sciendo INTERNATIONAL JOURNAL ON SMART SENSING AND INTELLIGENT SYSTEMS

Article | DOI: 10.2478/ijssis-2024-0006 Issue 1 | Vol. 17 (2024)

Forecasting the development of the industrial complex: Southern Federal District

Tatyana A. Makarenya,
Alexey I. Kalinichenko,
Ali Sajae Mannaa,
Svetlana V. Petrenko

Southern Federal University,
Rostov-on-don - Taganrog, Russia

*E-mails: mta-76@inbox.ru;
ali88mannaa@gmail.com;
alecsy.k@gmail.com;
lana.stash@gmail.com

Received for publication:
August 25, 2023.

Abstract

The purpose of this study is to build a cognitive model of the system–industrial complex of the Southern Federal District of Russia. The Southern Federal District is a region in the south of Russia, which includes the regions of Rostov, Volgograd, Astrakhan, and Krasnodar; the Republics of Adygea, Kalmykia, and Crimea; and the federal city of Sevastopol. The object of the study was the industrial complex of Southern Federal District, which ranks 6th in terms of the share of manufacturing among the federal districts. The study was conducted at the Southern Federal University, which is located in the Southern Federal District of Russia. This article discusses the use of the cognitive modeling method, which allows us to determine the degree of system stability and the direction of system development under varying degrees of influence of external factors. This method is used to build forecasts of the development of poorly structured socio-economic systems. The cognitive modeling method made it possible to predict one of the scenarios for the development of the industrial complex of the Southern region of the Russian Federation. For the subject under study, indicative, controlling, and regulating peaks have been identified, but the difficulty of forecasting is noted due to the lack of a general program for the industrial complex of the federal district. The article presents scenarios of industrial development of the Rostov and Krasnodar regions as the most industrially developed regions in the Southern Federal District. Cognitive modeling allows building scenarios of development of the studied systems of regions by means of impulse influence, that is, when one vertex affects another vertex. The modeling results made it possible to build a cognitive map of the industrial complex of the Southern Federal District. This map showed that in the case of impulse impact on the industrial complex, it is necessary to strengthen regulatory measures on the part of the state.

Keywords

Cognitive modeling, socio-economic systems, forecasting, long-term planning, computer modeling, industrial complex, Southern Federal District, cognitive map, planning, development

I. Introduction

The purpose of this article is to develop a forecast for the development of industry in the Southern Federal District of Russia.

The Southern Federal District, which is one of the eight federal districts and is located in the south of the European part of the Russian Federation, was chosen as the object of the study. The area of the Southern Federal District is 447.8000 km^2.

Open Access. Published by Sciendo. CC BY-NC-ND
© 2024 Makarenya et al. This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 License https://creativecommons.org/licenses/by-nc-nd/4.0/

The Southern Federal District contains 73% of all-Russian reserves of thermal waters and 30% of mineral ones, 41% of tungsten reserves, and 15% of cement raw materials. The district contains about 2% of Russian oil reserves and 7% of gas reserves.

The structure of the district includes eight entities, each of which specializes in various industries. The structure of the volume of shipped goods from manufacturing industries in the Republics of Adygea and Crimea, the Krasnodar Territory, the Rostov Region, and the city of Sevastopol is dominated by the production of food products, beverages, and tobacco products. The Republic of Kalmykia is dominated by the production of computers, electronic and optical products, and electrical equipment. The Astrakhan region specializes in the production of coke and petroleum products, rubber, and plastic products. Metallurgical production predominates in the Volgograd region, including the production of finished metal products, except for machinery and equipment.

a. Literature review

Models of global dynamics are currently being developed, such as mathematical modeling and management of the dynamics of development of regional socio-economic systems based on the ideas and theories of synergetics [8, 29], in cognitive modeling (2–7, 22, 26, 30–34).

As for the consideration of problems of planning socio-economic systems, the works of the following researchers were considered.

Gumerov [16] studied the economic and political aspects of the development of planning in the USSR, formulating the basic requirements for the ideology of strategic planning and management, and noting that the activity was reduced to formal changes in the regulatory framework and methodological support. Shafranskaya [35] notes that in the current conditions, it is necessary to build a full-scale strategic planning system. As Professor Orlenko [27] notes, we can consider the experience of implementing planned activities in Yugoslavia. Kryukov and Seliverstov [21] conducted an analysis of the draft strategy for the Socio-economic Development of the Siberian Federal District until 2035, and identified a number of shortcomings associated with systemic problems in regional development planning. One of the solutions is the use of a variable format for the development of the coal cluster, that is, the development of scenarios for existing and future trends in economic development.

Krupkina et al. [20] considered the issues of forecasting Russia's GDP using a structural factor model (DFM). The use of this model showed more stable results of GDP forecasting over time. The authors also point out that for a more effective forecast, it is better to give preference to models that also take into account the inverse relationship between variables.

Lazhentsev [24] considered the understanding of the "program-target method" as a scientific category that allows us to separate the objective causes of the mobilization economy from its reflexive interpretation. The author notes that a scientifically objective assessment of the current situation leads to solving the problems of long-term technological development.

Kleiner et al. [19] propose to use versions of strategic planning, taking into account the state of economic theory, economic policy, and the peculiarities of the functioning of the Russian economy.

A review of the scientific literature shows the increasing importance of planning issues for the development of economic entities, but insufficient attention is paid to the use of digital forecasting tools. Domestic and foreign research devoted to making forecasts using the cognitive modeling method deserves much attention.

Li and Chiang [11] studied the intelligent forecasting of financial time series based on a neurofuzzy approach with multiswarm intelligence. Applying CFS to CNFS can increase the adaptive capabilities of non-linear function mapping, which is valuable for non-linear forecasting. Istvan and Laszlo [18] studied fuzzy cognitive maps (FCMs), defining them as recurrent neural networks that are used to model complex systems using weighted cause-and-effect relationships.

Kwilinski and Kuzior [1] mention in their article about the theory of cognitive modeling for the development of industrial enterprises, but the article does not present real cognitive models for the development of industrial enterprises. Bąk and Cheba [9] present in their article the results of modeling a complex economic system of a country in order to achieve sustainable development goals. However, the article does not present scenarios of system behavior when exposed to the system under study.

Gorelova et al. [15] explore issues of cognitive modeling of socio-economic regional systems, which allowed them to propose development models for the Republic of Adygea in the context of the Granberg regional development model. However, these works did not consider the issues of cognitive modeling of certain industries or types of economic activity.

The models they developed provide directions for the development of the socio-economic systems under study, which can be used to make management decisions on the development of the region.

Kulba [23] proposed the construction of cognitive maps by using the method of summing the increments of factors. Maksimov [25] proposed a scenario analysis framework for cognitive modeling. Thus, there are different understandings in the planning tools for the development of weakly structured socio-economic systems.

Therefore, it is proposed to use a scenario-based approach using cognitive modeling to study forecasting the development of the industrial complex, since its application is possible without specific quantitative data. Thus, there are no works devoted to the construction of forecasts for the development of industry in the Southern Federal District. Gorelova G.V. worked in terms of forecasting the development of the subject – Adygea. Her forecasts were based on the use of cognitive modeling method. The analysis of statistical collections [17] has shown the absence of the necessary amount of data to build forecasts of industrial output using mathematical methods – exponential smoothing. Therefore, to build forecasts for industrial development, tools based on fuzzy logic were used – cognitive modeling, which does not require a large array of quantitative data of the predicted processes. The term "cognitive maps" was first proposed in 1948 by the American psychologist Tolman [37] in his work, "Cognitive maps in rats and humans". The development of this cognitive methodology was mainly due to the work of Atkin [7], Casti [10] and Roberts [30] [8]. We used the authors' concept of cognitive data modeling.

II. Methods and materials

Due to the lack of sufficient data to predict industrial development on the official website of Rosstat using the exponential smoothing method, the authors decided to build a model using cognitive tools [17, 36]. One of the tools for modeling the development of complex socio-economic systems is cognitive modeling. The authors of the article and the executors of the RNF scientific project, in accordance with the objectives of the scientific project, developed cognitive maps for predicting the development of the industrial complex of the Southern Federal District. By conducting a PEST analysis, target, indicative, regulatory, and control factors affecting the development of the industrial complex of the Southern Federal District, which form the tops of the cognitive model, were identified. Initially, 76 peaks were identified, which determine the development of the industrial complex of the Southern Federal District. These peaks were determined based on an analysis of statistics on types of products manufactured in the Southern Federal District [17, 36]. On the cognitive map, with such a number of vertices, it is quite difficult to understand the scenarios of the development of the socio-economic system. The second stage determined only the types of industrial production in accordance with the All-Russian Classifier of Economic Activities that exist in the industrial complex of the Southern Federal District on the basis of statistical reports of the subjects of the district: Rostov Region, Volgograd region, Astrakhan Region, Krasnodar Territory, the Republic of Kalmykia, the Republic of Crimea, the Republic of Adygea, and the federal city of Sevastopol. It should be noted that more detailed statistical reporting is not present everywhere and the indicators have different units of measurement: natural and cost, which makes it difficult to determine the main types of production.

The programs of socio-economic development of these subjects were also analyzed in one way or another related to the planning of industry. Unfortunately, there is no section in all programs that would be aimed at the development of industry with specific measures.

PEST – analysis and SWOT – analysis were carried out, which identified the tops of the cognitive model (Table 1).

Figure 1 shows the cognitive map G0 of the development of the industrial complex of the Southern Federal District, which is a result of the first stage of cognitive modeling – collecting information, determining the entities and trends in the development of economic integration, systematization of theoretical and conceptual provisions, analysis of the main properties and features, and development of a cognitive model of the system (determination of vertices, relationships between them, weight coefficients, functional dependencies). Due to the lack of reference cognitive models of industry in the Southern Federal District, it is not possible to compare it with the standard.

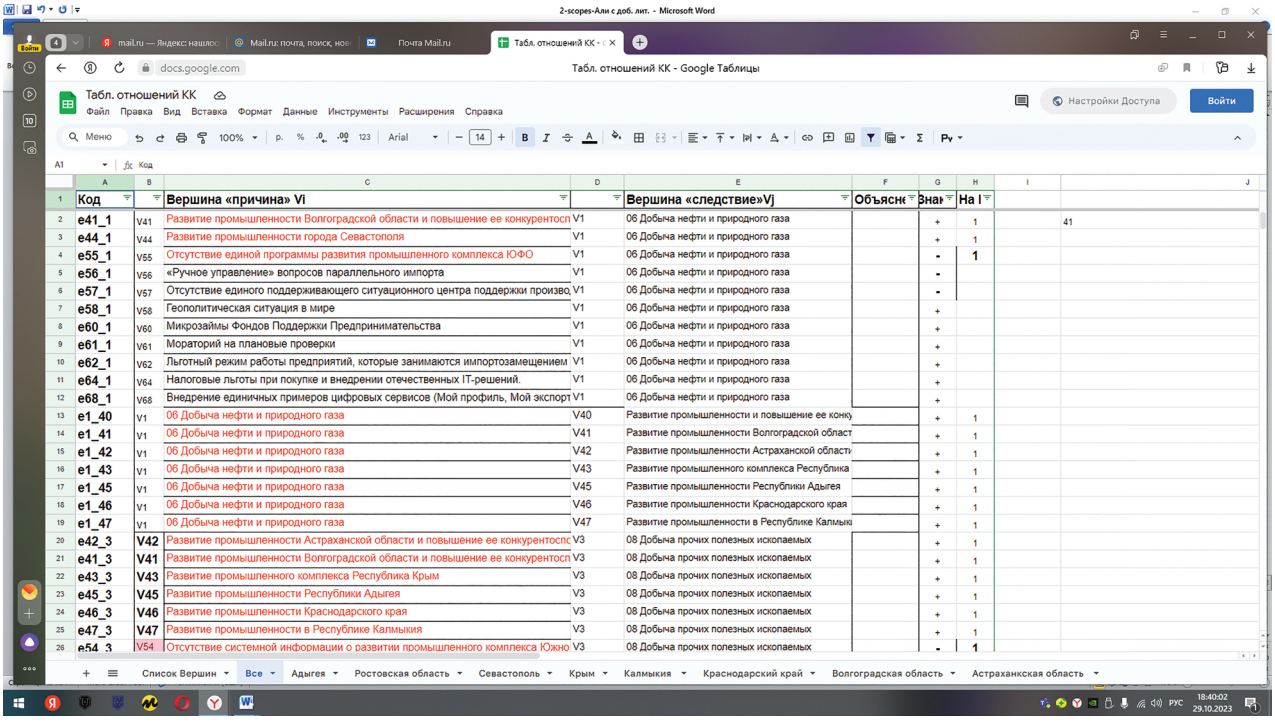
Mathematically, a cognitive map is a signed directed graph:

$$G = \langle V, E \rangle \tag{1}$$

Where:

V – the set of factors of the situation (vertices, objects, concepts), in which the vertices are elements of the system under study $V_i \in V$, $i = 1,2,\ldots,k$;

Table 1: Cognitive model vertex matrix G0.



Код		Вершина «причина» Vi		Вершина «следствие»Vj	Объясн	Знак	На I
e41_1	V41	Развитие промышленности Волгоградской области и повышение ее конкурентосп	V1	06 Добыча нефти и природного газа		+	1
e44_1	V44	Развитие промышленности города Севастополя	V1	06 Добыча нефти и природного газа		+	1
e55_1	V55	Отсутствие единой программы развития промышленного комплекса ЮФО	V1	06 Добыча нефти и природного газа		-	1
e56_1	V56	«Ручное управление» вопросов параллельного импорта	V1	06 Добыча нефти и природного газа		-	
e57_1	V57	Отсутствие единого поддерживающего ситуационного центра поддержки произво	V1	06 Добыча нефти и природного газа		-	
e58_1	V58	Геополитическая ситуация в мире	V1	06 Добыча нефти и природного газа		+	
e60_1	V60	Микрозаймы Фондов Поддержки Предпринимательства	V1	06 Добыча нефти и природного газа		+	
e61_1	V61	Мораторий на плановые проверки	V1	06 Добыча нефти и природного газа		+	
e62_1	V62	Льготный режим работы предприятий, которые занимаются импортозамещением	V1	06 Добыча нефти и природного газа		+	
e64_1	V64	Налоговые льготы при покупке и внедрении отечественных IT-решений.	V1	06 Добыча нефти и природного газа		+	
e68_1	V68	Внедрение единичных примеров цифровых сервисов (Мой профиль, Мой экспорт	V1	06 Добыча нефти и природного газа		+	
e1_40	V1	06 Добыча нефти и природного газа	V40	Развитие промышленности и повышение ее конку		+	1
e1_41	V1	06 Добыча нефти и природного газа	V41	Развитие промышленности Волгоградской област		+	1
e1_42	V1	06 Добыча нефти и природного газа	V42	Развитие промышленности Астраханской области		+	1
e1_43	V1	06 Добыча нефти и природного газа	V43	Развитие промышленного комплекса Республика		+	1
e1_45	V1	06 Добыча нефти и природного газа	V45	Развитие промышленности Республики Адыгея		+	1
e1_46	V1	06 Добыча нефти и природного газа	V46	Развитие промышленности Краснодарского края		+	1
e1_47	V1	06 Добыча нефти и природного газа	V47	Развитие промышленности в Республике Калмык		+	1
e42_3	V42	Развитие промышленности Астраханской области и повышение ее конкурентоспс	V3	08 Добыча прочих полезных ископаемых		+	1
e41_3	V41	Развитие промышленности Волгоградской области и повышение ее конкурентосп	V3	08 Добыча прочих полезных ископаемых		+	1
e43_3	V43	Развитие промышленного комплекса Республика Крым	V3	08 Добыча прочих полезных ископаемых		+	1
e45_3	V45	Развитие промышленности Республики Адыгея	V3	08 Добыча прочих полезных ископаемых		+	1
e46_3	V46	Развитие промышленности Краснодарского края	V3	08 Добыча прочих полезных ископаемых		+	1
e47_3	V47	Развитие промышленности в Республике Калмыкия	V3	08 Добыча прочих полезных ископаемых		+	1
e54_3	V54	Отсутствие системной информации о развитии промышленного комплекса Южно	V3	08 Добыча прочих полезных ископаемых		-	1

E – the set of cause-and-effect relationships between factors of the situation (arcs) $E_{ij} \in E$, $i, j = 1,2,\ldots,N$, in which the arcs reflect the relationship between the vertices V_i and V_j.

The analysis of the cognitive map includes the definition of routes, paths, and cycles that allow one to explore various cause-and-effect relationships. Highlighting these consecutive lines on a graph is not an easy task. The complexity of the system also entails problems of complexity in analyzing long causal chains, cycles, and management complexity.

The complexity of the system also entails problems of complexity in analyzing long causal chains, cycles, and management complexity. There are some definitions necessary for the analysis of cause-effect relationships and cycles.

The route $M = \{eij\}$, $i, j = 1, 2, \ldots n$ in graph G is a sequence (finite or infinite) of n arcs (edges) that every two adjacent arcs have a common vertex.

A chain, path is a route that does not contain repeating edges (arcs), that is, if ei1j1 is not equal to ei2j2 for any i, j, with $i \neq j$.

As indicative vertices, the following were defined (E_{ij}):

- Growth of production volumes;
- Growth in the number of enterprises;
- Increase in the number of jobs;
- Increase in the output of import substitution products.

The regulatory vertices were selected as follows:

- Lack of systematic information on the development of the industrial complex of the Southern Federal District in the context of types of products;
- Lack of a unified program for the development of the industrial complex of the Southern Federal District;
- Creating a portal Russoft.ru, where domestic software products are collected, with the support of the Ministry of Finance;
- Manual management of parallel import issues;
- Lack of a single supporting situational production support center;
- The geopolitical situation in the world;
- Microloans of Entrepreneurship Support Funds.

The programs (subprograms) of the subjects of the Southern Federal District related to the development of the industrial complex were selected as the managing vertices (V_i) as follows:

- Development of industry and increasing its competitiveness. Rostov region;

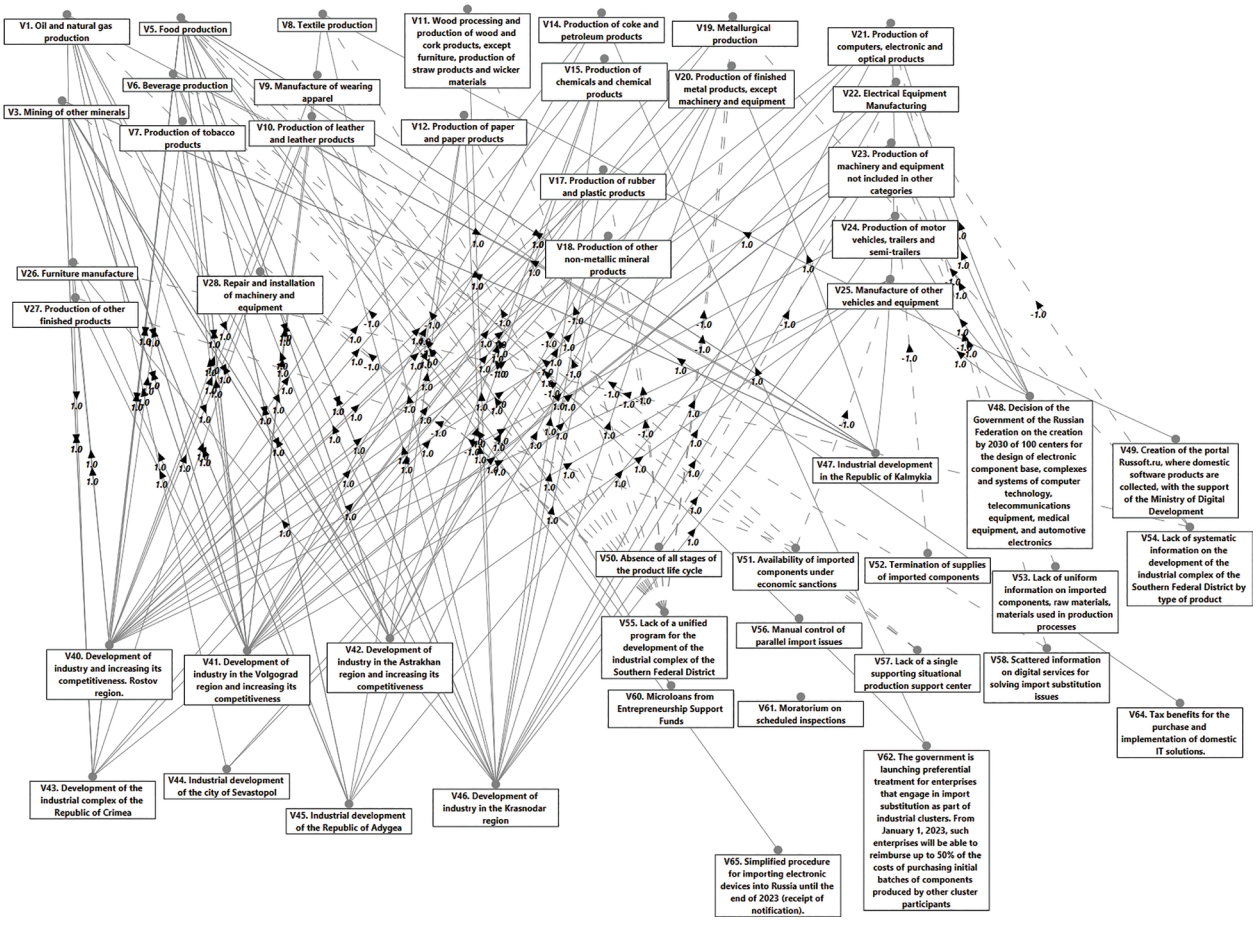


Figure 1: Cognitive map of industrial complex development.

- Development of industry in the Volgograd region and increasing its competitiveness;
- Development of the industrial complex of the Republic of Crimea;
- Development of industry in the Krasnodar Territory;
- Development of industry in the Astrakhan region and increasing its competitiveness;
- Development of the industry of the Republic of Adygea;
- Development of the industrial complex of the Republic of Crimea;
- Development of industry in the Republic of Kalmykia;
- Industrial development of the city of Sevastopol.

By analyzing the official statistical data of the Southern Federal District, the following peaks were selected – types of industrial production – opportunities for the development of the following industries have also been added [17,36] (V_j):

- Oil and natural gas production;
- Extraction of other minerals;
- Food production;
- Beverage production;
- Production of tobacco products;
- Manufacture of textiles;
- Manufacture of clothing;
- Manufacture of leather and leather products;
- Wood processing and production of wood and cork products, except furniture, production of straw products and materials for weaving;
- Production of paper and paper products;
- Production of coke and petroleum products;
- Production of chemicals and chemical products;
- Production of rubber and plastic products;
- Production of other non-metallic mineral products;

- Metallurgical production;
- Production of finished metal products, except machinery and equipment;
- Production of computers, electronic and optical products;
- Production of electrical equipment;
- Production of machinery and equipment not included in other groupings;
- Production of motor vehicles, trailers, and semi-trailers;
- Manufacture of other vehicles and equipment;
- Furniture production;
- Production of other finished products.

b. Southern Federal District

Using formula 1 and computer program [28], a cognitive map of the industry of the Southern Federal District was built (Figure 1). This cognitive map is a model of industrial development. It is impractical to reduce the number of vertices, since some types of industry will be absent. The cognitive map was built using a program that used formula (1) to build vertices (V_i) and connections E between them.

Stability analysis is directly related to the analysis of the processes of propagation of disturbances according to the concepts of the cognitive map. Let some changes begin at vertex 1, for example, the growth of industry in the Rostov region. The influence spreads along the routes M1 = {e12, e13, e14}. As you can see, an increase in the X1 indicator along the M1 route leads to an increase in 1. At a certain point in time, due to these oppositely directed processes, an equilibrium must occur between the vertices.

A qualitative analysis of routes and cycles does not reveal the full depth of the processes taking place in a real system. A further generalization may be to assign to each vertex i a numerical value Xi, $i = 1,2, \ldots, k$ and introduce the intensivity of the connection between vertices i and j as a function of $f(i, j)$.

Under the influence of various perturbations, the values of variables at the vertices of the graph can change; a signal received from one of the vertices propagates along the chain to the rest, amplifying or fading.

In general, if there are several vertices j adjacent to j, the process of perturbation propagation along the graph is determined by the rule:

$$x_i(t + 1) = x_i(t) + = f(x_i, x_j, a_{ij}) p_j(t) \quad (2)$$

Modeling can be carried out in steps or pulses.

The essence of such modeling is that a certain change is set at one of the vertices of the graph. This vertex actualizes the entire system of indicators, that is, the vertices associated with it, to a greater or lesser extent.

The second stage of cognitive modeling is the study of the properties of a complex system on a cognitive model, such as resistance to disturbances, structural stability, paths, cycles, complexity, connectivity, sensitivity, dynamics, and simplicial analysis.

The program was used to make forecasts [28] and formula (2). Figure 2 shows the results of calculating the eigenvalues of the adjacency matrix of the model G. The determination of the roots of the characteristic equation is necessary to analyze the stability of the system to disturbances and by the initial value. In this case, the stability criterion M < 1 is used, and M is the maximum modulo of the corresponding number (the root of the characteristic equation of the matrix) [12]. Since in this case M = 3.69 > 1, the Kranet system G is unstable neither to perturbations nor to the initial value.

The third stage of cognitive modeling is scenario analysis, carried out using pulse modeling [14, 16]. It makes it possible to significantly expand the

Eigenvalues

#	Real part	Imaginary part	Module (3.6716)
0	3.6716	0.0	3.6716
1	-3.6716	0.0	3.6716
2	-0.7206	0.0	0.7206
3	0.7206	0.0	0.7206
4	0.0	0.0	0.0
5	0.0	0.0	0.0

Figure 2: The results of calculating the eigenvalues of the adjacency matrix of the cognitive map G0.

possibilities of using indicators of industrial development and indicators of its components, and causal analysis is a methodology for the scientific analysis of these phenomena and processes.

Impulse modeling can be used to further simulate the development of the situation [13]:

$$x_i(n+1) = x_{Vi}(n) + \sum_{j=1}^{k-1} f_{ij} P_j(n) + Q_i(n) \quad (3)$$

Where:

$x_i(n)$ – the value of the impulse in the vertex V_i at the previous moment-stroke of modeling n;

$x_i(n+1)$ – at the moment of interest to the researcher $(n+1)$;

f_{ij} – momentum conversion coefficient;

$P_j(n)$ – is the impulse value in the vertices adjacent to the vertex V_i;

$Q_i(n)$ – is the vector of perturbations and control actions introduced into the vertices V_i at the moment n. This is the initial impulse.

When it is difficult to quantify the $x_i(n)$ then the $x_i(n) = 1$, $P_j(n) = 1$ will be accepted [10].

The program was used to make forecasts [28]. As can be seen from Figures 3 and 4, when implementing programs aimed at improving the industry of the Rostov region, its industry will begin to develop

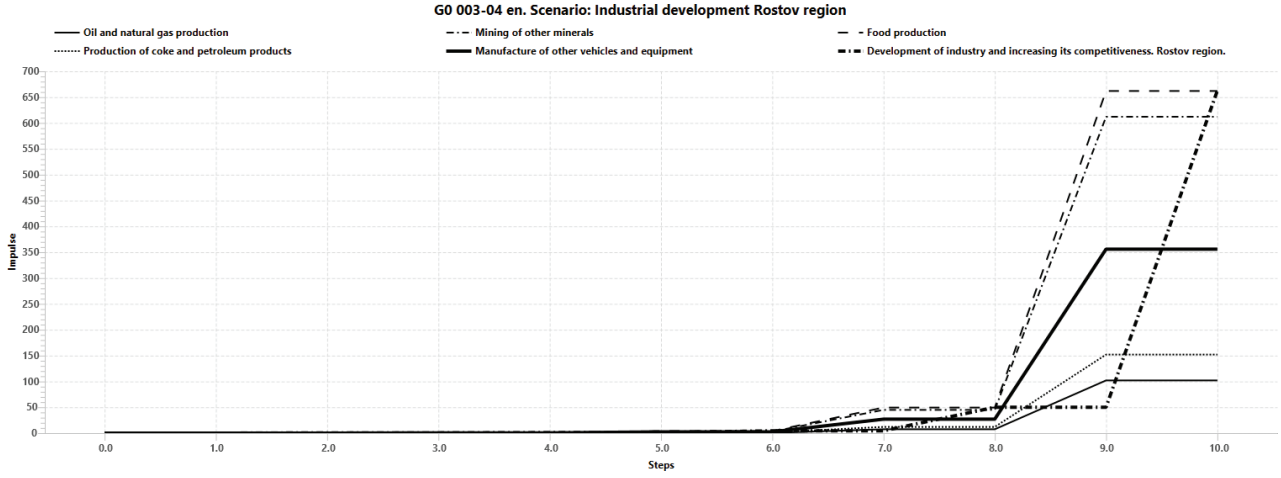


Figure 3: Simulation results according to scenario 1. Implementation of the industrial production program of the Rostov region.

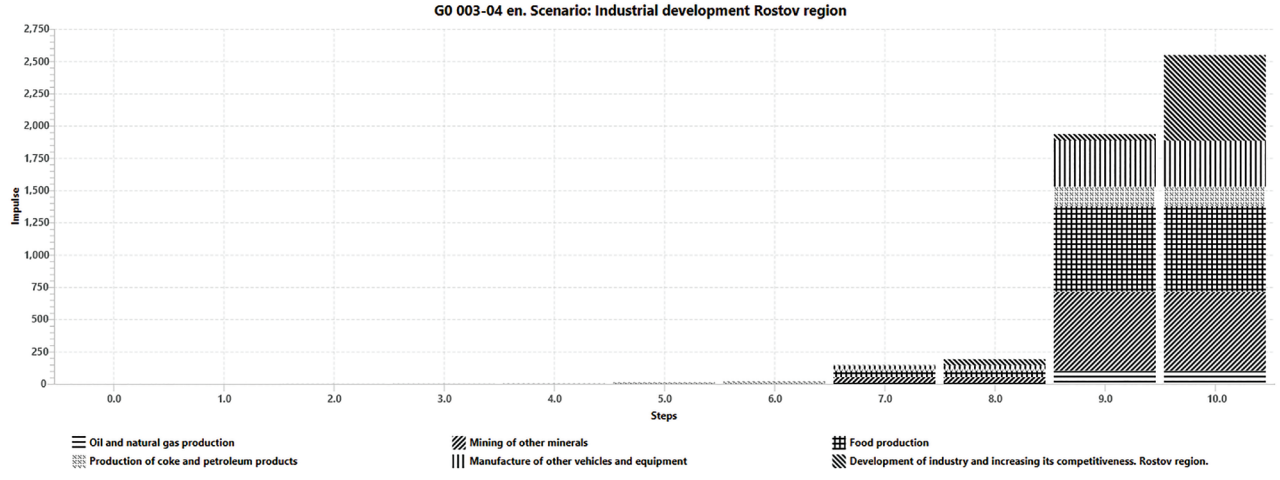


Figure 4: Simulation results according to scenario 1. Implementation of the industrial production program of the Rostov region.

rapidly. Pulse modeling was used for further modeling [23]. Since it is impossible to quantify the results of the influence of factors, according to the theory of cognitive modeling, impulse influence +1 is considered (there is an influence); – 1 (no impact).

To obtain forecasts of the development of the situation using cognitive maps, the method with summation of factor increments is used in this work [23]. Possible scenarios for the development of the system are considered in the example of the industry of the Rostov region – scenario 1 and the Krasnodar Territory – scenario 2, as subjects of the federal district, where the widest range of industries are represented and which were selected to determine the first scenario options. These scenarios are preliminary scenarios for a given set of factors.

Scenario #1. Let the program to increase the industry indicators of the Rostov region be implemented, the control pulse q40 = + 1 (q40 – vertices in Table 1); the perturbation vector $Q = \{q_{40} = +1\}$. The simulation results are presented in Figures 3 and 4.

Scenario #2. Let the program to increase the indicators of the Krasnodar Territory industry be implemented: the control $q_{46} = +1$ (q_{46} – vertices in Table 1) and the perturbation vector $Q = \{q_{46} = +1\}$. The simulation results are presented in Figures 5 and 6.

As can be seen from Figures 5 and 6, when implementing programs aimed at improving the industry

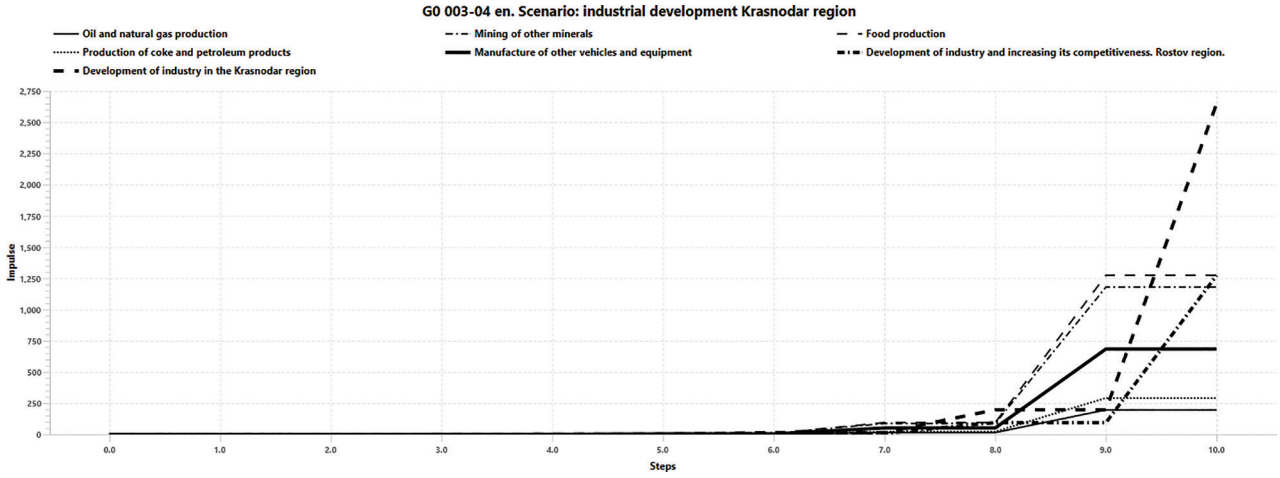


Figure 5: Simulation results according to scenario 2. Implementation of the industrial production program of the Krasnodar Territory.

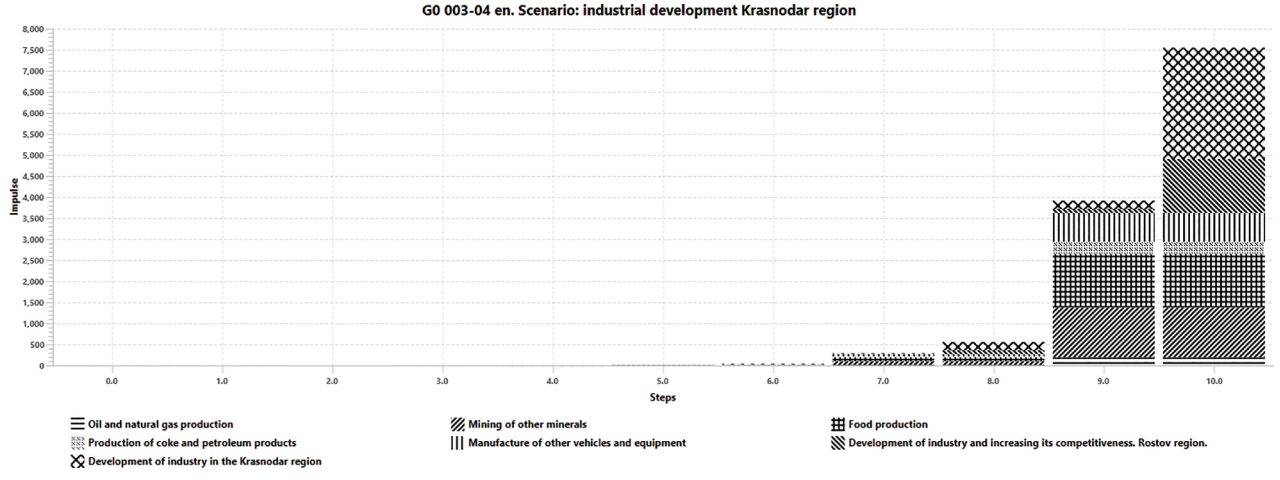


Figure 6: Simulation results according to scenario 2. Implementation of the industrial production program of the Krasnodar Territory.

of the Krasnodar Territory, its industry will begin to develop rapidly, and positively affect the industry of the region as a whole.

The results of the scenario analysis indicate the need to make decisions corresponding to these trends, which should have a positive impact on changes in target factors. The development model of the industrial complex of the Southern Federal District has shown that the industry of the district is in an unstable state.

III. Results and discussion

The system under study is in exactly this state. So a lot has been done at the government level to solve the sanctions problems. At the same time, the regional authorities of both the federal district and the subjects of the federation are making minimal efforts in this direction; we can say that they are before the situation of the introduction of economic sanctions, there are no systematic measures to support enterprises. Even the programs of the regions and territories of the Southern Federal District related to industry do not reflect the current external situation and do not contribute to the activation and increase the pace of industrial development.

Analysis of the development programs of the Southern Federal District has shown that there is no industrial development program or plan. The cognitive map G0 developed by the authors allow us to have a model of industrial development in the Southern Federal District, which has not been presented before. In the District, it is necessary for regional authorities to develop a regional development plan, which can be built on the basis of the cognitive model proposed by Maksimov [25]. Impulse influence in cognitive modeling makes it possible to determine the results of control actions from, for example, the government, and governors on the development of the system under study – the industrial complex of the Southern Federal District. The plenipotentiary representative of the President of the Southern Federal District and governors can use the cognitive model developed by the authors to develop an industrial development program. Further research on the development of industry in the Southern Federal District should be aimed at developing a plan for the production of industrial products in quantitative terms.

IV. Conclusion

It can be stated that at the country level, such governing and regulatory factors have now been introduced that will give a sharp jump in the development of industry, literally as early as 2023. The simulation results indicate that the system under study is unstable. It can be seen from the cognitive map (Figure 1) that there are unstable cycles in it, which contain positive connections and an even number of negative ones. In this variant, we do not separate the internal subsystem and the external one, so in real life, the internal subsystem cannot be isolated from the external subsystem. However, if we strengthen the impact of the governing and regulatory peaks, there will be a sharp breakthrough in development.

It should be noted that cognitive modeling does not make it possible to predict and plan accurate quantitative indicators. It is possible to determine the impulses of the development of certain types of industry. One of the solutions to the problem of planning the production of accurate quantitative indicators is the formation of a database of production capacities of enterprises both for the subjects of the district and for the federal district as a whole. The database data can be analyzed with the help of artificial intelligence for the growth of the output forecast. However, now, according to the authors, the task is to predict the development of industry, taking into account the influence of external factors that may contribute to or slow down the development of industry. According to the authors of the article, the use of artificial intelligence capabilities to make an accurate quantitative forecast of manufactured products in natural meters is one of the tools for predicting trends in the development of the system – the industrial complex of the Southern Federal District.

About the authors

Tatiana A. Makarenya, ORCID: 0000-0002-8251-3912, Doctor of Economics, Associate Professor, Head of the Department of Engineering Economics, Southern Federal University, e-mail: mta-76@inbox.ru.

Ali Sajae Mannaa, ORCID: 0000-0003-0824-8038: Assistant Dept. synergetics and management processes. prof. A.A. Kolesnikova Federal State Autonomous Educational Institution of Higher Education, Southern Federal University, email: ali-88mannaa@gmail.com

Aleksey I. Kalinichenko, ORCID: 0000-0002-5460-5369, PhD student, Southern Federal University, alecsy.k@gmail.com

Svetlana V. Petrenko, ORCID:0000-0002-0767-2200, Ph.D. economy Sci., Associate Professor, Department of Engineering Economics, Southern Federal University, email: lana.stash@gmail.com

Acknowledgments

The study was supported by grant No. 23-28-00537 of the Russian Science Foundation, https://rscf.ru/project/23-28-00537/

References

[1] Aleksy Kwilinski & Aleksandra Kuzior (2020). *Cognitive technologies in the management and formation of directions of the priority development of industrial enterprise*//Management Systems in Production Engineering, 28, Issue 2, pp. 133-138. DOI 10.2478/mspe-2020-0020)

[2] Atkin, R. H. (1974). An Algebra for Patterns on a Complex, 1. Int. I. ManMachine Studies 6, pp. 285-307.

[3] Atkin, R. H. (1974). An Algebra for Patterns on a Complex, 1. Int. I. ManMachine Studies 8, pp. 483-448.

[4] Atkin, R. H. (1997). Combinatorial Connectives in Social Systems. An Application of Simpicial Complex Structure to the Study of Large Organisations, Interdisciplinary Systems Research.

[5] Atkin, R. H. (1974). Mathematical Structure in Humman Affairs, Heinemann, L.

[6] Atkin, R. H., Casti J. Polyhedral Dinamics and the Geometry of Systems, RR-77-6.

[7] Atkin, R.H. (1977). *Combinatorial Connectivies in Social Systems. An Application of Simplicial Complex Structures to the Study of Large Organisations. Interdisciplinary Systems Research.* Birkhäuser Basel.

[8] Axelrod, R. (1976). *The Structure of Decision: Cognitive Maps of Political Elites.* Princeton. University Press.

[9] Bąk, I. & Cheba, K. (2020). *Fuzzy cognitive maps and their application in the economic sciences*// Econometrics. Ekonometria. Advances in Applied Data Analysis, 24(3)

[10] Casti, J. (1979). *Connectivity, Complexity, and Catastrophe in Large-scale Systems.* A Wiley – Interscience Publication InternationalInstitute for Applied Systems Analysis. Chichester – New York – Brisbane –Toronto: JOHN WILEY and SONS.

[11] Chushein, Li & Tai-Wei, Chiang (2012). *Intelligent Finansial times series forecasting: a complex neuro-fuzzy approach with multi-swarm intelligence*. Int. J. Appl. Math. Comput. Sci., 22, 4, 787–800 DOI: 10.2478/v10006-012-0058-x

[12] *Cognitive modelling as a tool for strategic planning of an industrial development*/A. Yu. Kazanskaya, T. A. Makarenya, Ya. A. Nalesnaya, S. V. Stash. DOI: 10.15405/epsbs.2021.09.02.91//ICEST 2021 II International Conference on Economic and Social Trends for Sustainability of Modern Society. – URL: https://www.researchgate.net/publication/330355377_APPLICATION_OF_COGNITIVE_MODELING_IN_PROJECT_MANAGEMENT.

[13] Gorelova, G. V., & Kalinichenko A. I. (2018). *Toolkit of cognitive modeling of complex systems// Proceedings of XXII International Scientific and Practical Conference "System analysis in design and management" (SAEC-2018), part 1. – SPbGTU: St. Petersburg.* pp. 399-412. (in Russian).

[14] Gorelova, G.V., Pankratova, N.D. (2015). *Innovative Development of Socio-Economic Systems on the Basis of Foresight Methodologies and Cognitive Modeling*//Kiev: Naukova Dumka. -. - 464 c. (In Russian).

[15] Gorelova, G.V., Zakharova, E.N., Radchenko, S.A. (2006) *Research of weakly structured problems of socio-economic systems: a cognitive approach*. - Rostov n/D: Publishing house of Russian State University. - 332 c. (In Russian).

[16] Gumerov, R. R. (2019). *Realization of national goals in the assumed model of strategic national economic planning//Russian Economic Journal. No. 5.* Pp. 110-120. (DOI: 10.33983/0130-9757-2019-5-3-24) (In Russian).

[17] http://rosstat. gov. ru - official website of the Federal State Statistics Service of the Russian Federation.

[18] Istvan A. Harmati & Laszlo T. Koczy (2019). *On the Convergence of sigmoidal fuzzy grey cognitive maps*. Int. J. Appl. Math. Comput. Sci., 29, 3, 453-466 DOI: 10.2478/amcs-2019-0033

[19] Kleiner, G.B., Rybachuk, M.A. & Karpinskaya, V.A. (2022). *Strategic planning and system optimization of the national economy*//Forecasting problems, 3(192), 2022. pp. 6-15. DOI: 10.47711/0868-6351-192-6-15

[20] Krupkina, A. S., Vinogradova, O. S., Orlova, E. A., & Ershova, E. N. (2022) *Forecasting Russia's GDP using the production method*//Bulletin of Moscow University. Series 6. Economics, (5), pp. 62-81. https://doi.org/10.38050/01300105202254

[21] Kryukov, V.A., Seliverstov, V.E. (2022) *Strategic planning of spatial development of Russia and its macro-regions: captive of old illusions*// Russian Economic Journal. # 5. Pp. 22-40. https://doi.org/10.33983/0130-9757-2022-5-22-40

[22] Kim, H. S., Lee K. C. (1998). Fuzzy implications of fuzzy cognitive map with emphasis on fuzzy causal relationship and fuzzy partially causal relationship. Fuzzy Sets and Systems,. Vol.97/P/303-313.

[23] Kulba, V. V. (2002). *Scenario Analysis of the Dynamics of Socio-Economic Systems Behavior* (Scientific publication)/Kulba. V. V., Kononov, D. A., Kovalevsky, S. S., Kosyachenko, S. A., Nizhegorodtsev, R. M., I. V. Chernov. - M.: IPU RAN,. - 122c. (In Russian).

[24] Lazhentsev, V. N. (2023). *Program-targeted mobilization of resources//* Forecasting problems, 1(196),. pp. 32-41. DOI: 10.47711/0868-6351-196-32-41

[25] Maksimov, V.I. (2001). *Cognitive Technologies - from Ignorance to Understanding*. Cognitive Analysis and Situation Development Management (CASC'2001). Proc. Int. Conf. - 2001. - Vol. 1. - pp. 4-18. (In Russian).

[26] Mnukhin, V. (1996). The Modular Homology of Inclusion Maps and Group Actions J. of Combinatorial Theory, S. A 74, pp. 285-300. Article No. 0051.

[27] Orlenko, L. P. (2018). *Advice to the New President of the Russian Federation on Creating a High-Tech Economy and Necessary Defense//*National Interests: Priorities and Security. T. 14. Issue. 5. pp. 808-823. URL: https://doi.org/10.24891/ni.14.5.808 (In Russian).

[28] Program for Cognitive Modeling and Analysis of Socio-Economic Systems of Regional Level. Certificate of state registration of computer programs No. 2018661506 of 07.09.2018.

[29] Prigozhin, I., Stengers I. Time, chaos, quantum. To the solution of the order of time: Transl. from English M.: Editorial office URSS, 2000; Prigogine I., Stengers and Order from Chaos. M.: Progress 1986.

[30] Roberts, F. (1978). *Graph Theory and its Applications to Problems of Society*. Philadelphia: Society for Industrial and Applied Mathematics.

[31] Roberts, F. (1976). Discrete Mathematical Models. Prentice-Hall, Englewood Cliffs. News Jersey.

[32] Saeed, K. The dynamics of economic growth and political instability in developing counties//System Dinamic Rewiev. 1986. Vol. 2 No. 1. pp. 20-35.

[33] Solso, R. Cognitive psychology: Transl. from English M.: Trivola, 1996.

[34] Stylios, C. D., Georgopoulos, V. C., Groumpos P. P. (1997). Introduction the Theory of Fuzzy Cognitive Maps in Distribited Systems. Proceedings of 12th IEEE Intern. Symposium on Inelligent Control, Instanbul. Turkey. pp. 55-60.

[35] Shafranskaya, A. M. (2023). *Economic and political aspects of the development of planning in the USSR*//Russian Economic Journal. No. 1. Pp. 110-120. (https://doi.org/10.52210/0130-9757_2023_1_110) (In Russian).

[36] Socio-economic indicators of the Southern Federal District in January-September 2022 Rostov-on-Don. 2022. [Electronic resource]. - URL: https://rostov.gks.ru/.

[37] Tolman, E. C. (1948). Cognitive maps in rats and men. *Psychological Review.* 55 (4), 189-208.