ТЕОРЕТИЧНІ ТА ПРИКЛАДНІ ПРОБЛЕМИ ІНТЕЛЕКТУАЛЬНИХ СИСТЕМ ПІДТРИМАННЯ ПРИЙНЯТТЯ РІШЕНЬ

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USING COGNITIVE MAPS TO STUDY ISSUES CONCERNING THE IMPROVEMENT OF THE QUALITY OF LIFE OF POPULATION IN THE FRAME OF INTERREGIONAL DISPARITIES

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Abstract. This paper studies issues of the rise in the standards of living and improvement of the quality of life of the population in the frame of intermunicipal disparities. Simulation and modelling are examined in relation to research of standards of living and quality of life. Tools of cognitive modelling and simulation are used to acquire new knowledge on the regional social and economic, ecological, and political system which determines the standards of living and quality of life. A cognitive model studying the quality of life was designed and its structural properties were analyzed. Scenarios were created to model possible developments of the situation under the influence of various factors. The novelty of the work is in applying a new informational technology of cognitive modelling to studying the improvement of the quality of life in the frame of intermunicipal disparities.

Keywords: cognitive modelling, quality of life of population, standards of living, regional development, intermunicipal disparities.

INTRODUCTION

With the RF pursuing the innovative socially-oriented development of economy in accordance with [1], it will be necessary to carry out a number of reforms interrelated in terms of resource and time limitations. In respect of human potential, it is supposed that an enabling environment should be created to develop an individual's talents and skills, improve people's quality of life and social welfare, provide a competitive edge to people and develop the related supporting socially-oriented economic sectors.

These reforms in accordance with the concept aim at 'overcoming negative demographic trends, stabilizing the population and providing for its growth, improving the population's quality of life; ensuring steady pay rise; providing access to quality education and medical care, ensuring safety and order; providing affordable and quality housing for people, creating comfortable urban environment and efficient public utility sector, developing a flexible population relocation system taking into account regional and national diversity…

A greater number of scientists have recently been using the notion of social stratification which refers to a society's categorization into groups based on such

criteria as income level or lifestyle, the existence or absence of privileges. Based on the social stratification, the standard of living indicator may be represented as the part of people who belong to a certain social stratum.

It is a rather complex and painstaking process to study and estimate people's standards of living and quality of life. Development and implementation of innovative tools analyzing the quality of life would solve a number of complex tasks while estimating the population's quality of life [2–4]. This paper suggests using cognitive techniques to study issues of the people's quality of life improvement, scientific prediction, and cognitive analysis of socioeconomic development of the region amid interregional disparities [5–8].

Cognitive modelling of complex objects includes development of a cognitive model of the system under the study (signed directed graph, functional graph); analysis of the developed model properties (complexity, stability, sensitivity); analysis of paths and cycles; scenario modelling; making the decision on the selection of the scenario most feasible for the implementation [9–16].

The cognitive study of the issues of the population's quality of life improvement in the frame of interregional disparities yielded the Standards of Living and Quality of Life (SL&QL) model as a hierarchical cognitive map which generalizes causal relations between socioeconomic development indicators at the regional level [17–27].

DEVELOPMENT OF THE SL&QL COGNITIVE MODEL

To develop the SL&QL model, the theory and practical provisions on the quality of life, as well as statistics, expert surveys, and results of a SWOT analysis [2, 3, 28] were used.

During the initial modelling phase, the research objective was formulated and approved; theoretical evidence and statistics were collected, and expert surveys were carried out. As a result of data processing, a set of vertices $V=\{v_i\}$ was created and relationships $E=\{e_{ij}\}$, $j=1,2,\ldots,k$ between the vertices were mapped $G=<V,E>$. The relationships can be defined as weighting factors w_{ij} and functions $F=\{f_{ij}\}$.

Table 1 contains the vertices which are the influences affecting the people's standards of living and quality of life in the region.

Table 1. Vertices of the cognitive map G_0 "The Standards of Living and Quality of Life"

Code	Vertex name	Vertex assignment
V_1	Quality of life in the region	Target
V_2	Living standards in the region	Target
V_3	Gross Regional Product	Indicative
V_4	Regional and municipal budgets	Basic
V_5	Ecological situation	Basic
V_6	State of education	Basic
V_7	Health status	Basic
V_8	Social environment	Basic
V_9	Social inequality	Outrageous
V_{10}	Demographic indicators	Indicative

Continued tabl. 1

Code	Vertex name	Vertex assignment
V_{11}	Industrial production	Manager
V_{12}	Agricultural production	Manager
V_{13}	Labor market	Outrageous
V_{14}	The salary	Managed
V_{15}	Population income	Basic
V_{16}	Inter-municipal differentiation	Outrageous
V_{17}	Regional migration	Outrageous
V_{18}	Investment climate	Basic
V_{19}	State policy in the field of improving the quality of life	Manager
V_{20}	Security (economic, social, environmental, legal)	Outrageous
V_{21}	Geopolitical situation	Outrageous

For the SL&QL cognitive map *G*, see Fig. 1. To create cognitive map G, the tools of the information-analytical Cognitive Modeling Software System (CMSS) were used [29]. In Fig.1, positive links are shown as solid lines. When the value of the signal at vertex V_i increases or vice versa, the value of the signal at V_j increases or decreases. Negative links are shown as dashed lines. When the value of the signal at vertex V_i increases or vice versa, the value of the signal at V_j decreases or increases.

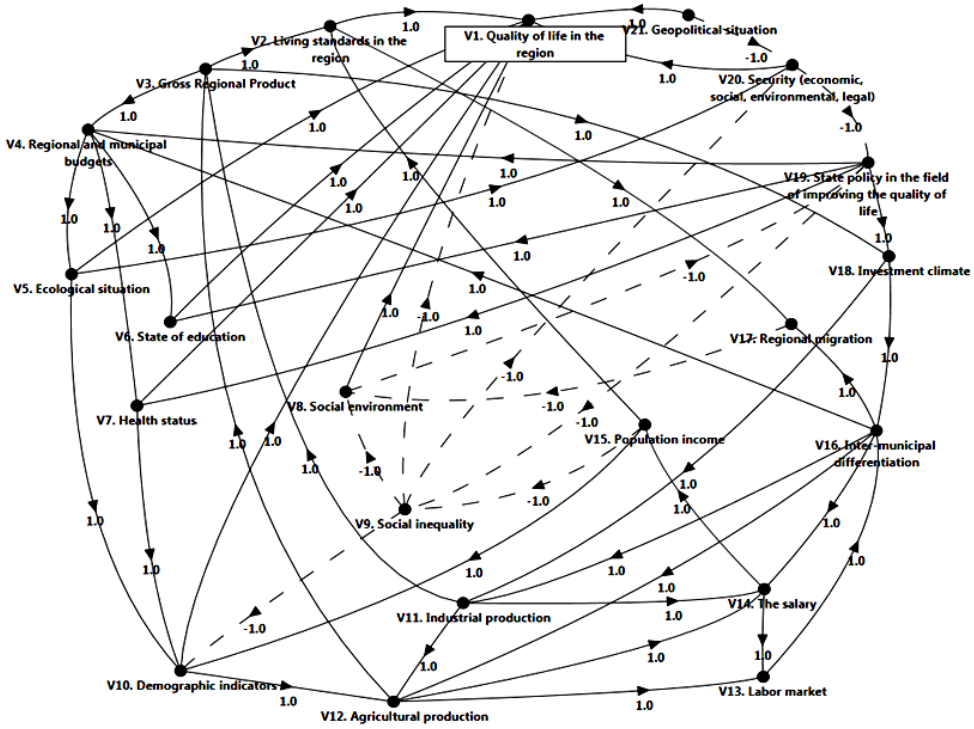

Fig. 1. The cognitive map G

During the second phase, the system stability for disturbances as well as the structural stability were analyzed.

When analyzing the system stability for disturbances, the roots were found for a characteristic equation of the relational matrix of SL&QL graph G. Solving the characteristic equation is shown in Fig. 2. As the maximum absolute of value of $|M| = 2 > 1$, then in accordance with the accepted criterion [30, 31], the system under study is unstable for disturbances and requires control.

Eigenvalues			
#	Real part	Imaginary part	Module (2,0007)
0	2,0007	0,0	2,0007
1	-0,1004	1,5721	1,5721
2	-0,1004	-1,5721	1,5721
3	0,7457	1,1233	1,1233
4	0,7457	-1,1233	1,1233
5	-1,1555	0,6208	1,1555
6	-1,1555	-0,6208	1,1555
7	-0,2267	0,9673	0,9673
8	-0,2267	-0,9673	0,9673
9	0,4402	0,5623	0,5623
10	0,4402	-0,5623	0,5623
11	-1,029	0,0	1,029

Fig. 2. The roots for a characteristic equation of the graph *G*

The analysis of positive and negative cycles of graph *G* allows concluding the model is structurally stable [9, 10, 30, 31]. For results of the computing experiment, see Fig. 3.

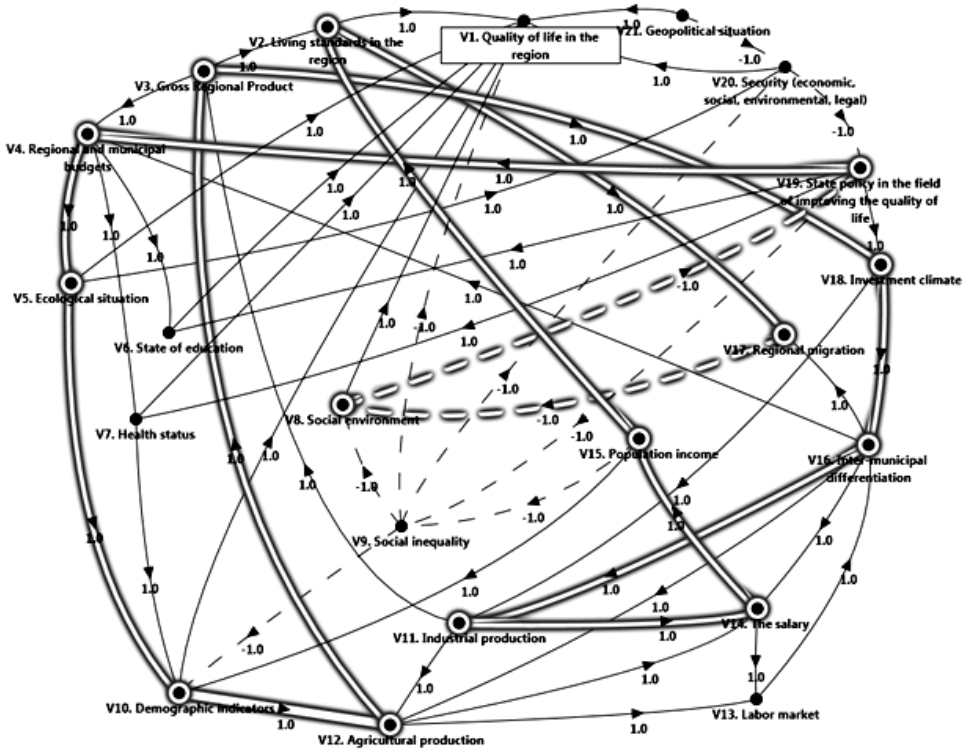

Fig. 3, a. The cycle of the graph *G*

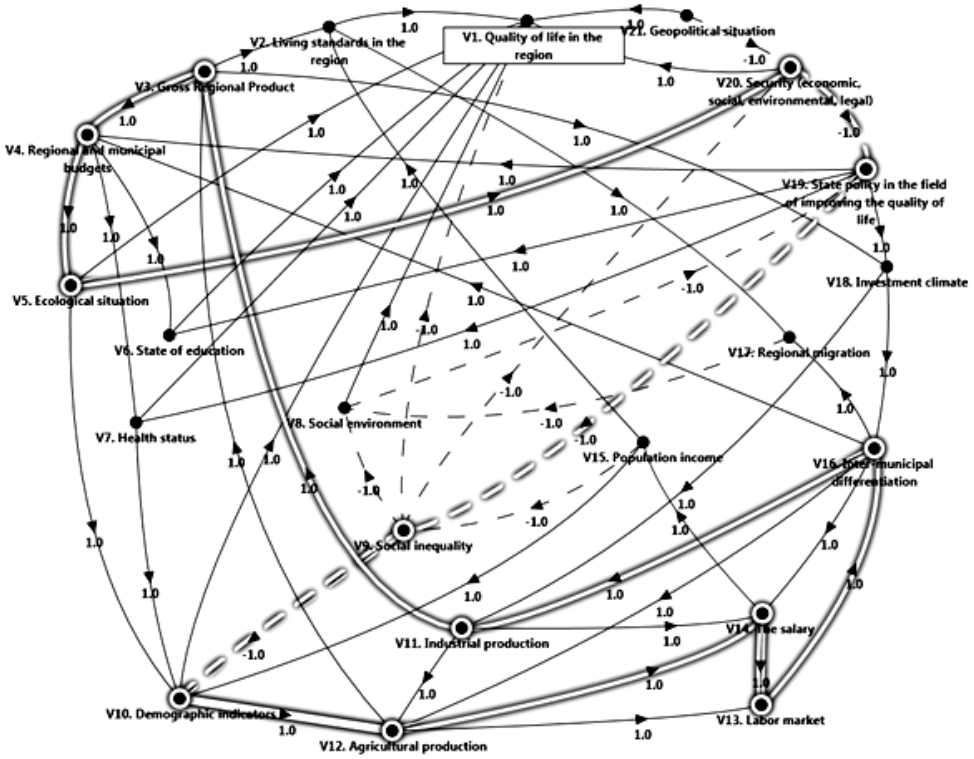

Fig. 3, b. The cycle of the graph *G*

In Fig. 3, as an example, the negative cycle which stabilizes the system (the upper graph) and the positive cycle which accelerates processes (the lower graph) are highlighted. SL&QL graph *G* includes 232 cycles, of which 101 are negative. An odd number of negative feedback cycles in graph G proves the system under consideration is structurally stable [30, 31].

SCENARIO MODELLING IN GRAPH *G*

The next step in the cognitive study involves pulse modeling of possible situation development scenarios on the regional level with the various controlling, restricting, and disturbing influences considered. When simulating possible system behavior scenarios, in the cognitive map at moment *n* signals are added as pulses q_i, at vertices V_i, the combination of which forms disturbance and control vector $Q(n) = \{q_1, \ldots, q_k\}$.

Prior to modelling scenarios in the SL&QL cognitive map, the computing experiment plan was worked out, which is a set $\{Q(n)\}$ which represents possible system behavior trends when the relevant control or disturbance influences are added.

Fig. 4 illustrates how the situation develops under conditions of a pulse process in accordance with scenario 1. Let us assume the state's social welfare policies are improving: $q_{19} = +1$.

Scenario 1. $Q_1(n) = \{q_1 = 0, \ldots, q_{19} = +1, \ldots, q_{21} = 0\}$.

Table 2 contains results of the computing experiment.

The acquired results are represented in the respective line charts which are drawn based on the results of the pulse process calculation (see Table 2). For the line charts most demonstrable in respect of the situation development trends at some vertices of graph G, see Fig. 4.

Table 2. Calculation of impulse processes in accordance with the scenario 1

Vertex	Step								
	0,0	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0
V_1. Quality of life in the region	0,0	0,0	0,0	3,0	10,0	13,0	10,0	10,0	41,0
V_2. Living standards in the region	0,0	0,0	0,0	0,0	0,0	1,0	8,0	16,0	18,0
V_3. Gross Regional Product	0,0	0,0	0,0	0,0	1,0	6,0	9,0	8,0	21,0
V_4. Regional and municipal budgets	0,0	0,0	1,0	1,0	2,0	1,0	5,0	14,0	28,0
V_5. Ecological situation	0,0	0,0	0,0	1,0	1,0	2,0	1,0	5,0	14,0
V_6. State of education	0,0	0,0	1,0	2,0	2,0	1,0	-1,0	4,0	16,0
V_7. Health status	0,0	0,0	1,0	2,0	2,0	1,0	-1,0	4,0	16,0
V_8. Social environment	0,0	0,0	0,0	1,0	1,0	0,0	-2,0	-2,0	-8,0
V_9. Social inequality	0,0	0,0	-1,0	-1,0	-1,0	1,0	0,0	-6,0	-12,0
V_{10}. Demographic indicators	0,0	0,0	0,0	2,0	4,0	4,0	4,0	7,0	25,0
V_{11}. Industrial production	0,0	0,0	0,0	1,0	2,0	2,0	1,0	10,0	26,0
V_{12}. Agricultural production	0,0	0,0	0,0	0,0	4,0	7,0	7,0	11,0	35,0
V_{13}. Labor market	0,0	0,0	0,0	0,0	0,0	6,0	14,0	17,0	25,0
V_{14}. The salary	0,0	0,0	0,0	0,0	2,0	7,0	10,0	14,0	39,0
V_{15}. Population income	0,0	0,0	0,0	0,0	0,0	2,0	7,0	10,0	14,0
V_{16}. Inter-municipal differentiation	0,0	0,0	0,0	1,0	1,0	1,0	6,0	18,0	25,0
V_{17}. Regional migration	0,0	0,0	0,0	0,0	1,0	1,0	2,0	14,0	34,0
V_{18}. Investment climate	0,0	0,0	1,0	1,0	1,0	0,0	4,0	8,0	10,0
V_{19}. State policy in the field of improving the quality of life	0,0	1,0	1,0	1,0	-1,0	-2,0	-1,0	2,0	2,0
V_{20}. Security (economic, social, environmental, legal)	0,0	0,0	0,0	1,0	2,0	2,0	1,0	1,0	11,0
V_{21}. Geopolitical situation	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

In accordance with Table 2 and Fig. 4, adding pulse $q_{19} = +1$ at vertex V_{19} (the state's social welfare policies) will yield positive results. Positive growing trends may be traced at the vertices of interest, e.g., at V_1 and V_2. At the same time, processes at 'undesirable' vertices tend to decrease, e.g., social inequality is reducing (vertex V_9) as well as intermunicipal disparities are narrowing (vertex V_{16}). However, the quality of life though tending to improve slightly during the 2nd modelling step then decreases, and a considerable improvement of the trend can only be observed during step 10. This indicates that a single influence at a vertex might not be enough to achieve the goal of improving the functioning of the SL&QL system in whole.

Now let us get to scenario 2 and assume that intermunicipal integration is developing $q_{16} = +1$.

Scenario 2. $Q_2(n) = \{q_1 = 0, \ldots, q_{16} = +1, \ldots, q_{21} = 0\}$.

For results of the computing experiment carried out under scenario 2, see Table 3.

For the line charts most demonstrable in respect of the situation development trends at some vertices of graph G, scenario 2 see Fig. 5.

T a b l e 3. Calculation of impulse processes in accordance with the scenario 2

Vertex	Step								
	0,0	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0
V_1. Quality of life in the region	0,0	0,0	0,0	0,0	2,0	10,0	29,0	52,0	76,0
V_2. Living standards in the region	0,0	0,0	0,0	0,0	3,0	6,0	7,0	18,0	51,0
V_3. Gross Regional Product	0,0	0,0	0,0	2,0	3,0	3,0	12,0	31,0	52,0
V_4. Regional and municipal budgets	0,0	0,0	1,0	1,0	3,0	7,0	11,0	21,0	43,0
V_5. Ecological situation	0,0	0,0	0,0	1,0	1,0	3,0	7,0	11,0	21,0
V_6. State of education	0,0	0,0	0,0	1,0	1,0	4,0	7,0	9,0	16,0
V_7. Health status	0,0	0,0	0,0	1,0	1,0	4,0	7,0	9,0	16,0
V_8. Social environment	0,0	0,0	0,0	-1,0	-1,0	0,0	-2,0	-10,0	-14,0
V_9. Social inequality	0,0	0,0	0,0	0,0	-1,0	-4,0	-4,0	-4,0	-15,0
V_{10}. Demographic indicators	0,0	0,0	0,0	0,0	3,0	6,0	15,0	24,0	44,0
V_{11}. Industrial production	0,0	0,0	1,0	1,0	1,0	5,0	12,0	14,0	27,0
V_{12}. Agricultural production	0,0	0,0	1,0	2,0	2,0	7,0	19,0	38,0	55,0
V_{13}. Labor market	0,0	0,0	0,0	2,0	5,0	6,0	13,0	39,0	80,0
V_{14}. The salary	0,0	0,0	1,0	3,0	4,0	6,0	20,0	42,0	69,0
V_{15}. Population income	0,0	0,0	0,0	1,0	3,0	4,0	6,0	20,0	42,0
V_{16}. Inter-municipal differentiation	0,0	1,0	1,0	1,0	3,0	8,0	11,0	17,0	50,0
V_{17}. Regional migration	0,0	0,0	1,0	1,0	1,0	6,0	14,0	18,0	35,0
V_{18}. Investment climate	0,0	0,0	0,0	0,0	2,0	4,0	3,0	10,0	26,0
V_{19}. State policy in the field of improving the quality of life	0,0	0,0	0,0	0,0	1,0	0,0	-2,0	-5,0	-1,0
V_{20}. Security (economic, social, environmental, legal)	0,0	0,0	0,0	0,0	1,0	2,0	7,0	11,0	15,0
V_{21}. Geopolitical situation	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Adding pulse $q_{16} = +1$ at vertex V_{16} (intermunicipal disparities) also gives positive results: production is developing and people's income is growing.

Let us consider a more complex scenario where social and economic security is declining $q_{20} = -1$ but intermunitipal integration is developing $q_{16} = +1$ and the state's social welfare policies are improving $q_{19} = +1$.

Scenario 3. $Q_3(n) = \{q_1 = 0, \ldots, q_{16} = +1, \ldots, q_{19} = +1, q_{20} = -1, \ldots, q_{21} = 0\}$.

The calculation of the pulse processes under scenario 3 is given in Table 4.

Table 4 contains results of the calculation experiment carried out under scenario 3.

T a b l e 4. Calculation of impulse processes in accordance with the scenario 3

Vertex	Step								
	0,0	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0
V_1. Quality of life in the region	0,0	0,0	-1,0	2,0	14,0	32,0	51,0	71,0	126,0
V_2. Living standards in the region	0,0	0,0	0,0	0,0	3,0	7,0	16,0	42,0	85,0
V_3. Gross Regional Product	0,0	0,0	0,0	2,0	4,0	10,0	27,0	48,0	81,0
V_4. Regional and municipal budgets	0,0	0,0	2,0	3,0	6,0	10,0	17,0	40,0	85,0
V_5. Ecological situation	0,0	0,0	0,0	2,0	3,0	6,0	10,0	17,0	40,0
V_6. State of education	0,0	0,0	1,0	4,0	5,0	7,0	7,0	12,0	36,0
V_7. Health status	0,0	0,0	1,0	4,0	5,0	7,0	7,0	12,0	36,0

Continued tabl. 4

Vertex	Step								
V_8. Social environment	0,0	0,0	0,0	0,0	1,0	1,0	-4,0	-14,0	-24,0
V_9. Social inequality	0,0	0,0	-1,0	-2,0	-3,0	-4,0	-3,0	-10,0	-33,0
V_{10}. Demographic indicators	0,0	0,0	0,0	2,0	9,0	14,0	23,0	35,0	76,0
V_{11}. Industrial production	0,0	0,0	1,0	2,0	4,0	9,0	15,0	25,0	63,0
V_{12}. Agricultural production	0,0	0,0	1,0	2,0	6,0	18,0	33,0	56,0	101,0
V_{13}. Labor market	0,0	0,0	0,0	2,0	5,0	12,0	33,0	70,0	122,0
V_{14}. The salary	0,0	0,0	1,0	3,0	6,0	15,0	37,0	66,0	122,0
V_{15}. Population income	0,0	0,0	0,0	1,0	3,0	6,0	15,0	37,0	66,0
V_{16}. Inter-municipal differentiation	0,0	1,0	1,0	2,0	5,0	10,0	18,0	41,0	93,0
V_{17}. Regional migration	0,0	0,0	1,0	1,0	2,0	8,0	17,0	34,0	83,0
V_{18}. Investment climate	0,0	0,0	1,0	2,0	4,0	5,0	7,0	22,0	44,0
V_{19}. State policy in the field of improving the quality of life	0,0	1,0	2,0	2,0	1,0	-3,0	-5,0	-4,0	3,0
V_{20}. Security (economic, social, environmental, legal)	0,0	-1,0	-1,0	0,0	3,0	5,0	9,0	12,0	26,0
V_{21}. Geopolitical situation	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

For the line charts most demonstrable in respect of the situation development trends at some vertices of graph G, scenario 3 see Fig. 6.

Scenario 3 shows how events in the system will develop if, with the deterioration of the heopolytic situation ($q_{20} = -1$), inter-municipal differentiation $q_{16} = +1$ and sound State policy in the field of improving the quality of life ($q_{19} = +1$).

In this case, perturbations are introduced into three vertices.

As can be seen from Fig. 6, joint action successfully resists the deterioration of the geopolitical situation.

The trend of the development of situations at all peaks can be considered positive. All indicators, with the exception of negative ones, increase, negative ones (reduced security, social inecuality) decrease.

At the same time, if we compare the results of modeling according to scenario 2, it can be seen that the processes are developing more intensively.

CONCLUSIONS

Cognitive modelling tools are a good management decision support instrument when complex systems are studied. This was proved by the cognitive analysis of the standards of living and quality of life. Analysis of the results of modelling the complex system's properties and behavior allows studying its desirable and undesirable features, developing and validating control strategies for a system containing a great number of objects and interrelations under circumstances of uncertainty and lack of empirical data.

Using cognitive simulation modelling, this paper studies how different factors affect people's standards of living and quality of life. The designed cognitive model allowed analyzing scenarios of the situation evolution when various factors affecting the standards of living and quality of life change in the frame of interregional disparities.

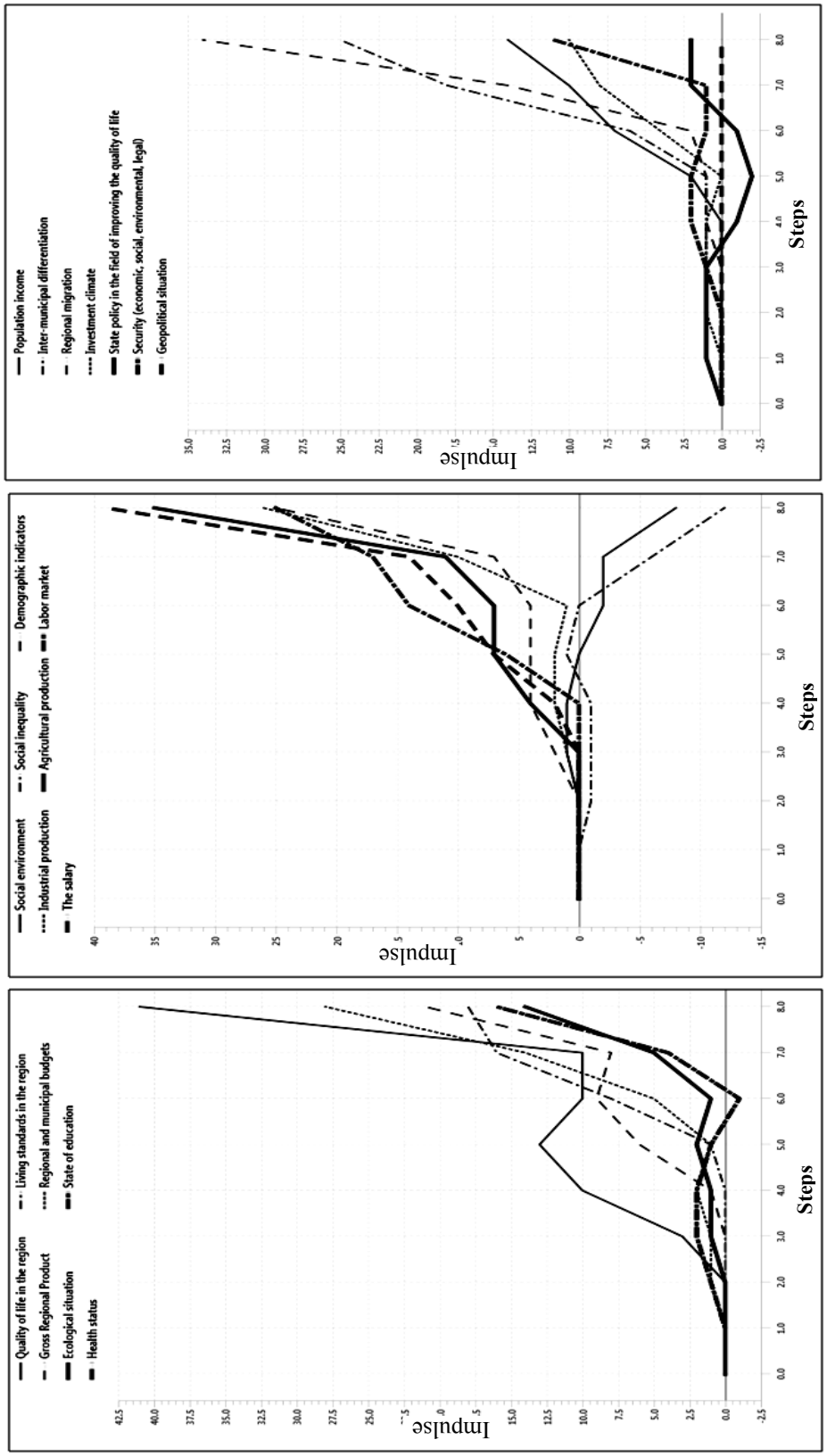

Fig.4. Graphs of impulse processes at the vertices of the cognitive map, scenario 1

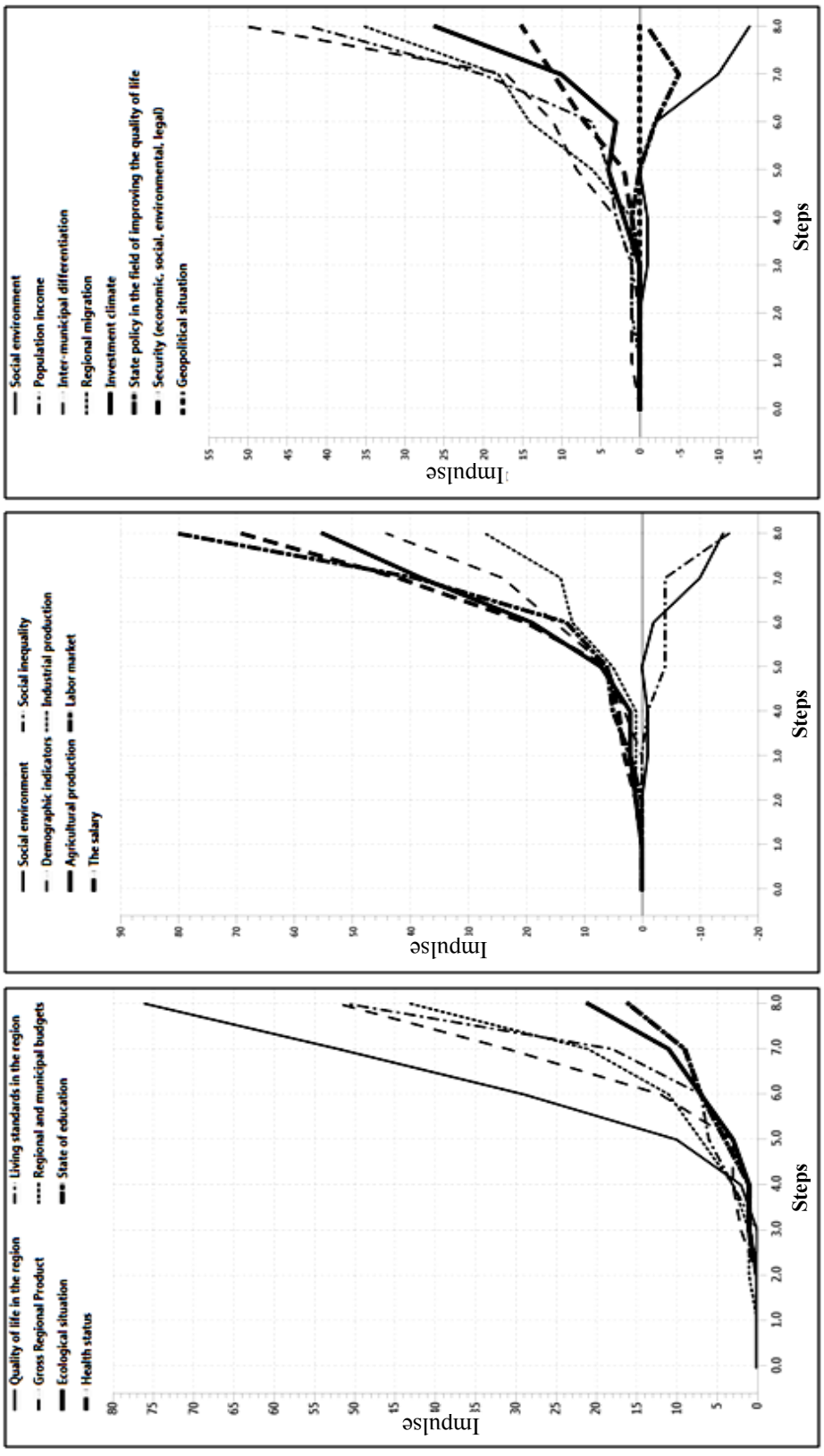

Fig.5. Graphs of impulse processes at the vertices of the cognitive map, scenario 2

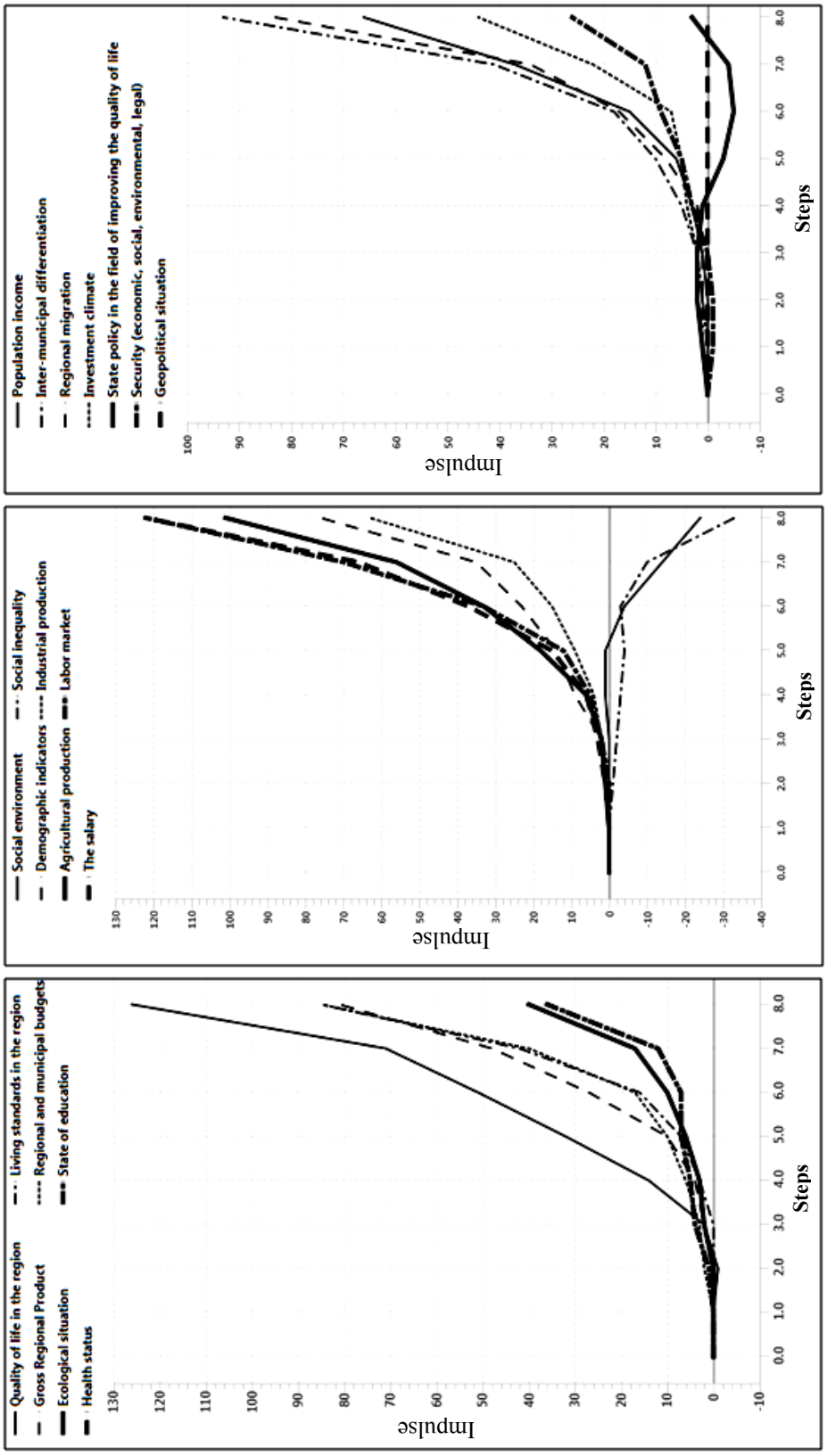

Fig.6. Graphs of impulse processes at the vertices of the cognitive map, scenario 3

It demonstrates that the local authorities need to participate in improving the people's quality of life and rising the standards of living to overcome negative demographic trends, reduce poverty, narrow the gap between the poor and the rich. As it has been noted earlier, the agricultural support slightly reduced disparity between the region's districts but the outpacing growth of the industry and commerce sector increases the income inequality of those employed in different sectors of economy. It is proposed that local authorities, taking into consideration municipal initiatives, should establish growth areas in relatively depressed territories by actively motivating the people and businesses. The long-term development concept should be the single basis for the measures, which incorporates estimates and suggestions of professional economists, managers, financial experts, industrialists, farmers, and social workers.

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ЗАСТОСУВАННЯ КОГНІТИВНИХ КАРТ ДЛЯ ДОСЛІДЖЕННЯ ПРОБЛЕМ ПІДВИЩЕННЯ ЯКОСТІ ЖИТТЯ НАСЕЛЕННЯ В УМОВАХ МІЖРЕГІОНАЛЬНОЇ ДИФЕРЕНЦІАЦІЇ / В.М. Тюшняков, Ю.Г. Ткаченко

Анотація. Роботу присвячено дослідженню питань підвищення рівня і якості життя населення в умовах міжмуніципальної диференціації. Розглянуто питання імітаційного моделювання під час дослідження рівня та якості життя населення. Інструменти когнітивного імітаційного моделювання використано для отримання нових знань про регіональну соціально-економічну, екологічну, політичну системи, що визначають рівень і якість життя населення. Розроблено когнітивну модель для дослідження якості життя, виконано аналіз її структурних властивостей, проведено сценарне моделювання можливого розвитку ситуацій під впливом різних факторів. Новизна роботи полягає в застосуванні нової інформаційної технології когнітивного моделювання до вивчення питань підвищення якості життя громадян в умовах міжмуніципальної диференціації.

Ключові слова: когнітивне моделювання, якість життя населення, рівень життя, регіональний розвиток, міжмуніципальна диференціація.

ПРИМЕНЕНИЕ КОГНИТИВНЫХ КАРТ ДЛЯ ИССЛЕДОВАНИЯ ПРОБЛЕМ ПОВЫШЕНИЯ КАЧЕСТВА ЖИЗНИ НАСЕЛЕНИЯ В УСЛОВИЯХ МЕЖРЕГИОНАЛЬНОЙ ДИФФЕРЕНЦИАЦИИ / В.Н. Тюшняков, Ю.Г. Ткаченко

Аннотация. Работа посвящена исследованию вопросов повышения уровня и качества жизни населения в условиях межмуниципальной дифференциации. Рассмотрены вопросы имитационного моделирования при исследовании уровня и качества жизни населения. Инструменты когнитивного имитационного моделирования использованы для получения новых знаний о региональной социально-экономической, экологической, политической систем, определяющих уровень и качество жизни населения. Разработана когнитивная модель для исследования качества жизни, выполнен анализ ее структурных свойств, проведено сценарное моделирование возможного развития ситуаций под воздействием различных факторов. Новизна работы состоит в применении новой информационной технологии когнитивного моделирования к изучению вопросов повышения качества жизни граждан в условиях межмуниципальной дифференциации.

Ключевые слова: когнитивное моделирование, качество жизни населения, уровень жизни, региональное развитие, межмуниципальная дифференциация.