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Article

Models for Improving Decision-Making Mechanisms in Regional Economic Management

Daliev Akhtam Sharafutdinovich

1. Candidate of Economic Sciences, Associate Professor National University of Uzbekistan named after Mirzo Ulugbek

* Correspondence: https://orcid.org/0000-0002-5836-3520, a.daliev@mail.ru

Abstract: The article considers the issues of improving decision-making mechanisms in regional economic management based on the integration of graph theory and multi-criteria optimization methods. The author justifies the need to transition from intuitive management methods to the construction of intelligent recognition control systems. The paper presents a two-level model – structural (factorial) and functional (managerial). An extended system of 24 constraints is proposed, taking into account the resource, technological, and social potential of the Samarkand region. The results of the study allow for the algorithmization of the process of selecting priority tasks for regional development and can be used to create software complexes for decision support in state management bodies.

Keywords: regional economy, decision-making mechanisms, management optimization, macroeconomic indicators, digital maturity, recognition management system.

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1. Introduction

Transformation of regional economic systems in conditions of global uncertainty requires fundamentally new approaches to public administration. The Republic of Uzbekistan, following the vector of the "Uzbekistan – 2030" strategy, sets the priority task of ensuring sustainable growth of the gross regional product (GRP) through the introduction of digital technologies and support for entrepreneurial initiatives [1]. However, the complexity of intersectoral links makes the management process vulnerable to subjective errors, which necessitates the development of rigorous mathematical models.

The object of the study is the mechanism of regional economic management, functioning in conditions of limited resources and strict environmental frameworks. The subject of the research is the methods of optimizing this mechanism based on graph structures. The aim of the work is the construction and theoretical justification of a discrete decision-making model that allows for maximizing the regional effect [2][3].

Literature review

Modern paradigm of management and administration is undergoing a radical transformation, moving from traditional hierarchical structures to flexible network models [4].

Fundamental foundations of regional analysis were laid in the classical works of W. Isard, who emphasized the role of analyzing complex social processes for resolving resource conflicts [5]. At the same time, his methods require adaptation to the digital environment. Institutional aspect of management was investigated by D. North, who argued that institutions determine the growth trajectory through the incentive structure.

At the same time, North's approach needs mathematical formalization for operational management.

In the context of modern strategic management, Wen and Fang (2024) point to the dependence of regional adaptation on the flexibility of management systems [6]. At the same time, the issue of macro-coordination remains open. Digital transformation of management was analyzed by the World Economic Forum, noting the reduction of transaction costs [7]. At the same time, this requires strict graph models to avoid data chaos.

In justifies the methodological foundations of territorial development in conditions of urbanization, emphasizing that a mathematically verified calculation is the foundation of commercial and managerial efficiency. S.V. Romankov identifies mathematical modeling as a relevant segment of digitalization, and E.I. Kiribaev (2025) emphasizes the role of models in increasing competitiveness [8].

At the same time, the regional level requires accounting for broader environmental determinants. The problematic of knowledge management is developed by D.Y. Yasinsky (2023) , which should be integrated into a general recognition management system. Thus, the relevance of the topic is due to the need for a synthesis of classical theories and digital decision-making algorithms [9].

The relevance of the problem under consideration is due to the critical necessity of formalizing decision-making processes in complex mesoeconomic systems. In classical management, a descriptive approach dominated for a long time, however, in the conditions of the digital economy, a need arises for normative models capable of not only describing the current state but also prescribing optimal development trajectories.

The problem of searching for an “effective solution” in regional management is closely related to the theory of strategic management and the concept of management by results. Research in recent years emphasizes that the management of large territorial entities without mathematical justification leads to “information entropy,” when management signals fade without reaching the real sector of the economy. In this context, the use of graph theory and discrete optimization methods becomes not just scientific research, but an urgent need for operational management at the regional level [10].

The relevance of developing optimization models is also dictated by a deficit of resources and the need to comply with strict environmental and social standards. In the state management systems of Uzbekistan, a mathematical model acts as an objective arbiter, allowing for the filtering out of ineffective projects and the concentration of capital at key growth points. This creates a scientific and methodological basis for the formation of decision support systems (DSS) integrated into the digital management environment.

2. Materials and Methods

The relevance of developing a structural model of development factors is dictated by the need for visualization and quantitative assessment of implicit relationships between macro- and microeconomic parameters of the region. The peculiarity of this model lies in its “dynamic sensitivity”: it is not a static snapshot of the economy, but represents a living mechanism of correlations, where a change in the weight of one node inevitably leads to a transformation of the entire system [11].

The uniqueness of the approach is manifested in the use of directed vectors that clearly separate cause and effect in regional processes. This gives the region's management an understanding of which primary factor needs to be influenced to obtain the maximum response in the resulting GRP indicator.

Factors	B1	B2	B3	B6	B4	B12
B1 (urbanization)	0	0,30	0	0,65	0	0,40
B2 (regional GRP)	0,20	0	0,55	0	0	0,50
B3 (potential)	0	0,45	0	0	0,55	0
B6 (industry)	0	0,45	0	0	0	0

B4 (innovative SME)	0	0,25	0	0	0	0
B12 (social conditions)	0,35	0	0	0	0	0

Based on the analysis of statistical data of the Samarkand region, the following dependencies have been established:

the linkage $B_1 \rightarrow B_6$ (0,65) – indication of a strong dependence of industrial growth on the degree of urbanization;

the linkage $B_3 \rightarrow B_4$ (0,55) – direct correlation between accumulated potential and innovative activity;

the linkage $B_6 \rightarrow B_2$ (0,45) – contribution of industry to the formation of added value;

the linkage $B_{12} \rightarrow B_1$ (0,40) – quality of life as a determinant of population inflow [12].

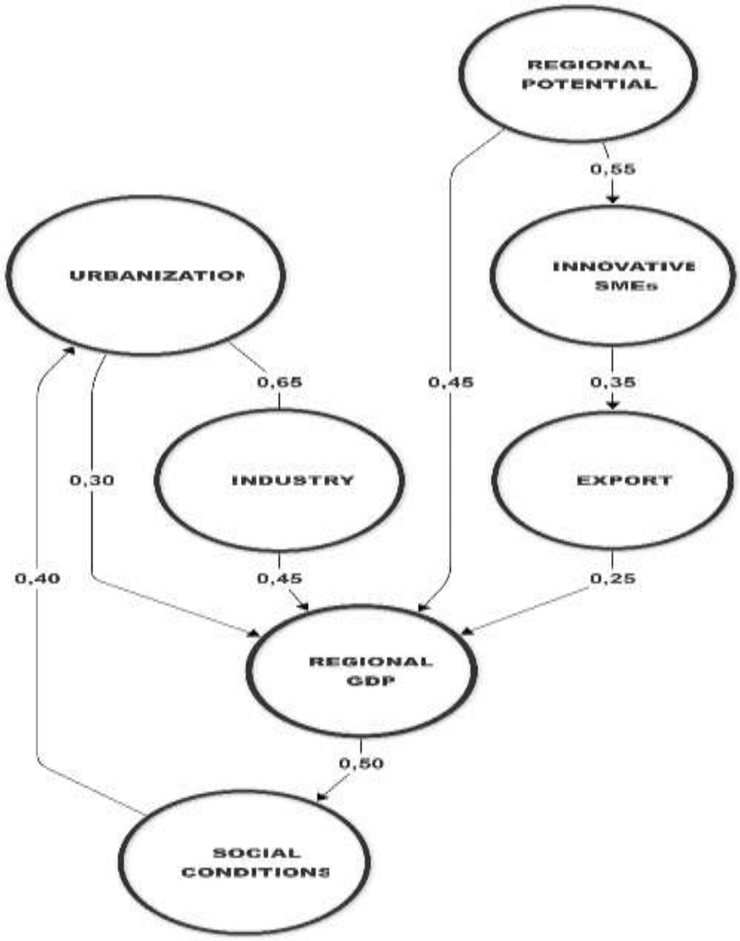

Figure 1. Regional economic sectors and coupling coefficients

It should be noted that the presented architecture of coefficients reflects a unique balance of industrial and agricultural forces of the Samarkand region. In the scientific and theoretical aspect, these values possess a high degree of regional specificity: for other territorial entities (for example, predominantly extractive or service-tourist zones), these weight characteristics may acquire fundamentally different values dictated by the uniqueness of local production relations and the resource base [13].

Economic model describes the decision-making process through 12 indicators (P_i), translated into a normalized value. Indicators are expressed in normalized scores (from 0 to 1), where 1 – maximum efficiency: T_1 (E-gov) – level of penetration of digital public services; T_2 – relative volume of foreign trade turnover; T_3 (digital maturity) – readiness of business for automation; T_4 (innovation) – share of high-tech industries; T_5 (employment) – share of those employed in the private sector; T_6 (SME) – growth rate of the number of small enterprises; T_7 (investment) – investment development coefficient; T_8 (Smart City) – level of technology in the urban environment; T_9 (logistics) - product delivery time reduction index; T_{10} (yield) – efficiency of using land resources; T_{11} (ecology) – coefficient of reduction of man-made load; T_{12} (income) – index of growth in purchasing power [14].

Target function is as follows

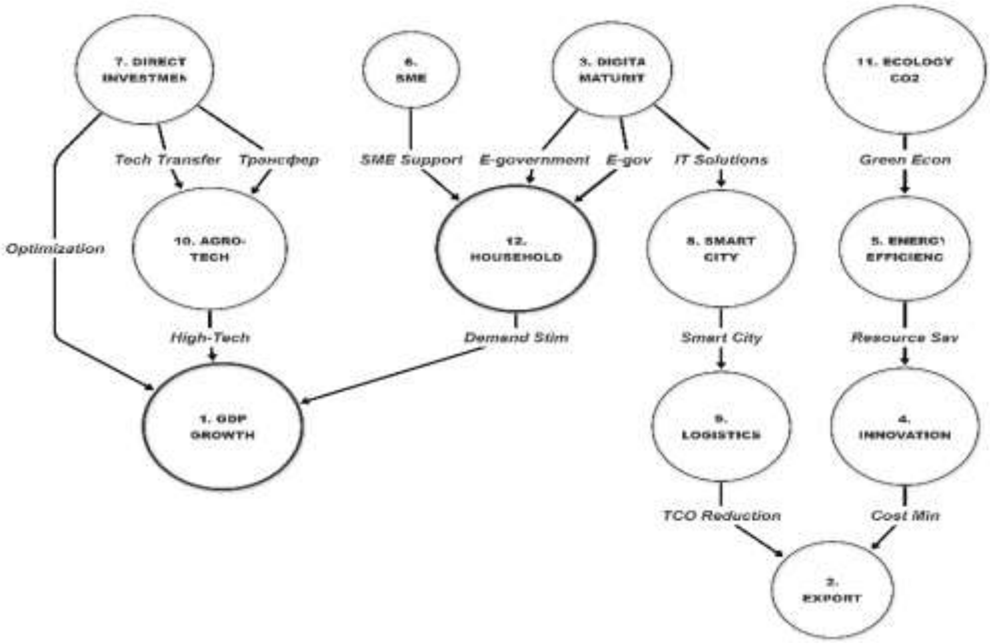

Figure 2. Target indicators and solution variants

$$S = \sum_{i=1}^{12} (W_i \cdot P_i) \rightarrow max$$

where n = 12 (number of management impact vectors according to figure No. 2), W_i – weight coefficient of task importance, P_i – resulting quantitative indicator of task fulfillment.

At the same time, the system of constraints and conditions for these tasks is as follows (using the example of the Samarkand region). Any management decision is limited by the reality of the resource base, and the task includes 24 conditions blocking unrealistic scenarios:

$\sum C_i \leq R_{budget}$ (costs within the development budget); $Q_{export} \geq Q_{min}$ (plan for foreign exchange earnings); $I_{energy} \leq I_{cap}$ (limit of regional energy consumption); $F_{reserve} \geq 0{,}1 \cdot S$ (reserve fund – 10% of cost); $W_{water} \leq W_{limit}$ (water use limit); $S_{land} = const$ (unchangeability of arable land area); : $E_{pollution} \leq E_{norm}$ (compliance with environmental MPC – maximum permissible concentration); $S_{forest} \geq S_{min}$ (preservation of forest fund area); $T_{tech} \geq T_{min}$ (threshold of technological equipment wear); $N_{digital} \geq 80\%$ (internet coverage of the territory); $T_{log} \leq T_{max}$ (maximum time for logistical operations); $V_{road} \geq V_{transit}$ (road network capacity); $K_{ware} \geq K_{min}$ (availability of certified warehouses); $P_{utility} \leq P_{cap}$ (capacity of utility networks, including gas and light); $L_{SME} \leq L_{total}$ (labor resource limit – EAP – economically active population); $N_{edu} \geq N_{target}$ (plan for graduating engineers and IT specialists); $Q_{skill} \geq 0{,}7$ (share of certified personnel); $I_{re-train} \geq I_{min}$ (budget for personnel retraining); $D_{social} \geq 0{,}5 \cdot B2$ (allocation of 50% of profit to the social sphere); $R_{food} \geq R_{crit}$ (food security threshold); $D_{cyber} \geq D_{req}$ (compliance with cybersecurity standards); $T_{admin} \leq T_{bench}$ (business registration time, E-gov); $I_{transparency} \geq 0{,}8$ (public procurement transparency index); $C_{safety} \leq C_{norm}$ (minimization of industrial accident risk).

At the macro-management level of the region, the key indicator becomes "Regional potential (B_3)". In this model, management is carried out through impact on macro-indicators – "investments" (T_7) and "innovations" (T_4). Management efficiency is measured by the ability of the administrative apparatus to convert input resources into growth of export potential (T_2) while simultaneously complying with constraints on social well-being (B_{12}).

Mechanism of macro-management of the region is implemented through the following strategic blocks: investment attractiveness (risk management); innovative diffusion (speed of technology spread); intellectual capital (development of the university environment); infrastructure framework (development of transport and other market nodes); export expansion (entry into foreign markets); environmental sustainability (closed-loop systems); digital platform (integration of data from departments); social inclusiveness (equalization of development of districts) [15].

Assessment of the efficiency of regional macro-management is a multi-level process of comparing GRP growth rates with qualitative transformations of the economic structure. At the macro level, efficiency is determined not only by achieving planned figures but also by the system's ability to remain resilient to external shocks. The key criterion here is the "coupling effect," when a management decision in one area stimulates growth in related industries.

In particular, for the Samarkand region, the assessment of macro-management has a specific character. Given its status as a tourist hub, macro-management is assessed through the balance between the preservation of cultural heritage and industrialization. The Samarkand agglomeration requires efficiency assessment through the "Smart-index" of population density. As a transport hub, the region is assessed by the throughput capacity of corridors. The presence of the largest universities makes the assessment of the commercialization of scientific developments a priority. Finally, the agricultural sector requires macro-management assessment through the prism of water use efficiency.

3. Result and Discussion

Analysis of the results based on the combination of two graph models allows for deep conclusions about management mechanisms in the Samarkand region. Analysis of the combination of graph models showed that in the Samarkand region, the $B_1 \rightarrow B_6$ (0,65) link makes infrastructure development (T_8) a critical condition for growth. According to Figure No. 1, the critical dependence of industrial development on urbanization (0,65) indicates that any delay in the development of urban infrastructure (T_8) instantly blocks GRP growth. Discussion showed that with current energy constraints, the investment block (T_7) cannot work at full capacity without the implementation of energy-saving IT solutions (T_3).

The "Digital maturity" (T_3) node possesses the maximum weight W_i, acting as a driver for logistics (T_9) and export (T_2). Considering the target function for n=12, we found that the "Digital maturity" (T_3) node possesses the maximum weight Wi. In the conditions of Samarkand, digitalization acts not just as an industry, but as a "recognition filter" that allows for the optimization of logistics (T_9) and export (T_2). At the same time, the system of constraints on personnel revealed that a shortage of specialists hinders the implementation of the innovative diffusion block.

Application of the system of 24 constraints allowed for the identification that the deficit of water resources (W_{water}) blocks the extensive development of the agro-industrial complex, requiring a redirection of investments into AgroTech-innovations (P_{10}), which is taken into account when making an effective decision.

Discussion of the macroeconomic block "Export expansion" showed that the entry of Samarkand enterprises into foreign markets is limited not so much by production volumes as by the speed of passing through logistical nodes (T_9). Mathematical modeling confirms that investing 1 unit of resources in the Smart-infrastructure of the city gives 15% more GRP growth than direct production subsidies, due to the removal of systemic constraints.

In the context of social conditions (B_{12}), the discussion of the results confirmed the hypothesis that ignoring the environmental constraint (T_{11}) leads to an increase in social tension, which in turn reduces the investment attractiveness of the region. Thus, the model proves the need for "balanced management," where every industrialization decision correlates with the environmental and social limit.

The dependence between GRP (B_2) and social conditions (B_{12}) with a coefficient of 0,50 confirms that exactly half of the economic growth should be reinvested in the social sphere. Otherwise, according to the model, the region's potential (B_3) begins to degrade due to a decrease in the quality of human capital. Thus, optimization according to the function S must be carried out under strict compliance with social standards.

4. Conclusion

1. The regional management mechanism must be based on a system of strict resource and social constraints. This allows for the formation of scientifically grounded development plans for the Samarkand region, excluding subjective management errors and ensuring the stability of the system.

2. The use of a graph-based target function provides transparency and measurability of public administration. Each management step receives a clear quantitative assessment of its contribution to the final indicator of the region's well-being.

3. Digitalization (T_3) is the foundation of the modern economy. Without the technological update of management nodes, the Samarkand region risks losing its export and investment growth rates in conditions of global competition.

4. The results of the study create a basis for the further development of an intelligent recognition management system for the regional economy. Such a system will allow for the automatic identification of "bottlenecks," the recognition of ineffective scenarios, and the proposal of optimal solutions for the management of enterprises and authorities. This will be an important step in the implementation of the "Digital Uzbekistan – 2030" program.

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