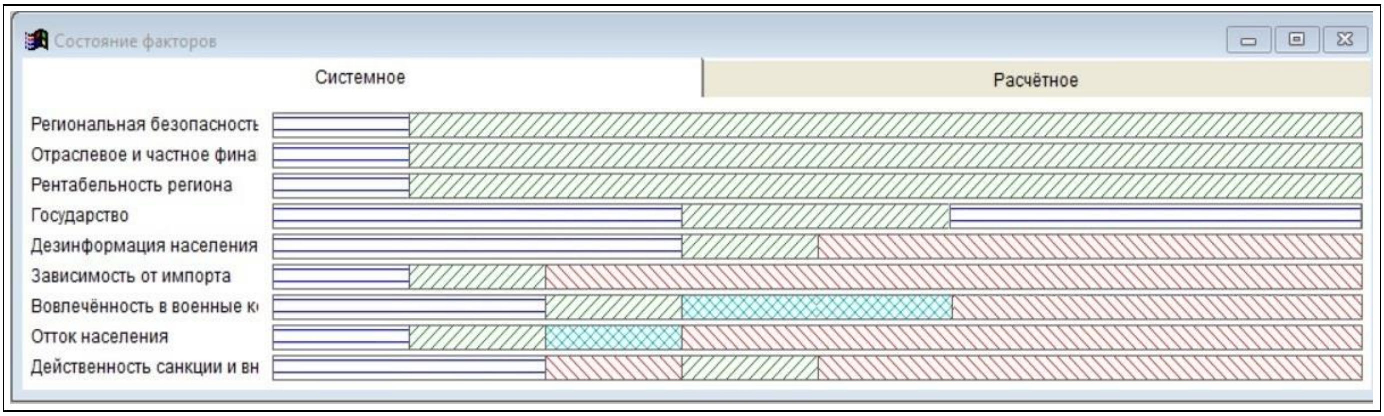


Fig. 6. Simulation results for the target scenario. The list of factors (top-down): "Regional Security," "Sectoral and Private Funding," "Regional Profitability," "State Funding," "Public Disinformation and Propaganda," "Dependence on Imports," "Involvement in Military Conflicts," "Population Outflow," and "The Effectiveness of Sanctions and Destructive Impacts." The white tab (left) corresponds to the systemic time and the gray one (right) to the calculated time.

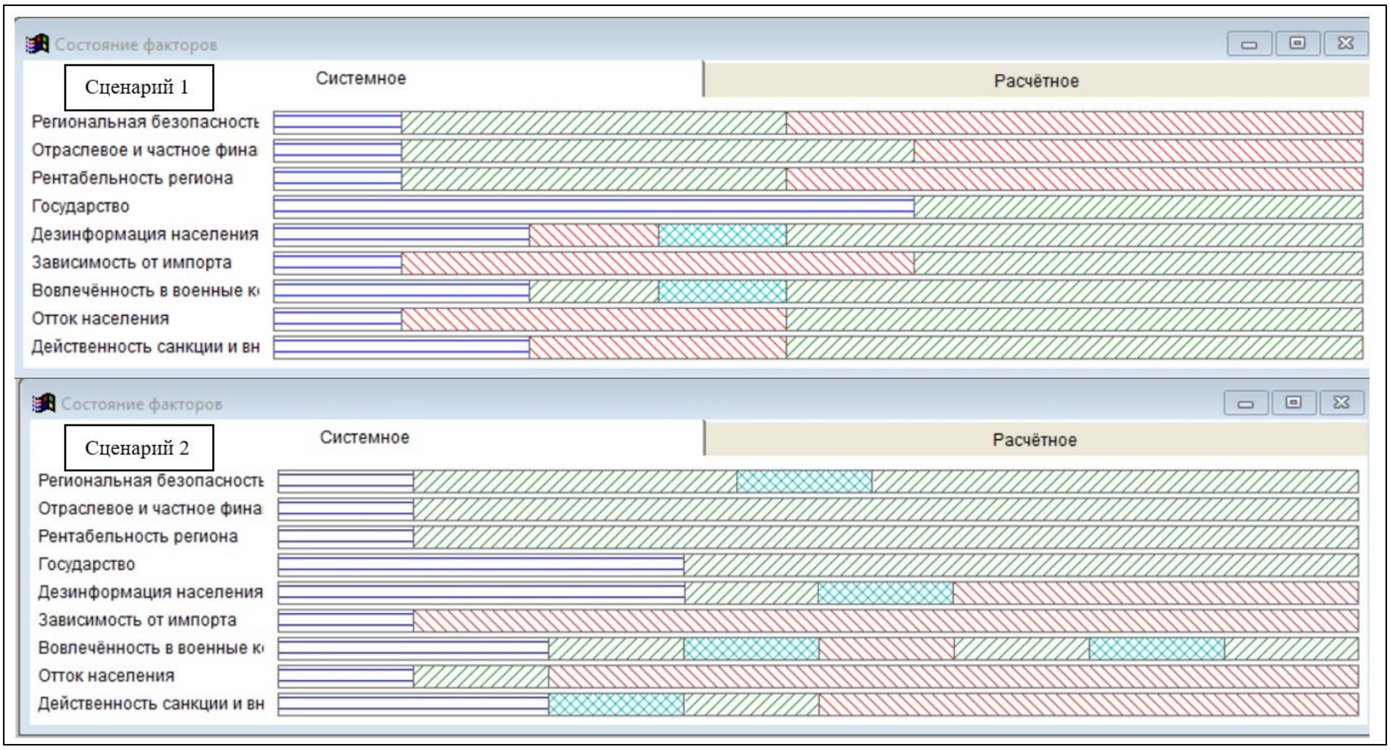


Fig. 7. Simulation results for Scenarios 1 and 2. The list of factors (top-down): "Regional Security," "Sectoral and Private Funding," "Regional Profitability," "State Funding," "Public Disinformation and Propaganda," "Dependence on Imports," "Involvement in Military Conflicts," "Population Outflow," and "The Effectiveness of Sanctions and Destructive Impacts." The white tab (left) corresponds to the systemic time and the gray one (right) to the calculated time.

The divergence is explained by the specifics of the current situation. With their coordinated control actions over a short period, different actors:

– stabilized key factors of regional development and

– prevented the system from a critical drop in the values of target indicators (factors).

However, the same actions did not exit the involvement in military conflicts (a problem determining the system's long-term dynamics). The current management mechanisms are therefore limited: being effective for short-term stabilization, they do not resolve the strategic contradiction. As a result, the state is forced to increase resource support to compensate for the negative consequences.

Thus, the current management model demonstrates a paradox of effectiveness: it successfully addresses operational tasks but exacerbates strategic risks. To settle this paradox, it is necessary:

– to refine the security-related target parameters in the long-term context,

– to implement adaptive management mechanisms for proper functioning under a permanent conflict, and

– to develop resource-saving strategies that reduce the burden on the budget.

3.2. Scenario Simulation of Multi-Actor Regional Management with State Support for Private Business

Based on the above analysis, results of the scenario study, and assessment of the state's measures and capabilities for stimulating private business, the simulation model of regional management was refined and systematized as follows.

It includes the following components: public-private partnerships; social and political factors; economic factors; and regional development threats.

The actors are "State," "Regional Authorities," and "Private Business" (as in the original model).

"State Subsidies," "Tax Incentives," and "Infrastructure Support" are considered as state support measures and tools for influencing the interests of the business sector.

"Sanctions," "Military Conflicts," "Propaganda," and "Social Unrest" are the factors selected to simulate threats and external disruptive impacts.

The modified structure of the scenario simulation model of regional management is presented in Fig. 8.

Within this study, a series of scenario simulation experiments was carried out in PAC *Polyus* to compare the effectiveness of various regional management strategies under external and internal threats.

3.2.1. Simulation Methodology

For a comprehensive assessment, four alternative trajectories of the situation's development were simulated, differing in:

• the nature of control actions (operational response or preventive forecasting);

• the degree of private sector involvement (with or without incentives);

• the decision mechanism (single-actor management or cooperative interaction).

Four possible trajectories of the situation's development were simulated as follows.

Scenario 1: an operational response by "State" as the actor to negative trends in the region, without incentives for "Private Business."

Scenario description: all negative trends in the region have a response after the fact; the private sector receives no incentives and operates autonomously; the emphasis is on administrative methods of regulation.

Scenario 2: an operational response by "State" with incentives for "Private Business."

Scenario description: a system of incentives for "Private Business" is introduced; synergy between state control and market activity is assumed.

Scenario 3: forecasting potential threats and a preventive response by "State" (basic predictive strategy).

Scenario description: "State" uses threat forecasting tools; preemptive measures are implemented before crises occur; the private sector is not involved in cooperative management.

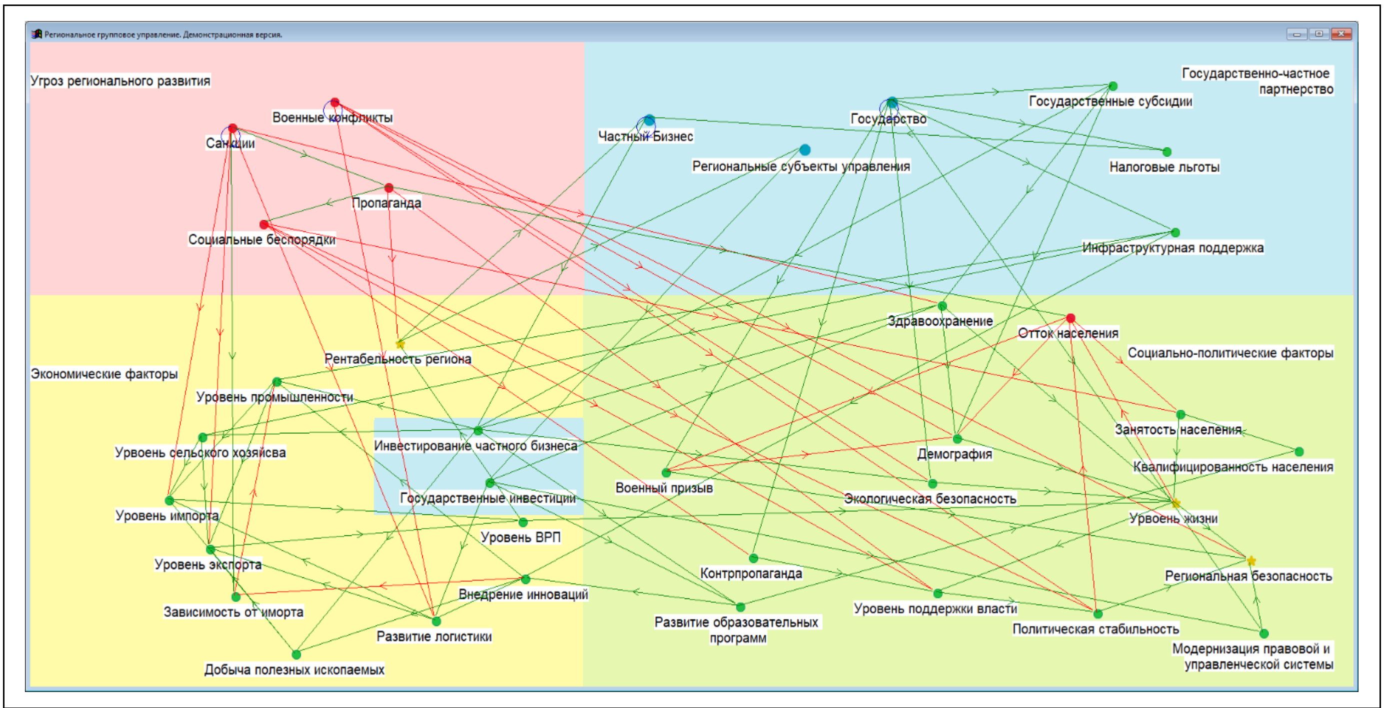


Fig. 8. The structure of the scenario simulation model.

Scenario 4: threat forecasting and a preventive response by "State" with the involvement of "Private Business" using incentive mechanisms.

Scenario description: mechanisms to motivate and incentivize "Private Business" are applied; a system for joint counteraction against threats is established. The simulation results are presented in Fig. 9. The key factors for tracking are "Standard of Living" (a social indicator), "Political Stability" (an institutional indicator), and "Regional Security" (a composite indicator).

3.2.2. Analysis of the Results

Scenario 1 demonstrated the ineffective efforts of actors to counter threats. The absence of coordination with the private sector limited the resource base. The system remained trapped in a cycle of crisis, maintaining a high level of vulnerability.

According to Scenario 2, the joint management strategy with state incentives for private business allows restoring stability in the region. However, this approach:

– requires significant time and resources,

– causes an exit from the secure-scenario zone, and

– does not reduce the level of destructive impacts.

Scenarios 3 and 4 (prognostic) outperform Scenario 2:

– by accelerating the system's return to a stable state,

– by minimizing the required resources.

Scenario 4 demonstrated the possibility of neutralizing threats from adversaries through the joint control efforts of actors. According to the event-by-event comparison with the target scenario, we observe:

– no obvious contradictions between the control efforts of different actors, and

– a significant deviation of Scenarios 1–3 from the target parameters in terms of stabilization time, resource costs, and the degree of achieving the target parameters.

The scenario assessments are provided in Table 6; here, the green (red) color indicates the results that agree (do not agree, respectively) with the management goals.

The desired event in the target scenario is a situation where the pressure of sanctions and involvement in military conflicts will decrease while the values of regional indicators will increase. Let this event be assigned the identifier "1." In addition, suppose that in the target scenario, only admissible events occurred before the desired one; let an arbitrary admissible event be encoded by "0." Then the text string for the target scenario takes the form $TSc^{(\mathrm{tar})}=$ "0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1" , where the desired event occurs after simulation step 170.

Next, using the simulation results, we identify unique events according to the above algorithm, without event duplication (Fig. 9). Consequently, the following text strings of the resulting scenarios are formed:

1. $TSc^{(1)}$ = "2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3" ,

2. $TSc^{(2)}$ = "2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 4, 5, 5, 5, 6, 6",

3. $TSc^{(3)}$ = "3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 4, 5, 5, 5, 7, 7, 8, 8, 8, 6, 5, 5",

4. $TSc^{(4)}$ = "3, 3, 3, 3, 4, 4, 4, 4, 5, 5, 5, 5, 5, 5, 5, 5, 9, 10, 10, 10, 1, 1, 1, 1".

(For convenience, the event identifiers are concatenated every ten simulation steps.)

In Fig. 9, the event identifiers and their partition are marked in red.

Next, we treat all admissible events as equivalent to an arbitrary admissible event and assign them the identifier "0." (An event is admissible if it satisfies the growth condition of regional development indicators and inadmissible otherwise.) After the analysis, the following event identifiers were separated out: "5," "6," "7," "8," "9," and "10." The string representations of the resulting scenarios are as follows:

1. $TSc^{(1^*)}$ = "2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3" ,

2. $TSc^{(2^*)}$ = "2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0" ,

3. $TSc^{(3^*)}$ = "3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0" ,

4. $TSc^{(4^*)}$ = "3, 3, 3, 3, 4, 4, 4, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1" .

The strings were compared pairwise with the target scenario using the Hamming distance, and the following conclusions were drawn.

In Scenario 1, the similarity measure is $\delta_H\left(\mathfrak{R}^{(\mathrm{tar})},\mathfrak{R}^j\right)=0$; in Scenario 2, $\delta_H\left(\mathfrak{R}^{(\mathrm{tar})},\mathfrak{R}^j\right)=0.04$; in Scenario 3, $\delta_H\left(\mathfrak{R}^{(\mathrm{tar})},\mathfrak{R}^j\right)=0.12$; and in Scenario 4, $\delta_H\left(\mathfrak{R}^{(\mathrm{tar})},\mathfrak{R}^j\right)=0.52$. At the qualitative level, according to the pairwise comparison and assessment of the event type identifiers, Scenario 4 is closest to the secure trajectory and also achieved the required event. In the future, we will develop a methodology for generating a target scenario and introduce a classification for the degree of event admissibility.

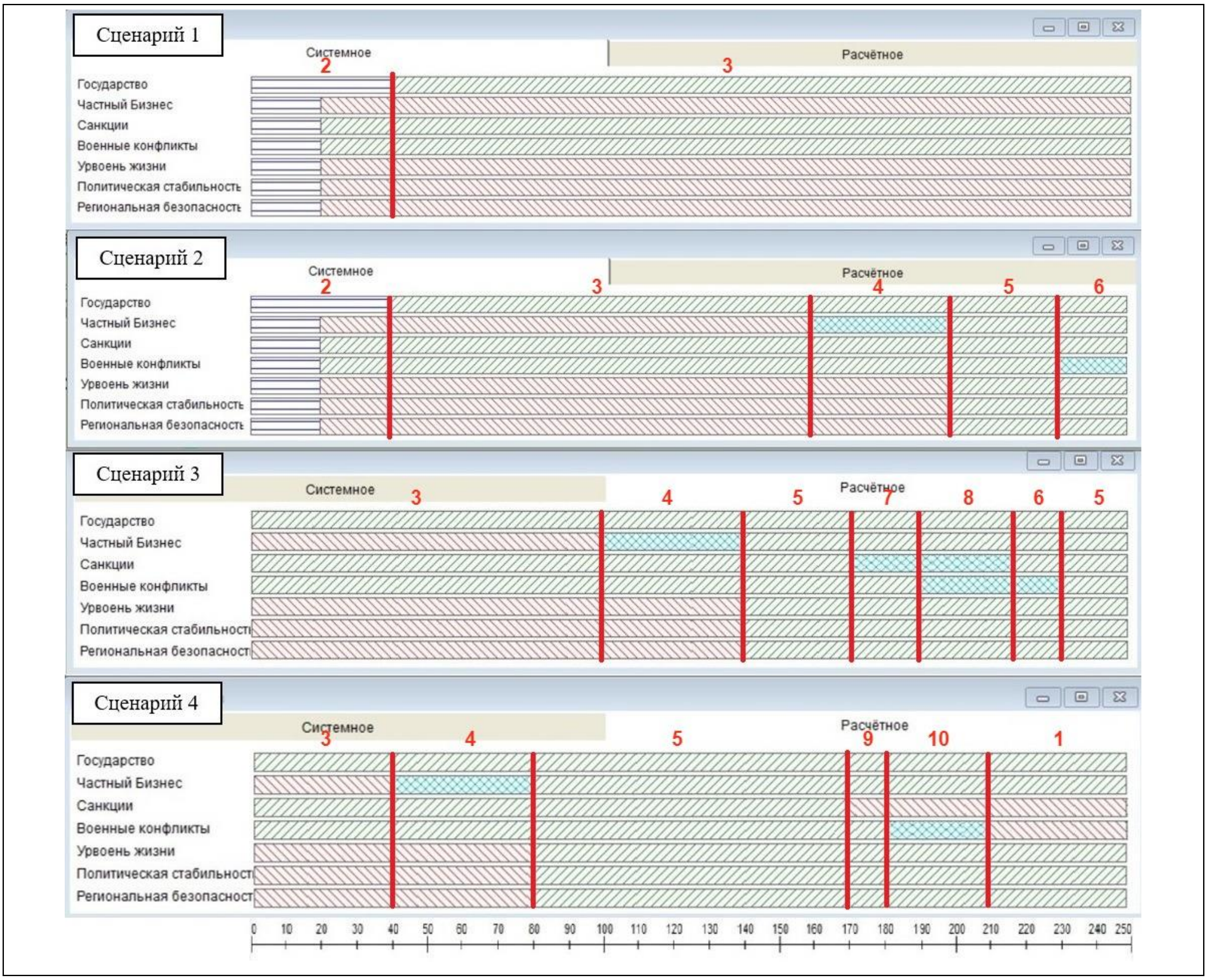


Fig. 9. Simulation results for Scenarios 1–4. The list of factors (top-down): “State,” “Private Business,” “Sanctions,” “Military Conflicts,” “Standard of Living,” “Political Stability,” and “Regional Safety.” The white tab (left) corresponds to the systemic time and the gray one (right) to the calculated time.

Table 6

Analysis of the simulation results

Factor	Type of dynamics				
	Target	Scenario 1	Scenario 2	Scenario 3	Scenario 4
State	$FSc(v_1)=1$	$FSc(v_1)=1$	$FSc(v_1)=1$	$FSc(v_1)=1$	$FSc(v_1)=1$
Private Business	$FSc(v_2)=1$	$FSc(v_2)=2$	$FSc(v_2)=1$	$FSc(v_2)=1$	$FSc(v_2)=1$
Sanctions	$FSc(v_6)\neq 1$	$FSc(v_6)=1$	$FSc(v_6)=1$	$FSc(v_6)=1$	$FSc(v_6)=2$
Military Conflicts	$FSc(v_{19})=2$	$FSc(v_{19})=1$	$FSc(v_{19})=5$	$FSc(v_{19})=1$	$FSc(v_{19})=2$
Standard of Living	$FSc(v_{27})\neq 2$	$FSc(v_{27})=2$	$FSc(v_{27})=1$	$FSc(v_{27})=1$	$FSc(v_{27})=1$
Political Stability	$FSc(v_{29})\neq 2$	$FSc(v_{29})=2$	$FSc(v_{29})=1$	$FSc(v_{29})=1$	$FSc(v_{29})=1$
Regional Security	$FSc(v_{31})\neq 2$	$FSc(v_{31})=2$	$FSc(v_{31})=1$	$FSc(v_{31})=1$	$FSc(v_{31})=1$
Closeness to the Secure Trajectory	Secure scenario	–	–	–	+
Time Cost	Target value	–	–	+	+

Scenario 4 is the most preferable one, as it satisfies all efficiency criteria owing to:

– shifting the decision center to "State";

– using scenario-event forecasting for the early detection of threats,

– involving motivation and incentive mechanisms for "Private Business", and

– expanding the capabilities for action under disruptive challenges.

Thus, this management strategy appears to be optimal for a period of instability.

CONCLUSIONS

This paper has attempted to create a system of criteria for assessing the effectiveness of scenarios in simulation modeling of multi-actor regional management. On this way, key indicators of scenario effectiveness have been identified: closeness to target parameters and closeness to a target trajectory.

Target parameters are assessed using the methodology of pairwise comparisons: the simulation results are contrasted with desired management results (in terms of a predetermined behavior of model factors). A scenario trajectory is assessed by the methodology of event-by-event representation and analysis. This methodology allows:

– identifying each event,

– assessing a scenario based on visual and numerical representations of the corresponding data, and

– determining the degree of closeness of a scenario trajectory to a target one.

During this study, we have also qualitatively assessed resource and time costs (the efforts needed to mitigate simulated threats and destructive impacts).

According to the results, in the face of threats, preemptive management is the most effective strategy. Its key characteristics are:

– forecasting threats and destructive impacts,

– joint decision-making,

– bringing together the state (as the management center) and the region's private sector,

– maintaining security and stability in the region.

Such a strategy shall include:

– methods for forecasting emerging threats (based on a scenario approach);

– mechanisms for the state to incentivize and motivate the business sector.

The results of this study can serve to develop systems for assessing the effectiveness of strategic decisions made by regional authorities. They will be used in the author's further research into scenario monitoring of the evolving situation, improving the early detection methodology for undesirable events and changes in the dynamics of significant factors and their determinants, and automating event encoding and the development of response procedures.

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