Modelling of Ecological Development of the Country on the Basis of Cognitive Maps

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Abstract: The article substantiates the use of cognitive modeling as a method of situational management, which makes it possible to describe an object and the laws of its functioning, to develop a mathematical model as close as possible to a real situation. Situational management involves collecting, accumulating, monitoring information, analyzing, and modeling situations, choosing the best development scenarios, and graphically presenting the results obtained. The basis of cognitive modeling is the construction of cognitive maps of the investigated system. The cognitive model, formally represented as an oriented sign graph, describes expert knowledge of the laws of development and properties of the analyzed situation and reflects the strengths of causation and the values of factors in the cognitive map. The paper substantiates the use of simulation modeling to analyze the situation of the environmental state with respect to further development of the economic system based on sustainable development. Three possible scenarios of environmental development to improve the ecological situation in Ukraine are analyzed based on impulse modeling. It has been proven that the maximum effect can be achieved if the third management scenario is adopted. According to this scenario, a system of environmental monitoring and environmental insurance should be introduced, environmental legislation should be improved, alternative energy sources should be used, the systems for cleaning emissions and discharges should be improved, and waste accumulation should be reduced.

1 INTRODUCTION

In today's pandemic conditions, more than ever, scientists are paying attention to the environmental development of countries. Environmental issues play an important role in everyone's lives. Under conditions of significant climatic changes can be noted structural changes in the budgets of countries around the world, through an increase in the share of payments for the protection of the environment. The key expenditure items are the elimination of pollutants and recycling of waste. Most of the environmental problems, namely climate change, deterioration of the natural environment, reduction of biodiversity loss can be attributed to failure to take into account the external impact of the business activities on the environment when managing economic development. To include this impact in calculations of product collectivities or in planning a new development strategy for an enterprise, region or country, researchers suggest that environmental services, i.e. services provided to docktails, should be defined as a separate resource that can be depleted under the condition of non-static use.

Today, there are two approaches to defining environmental services. On the one hand, it can be

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said that by emitting greenhouse gases, the industry uses an environmental service, namely the ability of the atmosphere to capture greenhouse gases. On the other hand, these emissions can be considered as a negative output of the industry.

The system of national payments covers environmental services related to the use of land, mineral and energy resources, certain biological and water resources, provided that there is a cost benefit to their owner.

Since the change in factor productivity is measured as the difference between the change in output and the change in the number of resources required for its production, the increase in unaccounted environmental services is reflected in the calculations as an increase in factor productivity. Therefore, the direct inclusion of key environmental services in the empirical analysis will enable a more accurate identification of economic growth factors and greening paths. The efficiency of the environmental sustainability analysis indirectly depends on the completeness and quality of the information and methods used. Therefore, the economic and statistical analysis of the environmental situation in Ukraine is an urgent task.

2 ACTUAL SCIENTIFIC RESEARCH AND ISSUES ANALYSIS AND THE RESEARCH OBJECTIVE

The globalisation of the world economy is increasing international competition and the strategies of the leading companies are increasingly linked to environmental aspects. The current world market can be characterised by a certain cordon reduction between the industries, a shorter product life cycle and an increased focus on environmental issues.

As Kenneth Boulding defines it, prosperity and progress are measured not by the rate of economic growth, but by the state of food supplies, acid, water, and other necessities. It divides the economy into open and closed. The main focus of sustainable development scientist considers the maintenance of reserves and any technological changes that lead to the maintenance of a given total stock with a reduced volume of production and spozhivaniya. Another important contribution to the study of the ecological status of countries is the Nicolás Georgescu-Regen Theorem, called "Bioeconomics". According to this theory, the biologic approach of the economic process should be taken into account at all times, which fully reflects the problem of human existence with a limited supply of available resources, nervously dispersed and nervously adapted (Giampietro, 2019).

Thus each scientist identifies the inextricable link between the development of the economy and the environmental situation, and consequently the importance of environmental assessment for determining the quality of life of the population.

T. Kobilinska made a significant contribution to the methodology of the study of the ecological state of the country. Her work was devoted to a statistical assessment of the environmental impact of agricultural enterprises; The system of indicators of environmental impacts of agricultural enterprises and environmental monitoring was developed and improved in the National Accounting System of Ukraine (Kobylynska, 2018; Shmygol, 2021).

Statistical modeling and forecasting of socio-economic development, integrated assessment of security of old development is proposed in the research of R. Kulinich (Kulynych, 2018; Perevozova, 2019). The issues of energy and energy-economy modelling and forecasting are outlined in the works of C. Kudry (Kudria, 2015), M. Kulik, O. Malyarenko, N. Maistrenko (Kulik, 2017).

Ukrainian scientist A. Dejna developed a conceptual model of statistical support for evaluation and regulation of energy dependence in Ukraine. He determined the trends of the main indicators of energy dependence, potential and perspectives of using energy from renewable sources in Ukraine (Deina, 2017). P Khazan devoted his research to the methodology of implementation of renewable energy sources in the Ukrainian economy and in particular he developed an integral indicator of assessment of the development of renewable energy sources and suggested a methodology for its calculation (Khazan, 2018).

The works of Antonina Sidorova and Olena Cherenkevich provide a methodological approach to the assessment of environmental and economic subsystems for the analysis of their imbalance on the basis of the method of richly valuable classifikatsii, The correlation and regression models have been developed to determine the efficiency of inputs into environmental protection measures (Sydorova, 2020; Cherenkevych, 2020).

Due to the difficult ecological situation, depletion of natural resources and deterioration of the population's health the issues that give rise to the creation of effective ecological taxes are of topical importance. The problems of environmental taxation in Ukraine and the world have been investigated by such scientists as Y. Shvets, L. O. Shvets (Shvets,

2017)., O. V. Lega, L. V. Yalovega, T. B. Priydak (Leha, 2017), K. V. Kanonishena-Kovalenko (Kanonishena-Kovalenko, 2017)., N. P. Yavorska (Yavorska, 2018), and many others. These studies identify the economic and legal essence of the concept of environmental taxation, peculiarities of the environmental tax collection, analyze the international experience of environmental taxation, as well as identify the ways to reform the environmental tax in Ukraine.

Giving credit to the importance of the works of the above authors, it should be emphasized that a low number of methodological tasks remain insufficiently resolved. In particular, the methodology of ecological development management on the basis of the old development, which would take into account the destabilizing factors of the environment and the changing goals of development of the economic system in accordance with the globalization processes, requires further research,

3 RESULT AND DISCUSSION

The concept of sustainable development emerged from the process of combining three main points of view: economic, social and environmental. That is, "adopting measures aimed at the optimal use of limited resources and the use of environmental - nature-, energy- and materials-saving technologies, at preserving the stability of social and cultural systems, at ensuring the integrity of biological and physical natural systems.

The main goal of old development is the stability of physical and ecological systems, because neglecting the needs of ecology will lead to the degradation of the environment and endanger the existence of all humanity.

Among the main current areas of environmental activities are: international standards system, product branding, environmental management and marketing, environmental auditing, environmental auditing and environmental audits.

The problems of economics and ecology, science at first glance totally different, are intimately interconnected. An example of this relationship is presented in Figure 1.

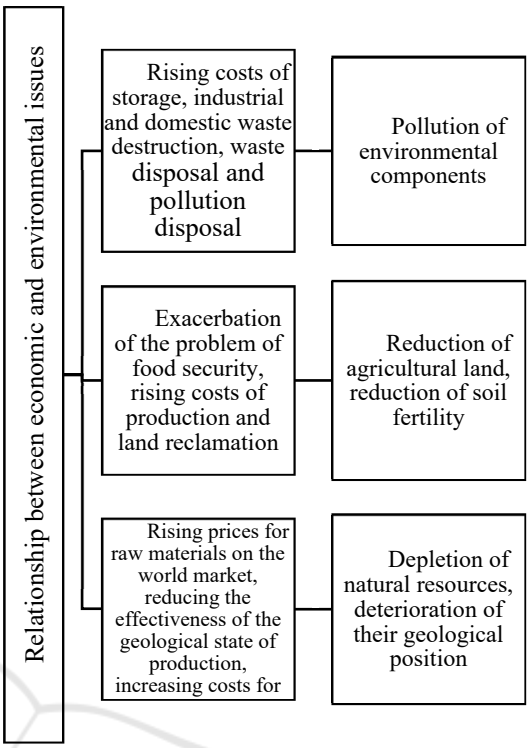


Figure 1: The relationship between economic and environmental issues.

Thus, there is a close relationship between the problems that arise in the environmental field and their impact on economic activity and vice versa. Business activities that underpin the economy invariably have an impact on the environment, be it resource extraction or consumption, atmospheric emissions, use of natural potential, etc. As a rule, such activities are often negative.

Ecology (in particular the natural environment) in turn also affects economic activity. Unsustainable resource use leads to the depletion of natural resources, and the pollution of the environment causes the need for additional costs to reduce the negative effects.

It should also be noted that, as a result of the impact of ecology, the economy is divided into the economics of agriculture and the economics of natural resources. The first deals with the relationship between the natural world and the economy. This jurisdiction covers specific economic issues directly linked to the pollution of the environment as a result of economic activity. The other is engaged in research on the optimal use of natural resources. This could include, for example, alternative energy and water use.

For the country to develop in the field of ecology and ecological security, it is essential that environmental policies are properly implemented.

The aim of the national environmental policy is to stabilize and improve the environmental conditions of Ukraine to achieve the sustainable development of the state through the creation of legal and institutional conditions for economic, energy and environmental security and the improvement of the well-being of the population.

The basic principles of national environmental policy are:

Strengthening the role of environmental management in the Ukrainian governance system in order to achieve a balance among the three components of development (economic, environmental, social), which leads to an orientation on the priorities of sustainable development;

Taking environmental impacts into account when making management decisions, when drafting documents that contain policy and/or policy frameworks for national, sectoral, regional and local development;

Cross-sectoral partnership and involvement of the public in decision-making on the implementation of environmental policy.

Thus, it can be concluded that an assessment of the state of the environment is impossible without an assessment of the state of the economy. The two concepts are closely linked; consequently, it is impossible to develop the economy without developing ecology. This is due to the existence of certain links between economic and environmental issues.

The most important condition for the implementation of the policy of sustainable development we consider the universal equilibrium and balance of interests of social progress, We believe that a comprehensive balance and balance between the interests of social progress and environmental and economic development should be achieved at the highest possible degree of geographical, social, environmental, economic, production and technical-technological indicators.

Human interaction with the environment is based on "natural capital" and "piece capital". According to universally accepted criteria, natural capital is comprised of the planet's resources, while piece capital is everything humanity creates with the use of the planet's resources. A sustainable economy seeks to eliminate inequitable relations between nations, respecting the aspect of sustainability as the requirements for establishing equitable relations within a single generation.

In our view, the process of balanced growth of all parameters and elements of the system to preserve its integrity, the harmonisation of the development of all components, taking into account the interests of each individual person and society as a whole, is the development of the country.

The problem of imbalanced environmental and economic development takes priority among the problems of old economic development. Increase in the volume of social production, The total increase in the impact of extensive and intensive factors on the distribution of material and energy flows between the economic and ecological subsystems leads to a low level of adverse reactions of the ecosystem and imbalances in the consumption and production of resources.

Moreover, there is a growing threat of a negative attitude towards natural resources when their use is in the economic sphere and nature conservation is traditionally in the non-economic sphere, which does not allow direct and indirect impacts of economic activities to be assessed and the results of the assessment to be adequately incorporated into practice.

Since the object of economic research in the context of the concept of sustainable development is the environmental and economic relations and the environmental and economic subsystem, there is a need to develop a methodology for assessing the imbalance of environmental and economic development of public administration systems, which takes into account the basic principles of the sustainable development strategy.

In economically developed western countries, the source of primary environmental and economic information includes data from environmental accounting, environmental controlling and the preparation of environmental balance sheets.

The main elements of the content of environmental information:

Indicators, standards and outputs that describe the actions taken in the main areas of environmental protection;

Environmental aspects of the organisation's activities, including levels of discharges, rebates, waste disposal, etc;

Financial indicators and data on the organisation's assets (operating costs, costs of post-war activities, acquisition of environmental assets, etc.);

The responsibility for environmental accidents;

Information contained in the supplementary financial statements showing the value of costs resulting from the impact of the company on the

environment and the impact of the environment on the organisation.

The first two positions are environmental accounting, which may also be called statistical accounting. Standardization in the field of ecology is beginning to play a significant role in the activities of national and international standardization organizations. Increasingly, standards are seen as a necessary means of regulating relations in the field of environmental protection and resource use.

To determine the state of the environment, the indicator of the amount of waste is the main one, because the pollution of natural environment, in particular the water environment, is the main problem for the ecology of the country. In addition, it is advisable to study the dynamics of the main environmental and economic indicators of Ukraine for the period 2014-2020.

Figure 2 shows the dynamics of the number of inputs in Ukraine for the period 2000-2019.

The most important role in the pollution of water is played by industrial production waste, i.e. it can be said that today environmental safety is closely linked to the economic development of the country. Thus, having investigated this relationship in the period 2000-2019, it was found that the correlation index of the indicator of the number of wastes with the GDP indicator was 0.62.

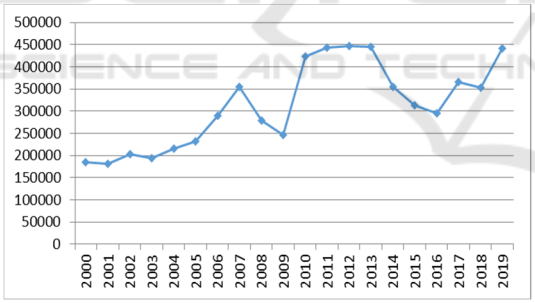


Figure 2: Dynamics of change in the number of inputs in Ukraine from 2000 to 2019.

*Based on data (State service of statistics of Ukraine, 2022) provided by the author

At the same time, the correlation index of the number of incomes indicator with the population indicator was -0.62, indicating an inverse relationship.

Disease or health hazards in the population are closely linked to the volume of industrial production, the state of contamination of certain natural spheres, and unsafe technogenic production by industrial giants, The impact on the planetary climate change, i.e. a decrease in the ozone layer and warming of the climate, makes research and improvements in environmental security one of the most topical and important issues for each country.

In assessing the extent of environmental degradation, it is important to take into account the scale of the impact on human health:

- Global environmental degradation is a problem for the entire human society, but it is not a particular problem for a single person;
- Regional environmental pollution is a problem for the inhabitants of the region, but it is not necessarily harmful to the health of one particular person;
- Local environmental pollution - poses a serious threat to the health of the population of a particular city/area as a whole as well as to the individual inhabitants of the area.

Thus, it is easy to see that the dependence of human health on the polluted air of a particular street where one lives is greater than on the pollution in the area in general. Scientific research conducted by the World Health Organization (WHO) has shown a strong link between polluted dwellings and the incidence of prematurity, The study found a strong association between prenatal obstruction and the incidence of prematurity and chromosomal disorders in children, allergic pathologies, anaemia, mental retardation and behavioural and physical abnormalities in children. Children living in ecologically deprived areas show evidence of congenital conditions, recurrent bronchitis, allergic diseases, reduced IQ, bronchial asthma, neuropsychiatric diseases, oncopathology, etc.

Figure 3 shows the dynamics of releases of pollutants into the atmospheric air in Ukraine for the period 2014-2020.

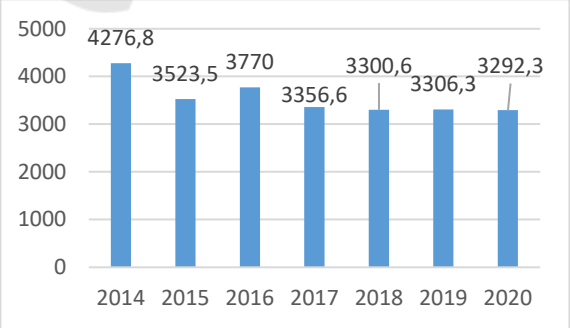


Figure 3: Dynamics of the amount of pollutant emissions into the atmosphere of Ukraine 2014-2020, thousand tonnes.

*Based on data (State service of statistics of Ukarine, 2022) provided by the author

It can be seen that since 2016 there has been a gradual decrease in this indicator, which has a positive impact on the environmental condition of the country and the health of the population.

When analysing the economic situation of a country, GDP is the main indicator. Many experts still use GDP as the main indicator of the country's development and wellbeing (Fig. 4).

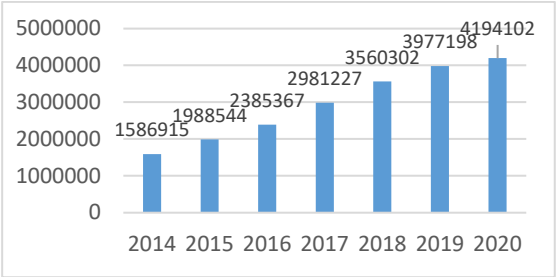


Figure 4: GDP dynamics4 of Ukraine 2014-2020, mln UAH.

Based on data (State service of statistics of Ukarine, 2022) provided by the author

The main factor determining the standard of living of the population is the level of longevity, and the state of the environment inevitably influences this indicator. The analysis of scientific works and research on the mentioned problem shows that among the factors determining the level of morbidity, the state of the environment takes approximately 20%, while the dependence on the level of development of the health care system is only 7-12%. (Khazan, 2018).18-20

It should be noted that there is a correlation r=0.4 between the GDP value and the Average Life Span of the Population. However, since the correlation is not significant it is not reasonable to use the GDP value to assess the development of the economic situation in the country.

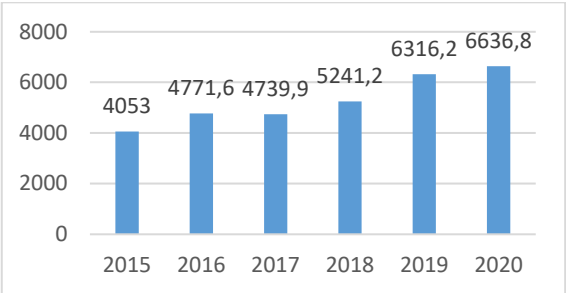


Figure 5: Dynamics of the amount of expenses for the sphere of environment protection, mln. UAH.

Based on data (State service of statistics of Ukarine, 2022) provided by the author

In Ukraine since 2015, there has been a dynamic growth in amounts spent on the protection of the natural environment (Fig. 5), but if we analyze these amounts as a percentage of the total state budget, the values are only about 0.5%.

A negative impact is also caused by growing inflation, which significantly decreases the amount of expenses, for example, in 2016 the actual amount was 4,771.6 million UAH (0.72% of the state budget) and in 2020 - 6636.8 million UAH (0.53% of the state budget). However, considering the growing inflation index, the cost of environmental protection in 2020 is lower than in 2016.

It is also important to note that although the 2020 pandemic had a negative impact on economic development, especially for Ukraine, but analysts have identified an improvement in the environmental situation worldwide, through the COVID-19 pandemic, namely a significant reduction in the number of contaminants and wastes (Figure 6).

Studying the dynamics of the main indicators of Ukraine in the field of ecology, it is also important to consider the volume of utilized waste. Since analyzing the data from 2014-2019, a significant increase in the volume of waste generation and, accordingly, an increase in the volume of recycled waste can be observed. However, if we look at the growth rate, the amount of waste recycled in Ukraine is often lower than the amount produced. In 2020, only 21% was recycled, while the average recycling rate in 2014-2020 was 27%.

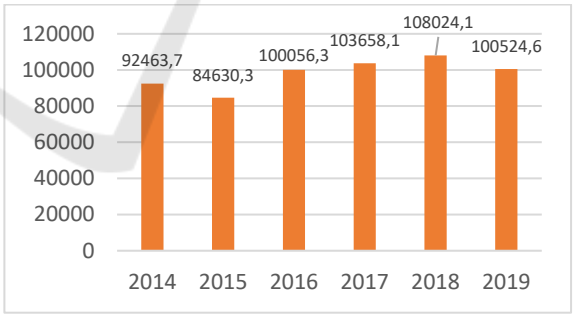


Figure 6: Dynamics of recycled waste volume 2014-2019, thousand tonnes.

Based on data (State service of statistics of Ukarine, 2022) provided by the author

Developing a cohesive picture to manage Ukraine's environmental situation. Steel growth is not an arithmetic sum of the steady growth of its individual components (based on the nature of the capacity of systems).

The term 'old growth' can be used to define the criteria for its manifestation:

— Ensuring integrity. Steel development is made up of components which are already equivalent at the time of its formation. With the combination of variable rates of economic growth and one-time pollution of the environment, steel development becomes impossible.

— Staleness and equilibrium of the components of old development. Stability means that despite continuous changes in the socio-economic system and its subsystems, some fundamental parameters remain unchanged (e.g. population life). The equilibrium of the socio-economic system means the balancing of individual components to ensure sustainable development in order to prevent the collapse of the system and preserve it as a single whole.

— The level of organization of the socio-economic system, which depends on the complexity of its functions and the thoroughness of its structure. Steel development can be ensured solely by pursuing a progressive structural-investment policy. This implies a high level of organization of the socio-economic system with a significant diversity of functions, which are performed, and appropriate structures that contribute to maintaining the consistency of the system. Economic and environmental systems are characterized by steady growth, which is ensured mainly by intensive factors (including a high level of impact of scientific and technological progress). For systems with a low level of organization, socio-economic development is achieved mainly through extensive factors with a low level of scientific and technological progress.

In today's world, under conditions of significant climatic changes, structural changes in the budgets of countries around the world can be seen, through an increase in the share of environmental protection expenditures. The key expenditure items are the elimination of pollutants and the recycling of waste. Therefore, it is important to study the management process and ways of management in this area.

Firstly, it is necessary to define the notion of environmental protection as well as proper management. Environmental protection is a set of state, administrative, legal, economic, political and social measures aimed at rational use, creation and preservation of natural resources of land, limiting the negative impact of human activity on the environment (Khilchevskyi, 2016; Horal,2021; Zelinska, 2021). Management can be seen as a goal-oriented impact on the organized system, which ensures preservation of its structure and activity goals. (Khilchevskyi, 2016; Kiv, 2020, Derbentsev, 2020).

One of the promising approaches to the analysis of dynamical systems is the analysis based on the cognitive map, which is a model of experts' knowledge about the laws of development and properties of the situation, which is analyzed in the form of elementary semantic categories, which are connected by relations. The cognitive map can be presented in the form of an oriented graph. The vertices of the graph correspond to the factors that define the situation, the oriented edges correspond to the cause-and-effect relations between the factors. Cognitive pictures are not only a means of structuring and formalizing the situation, but also a tool for its analysis. Different interpretations of vertices, edges and valued coefficients on edges lead to development of different models and methods of their analysis. (Tkachenko, 2019; Kiv, 2020, Derbentsev, 2020). Analyze the environmental pressure and environmental management in Ukraine. On the first stage we will create a map of the environmental situation in Ukraine (Fig. 7). The system of indicators $ZZbul_{1\text{-}13}$ was developed on the basis of consolidation of legislative acts, which is presented in Table 1.

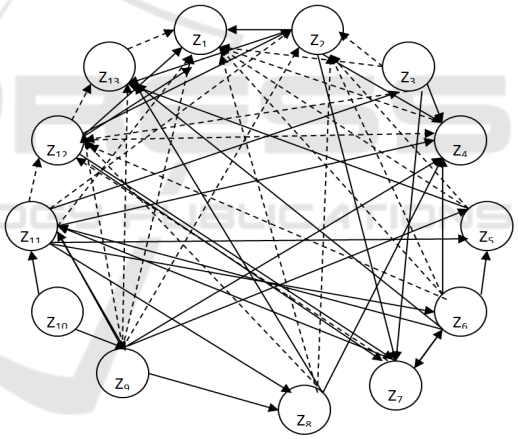


Figure 7: Cognitive map of the environmental situation in Ukraine.

On the cohesive map, the dotted line represents arcs with an intrinsic value, and the continuous line represents arcs with an additional value.

Development of environmental management scenarios on the basis of immutational modelling. The cognitive modelling methodology is based on the developed cognitive models to identify possible and efficient ways of managing the economic system in order to bring it closer to the target state. In order to conduct a structural analysis of the cognitive picture of environmental management, a q-analysis of the relationship between factors (indicators of environmental status) and ways to influence them was conducted.

Table 1: Cognitive framework for assessing the environmental situation in Ukraine.

No. n/a	The mindset of cognition	Explanation:
1	Z_1	Level of environmental pressure
2	Z_2	Doses of narcotic substances to the atmosphere per person
3	Z_3	Amount of alternative sources of energy in the total amount of energy used
4	Z_4	The relationship between woodland creation and timber harvesting
5	Z_5	The area of the natural reserve fund of the country
6	Z_6	Proportion of enterprises subject to environmental monitoring out of the total number
7	Z_7	Number of citizens' appeals against environmental legislation
8	Z_8	The relationship between the creation and use of secondary raw materials
9	Z_9	Proportion of enterprises with environmental insurance as a percentage of the total number
10	Z_{10}	Proportion of international innovative projects in the total number of projects in the child welfare sector
11	Z_{11}	Number of sanctions imposed on businesses that exceed the tolerance limit
12	Z_{12}	Volume of accumulated waste
13	Z_{13}	Environmental taxation

The problematic situation in the management of the economic system is presented in the form of an equilibrium orgraph:

$$G = < Z, W>, \quad (1)$$

de Z is the multiplicity of vertices,

$yx_{i,i}Z$, i =1,2,...,K - vertices that are elements of the system under study; W is the wagon set, $w(x_i, y_i)$ is the wagon of each arc.

The arc value can be positive, negative or zero. An important orgraph in which all the values of $w(x_i, y_i)$ are integer-valued is called integer-valued. Thus, any signed orthography can be represented as a numbered orthography with $w(x_i, y_i) = 1$, if (x_i, y_i) has a plus sign, $w(x_i, y_i) = -1$, if (x_i, y_i) has a minus sign, and $w(x_i, y_i) = 0$, if the connection does not exist. The sign of the closed path of the contour is the complement of signs of its arcs, in the complement the plus sign is replaced by +1, the minus sign is replaced by -1. In mathematical modelling of complex systems, it is necessary to find a compromise between the accuracy of modelling results and the possibility of obtaining the detailed information needed to build the model. Signs and valid orgraphs can be used in the development of simple mathematical models of complex systems and in the analysis of the results, which are obtained on the basis of minimal information.

To analyze the cognitive map, we present it as a matrix of relations Aa_G according to the formula:

$$A=_G[a_{ij}]_{k\square k}, \; a_{ij}= w(x_i, y_i). \quad (2)$$

As a result of the analysis of the q-correlation of environmental status indicators and methods of influence on them, a symmetric complex was created according to the formula:

$$K_X (Y, R) = \{\sigma^{(11)}{}_9, \sigma^{(6)}{}_7, \sigma^{(9)}{}_7, \sigma, \sigma^{(3)}{}_4{}^{(8)}{}_4, \sigma^{(12)}{}_4, \sigma^{(2)}{}_3, \sigma^{(4)}{}_2, \sigma^{(5)}{}_2, \sigma^{(7)}{}_2{}^{(10)}{}_2{}^{(13)}{}_0, \sigma^{(1)}{}_0\} \quad (3)$$

The analysis of the results of the symptom analysis and its meaningful interpretation of the situation under study have led to the following conclusions. The environmental management system has a high level of q-correlation, which indicates a high level of sensitivity of the system to internal and external parameter changes. Calculation of the link values of the complex K_X (Y, R) showed indirect links between the tops of the cognitive picture. Thus, for example, active public participation, Z_7, has only an indirect impact on environmental pressure, Z_1, through the system of environmental monitoring, Z_6, improvement and implementation of environmental legislation, Z_{11}, and waste accumulation, Z_{12}.

The analysis of the symplectic complex eccentricities of K_X (Y, R) has shown that the richly symplectic $\sigma^{(11)}{}_9$, $\sigma^{(6)}{}_7$, $\sigma^{(9)}{}_7$, which were created in accordance with the vertices Z_{11}, Z_6, Z_9, have high values of eccentricities, which indicates both their greatest importance for the complex as a whole, and the importance of each individual simplex as Z_{11}, Z_6, Z_9 as a joint line.

Impulse modelling was carried out to determine the effectiveness of management action to improve the environmental situation in Ukraine.

To obtain a more accurate prediction, the graph was converted into a weighted graph based on the results of the expert analysis.

The selection of tops to which impulses were applied was made based on Ukrainian legislation and the results of q-value analysis. Four possible scenarios of managerial action were calculated. The vector of initial values was calculated as a relative value considering the benchmark value, the norm by the formula:

$$V(0) = (v_1(0), v_2(0),...,v_n(0), \quad (4)$$

The values corresponding to each vertex and the impulses at time t, t = {0,1,2,3}, were calculated by formulae (5) and (6).

$$v_i(t+1) = v_i(t) + \sum_{j=1}^{n} w(y_j, x_i) p_j(t), \quad (5)$$

where $w(x_i,y_j) = 0$ if the arc (x_i,y_j) is absent. If the arc from y_j to x_i has value $w = w(x_i,y_j)$ and the value of vertex y_j increases by k units at time t, then the value of vertex x_i at time t+1 increases by kw⊕ units.

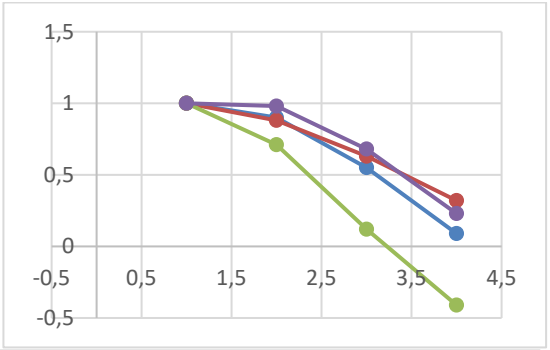
Since $v_i(t+1) - v_i(t) = p_i(t+1)$, the equation (5) takes the form:

$$p_i(t+1) = \sum_{j=1}^{n} w(y_j, x_i) p_j(t). \quad (6)$$

Analysis of the results of impulse modeling of the environmental state control has shown that the maximum effect can be achieved by influencing the vertices with the maximum value of eccentricity. For example, the first scenario involves an impulse to Z_6, Z_9, Z_{11}, i.e. a management action must be taken to improve the environmental monitoring system, implement environmental insurance and improve and enforce environmental legislation.

The result of management under the first scenario is a decrease in environmental pressure from 1 to 0.09.

Scenario 4 differs from Scenario 1 in that the management action included recycling of accumulated waste, which cannot be avoided in the scenario. As a result, the effect of the management action decreased by 0.14 basis units. To identify the most effective scenario a graph was created based on the resulting indicator which reflects the environmental pressure. (Fig. 8).



Scenario 1: q6=0,1, 99 = 0,1, q11 = 0,1
Scenario 2: q4=0,1, q7= 0,1, q11 = 0,1
Scenario 3: q3 = 0,1,q6 =0,1, q8=0,1,q9=0,1, q11 = 0,1, q12 = -0,1
Scenario 4: q6=0,1, 99 = 0,1, q11 = 0,1, q 12 =

Figure 8: Forecast value of environmental pressure for 3 periods according to scenarios.

Figure 8 shows that the maximum effect can be achieved by adopting the third management scenario, i.e. by introducing a system of environmental monitoring throughout the entire country. An environmental monitoring system has been in place for three years in the Dnipropetrovsk region, one of the most polluted in Ukraine. In real time, the pollution of the air, the Dnieper water, etc. is being investigated. Implementation of environmental insurance (insurance of civil liability for damage to the state, life, health and property of natural persons, legal entities and natural persons - entrepreneurs as a result of violation of legislation on the protection of the natural environment.) According to Article 49 of the Insurance Law adopted on 18.11.2021, which will be in force from 01.01.24 (Law of Ukraine, 2021). Alternative sources of energy, improved systems of waste and discounts treatment and reduced waste accumulation should also be implemented. This can be achieved, first of all at the state level, by means of ecological taxes, using foreign experience (Yelisieieva, 2018). Under such conditions, the ecosystem completely renews the resources used in the economic activity process, as evidenced by the high value of the indicator of environmental pressure.

4 CONCLUSIONS

The most important condition for the implementation of a sustainable development policy at the level of macrosystems is a comprehensive balance and balance of the interests of social progress, ecology, and economy with the maximum possible number of

geographical, social, environmental, economic, production, and technical and technological indicators. The article substantiates the use of cognitive modeling as a method of situational management, which allows you to describe the object and the laws of its operation, to develop a mathematical model as close as possible to the real situation. Situational management involves the collection, accumulation, monitoring of information, situation analysis, modeling of situations, selection of the best development scenarios, graphical presentation of the results. The basis of cognitive modeling is the construction of cognitive maps of the system under study. The cognitive model, which is formally represented as a directed sign graph, is a model for describing experts' knowledge about the laws of development and properties of the analyzed situation, and also reflects the strength of cause-and-effect relationships and the values of factors on a cognitive map.

The paper substantiates the use of simulation modeling to analyze the situation of the ecological state with respect to the further development of the economic system based on sustainable development.

The study of the results of simplicial analysis and its meaningful interpretation of the situation under study, allowed us to draw the following conclusions. Environmental management systems have a high level of q-connectivity, which indicates a high degree of system sensitivity to internal and external changes in parameters. The calculation of the values of the connectivity of the complex KX (Y, R) showed the presence of indirect connections between the vertices of the cognitive map.

To improve the ecological situation in Ukraine on the basis of impulse modeling, three possible scenarios of ecological development are analyzed. It has been proven that the maximum effect can be achieved if the third management scenario is adopted. According to this scenario, a system of environmental monitoring and environmental insurance should be introduced, environmental legislation should be improved, alternative energy sources should be used, the systems for cleaning emissions and discharges should be improved, and waste accumulation should be reduced. The negative value of the indicator of the ecological load indicates that the ecosystem fully restores the resources consumed in the process of human life and multiplies them.

REFERENCES

Giampietro, M. (2019). On the circular bioeconomy and decoupling: implications for sustainable growth. Ecological economics, 162, 143-156.

Kobylynska T. V. Statystychna otsinka vykydiv nebezpechnykh rechovyn vid silskohospodarskoi diialnosti pidpryiemstv: rehionalnyi aspekt rehionu / T. V. Kobylynska //Statystyka Ukrainy. 2018. № 2. S. 70–78.

Shmygol, N., Galtsova, O., Shaposhnykov, K., & Bazarbayeva, S. (2021). Environmental management policy: an assessment of ecological and energy indicators and effective regional management (on the example of Ukraine). Polityka Energetyczna-Energy Policy Journal, 43-60.

Shmygol, N., Solovyov, O., Kasianok, M., Cherniavska, O., & Pawliszczy, D. (2021). Model of sectoral competitiveness index by environmental component. In IOP Conference Series: Earth and Environmental Science (Vol. 628, No. 1, p. 012023). IOP Publishing.

Kulynych R.O. Kompleksna otsinka zabezpechennia staloho liudskoho rozvytku / R.O. Kulynych, O.I. Kulynych // Universytetski naukovi zapysky. Naukovyi 211 chasopys Khmelnytskoho universytetu upravlinnia ta prava, 2018. – № 3, 4. – S. 368–380.

Perevozova, I., Shmygol, N., Tereshchenko, D., Kandahura, K., & Katerna, O. (2019). Introduction of creative economy in international relations: Aspects of development security. Journal of Security and Sustainability Issues, 9(1), 139-154..

Kudria C.O. Stan ta perspektyvy rozvytku vidnovliuvanoi enerhetyky v Ukraini / C.O. Kudria // Visnyk NAN Ukrainy. – 2015. – № 12. – S. 19–26.

Kulyk M.M. Zastosuvannia metodu kompleksnoho prohnozuvannia dlia vyznachennia perspektyvnoho popytu na enerhetychni resursy. / M.M. Kulyk, O.Ie. Maliarenko, N.Iu. Maistrenko, V.V. Stanytsina, A.I. Spitkovskyi // The problems of general energy. – Issue 1 (48), 2017. – S. 5–15.

Deina A.Iu. Teoretychni osnovy statystychnoho zabezpechennia rehuliuvannia enerhonezalezhnosti Ukrainy / A.Iu. Deina // Ekonomika i orhanizatsiia upravlinnia. - 2017. - №1(25) - s. 160-170.

Khazan P. V. Vykorystannia faktornoho analizu dlia otsiniuvannia rozvytku vidnovliuvanykh dzherel enerhii. / P. V. Khazan // Biznes Inform. 2018. № 9. S. 98–104.

Sydorova A.V. Vyiavlennia tendentsii ekolohichnoi ta ekonomichnoi zbalansovanosti yak faktoru ekolohichnoi bezpeky Ukrainy / A.V Sydorova., O.S. Cherenkevych // Biznes-inform. 2020. № 7.– s. 131-138

Cherenkevych O.S. Statystychna otsinka efektyvnosti finansuvannia pryrodookhoronnykh zakhodiv v Ukraini. / O.S. Cherenkevych // Efektyvna ekonomika. 2020. № 11.– URL: http://www.economy.nayka.com.ua/?op=1&z=8325

Shvets Yu.O. Ekolohichnyi podatok yak instrument ekonomiky pryrodokorystuvannia./ Yu.O. Shvets., L.S.

Hryhorovych // Visnyk Mukachivskoho derzhavnoho universytetu. 2017. Vyp. 10. S. 488–493.

Leha O.V. Ekolohichnyi podatok: osoblyvosti obliku i opodatkuvannia u konteksti normatyvno-pravovykh zmin. ./ O.V. Leha , L.V. Yaloveha ,T.B. Pryidak // Visnyk Kharkivskoho natsionalnoho tekhnichnoho universytetu silskoho hospodarstva imeni Petra Vasylenka. 2017. Vyp. 185. S. 231–242.

Kanonishena-Kovalenko K.V. Ekolohichnyi podatok vid A do Ya / K.V. Kanonishena-Kovalenko // Kyiv : Fundatsiia «Vidkryte Suspilstvo», 2017. 108 s.

Yavorska N.P. Ekolohichne opodatkuvannia v krainakh YeS yak instrument pidvyshchennia efektyvnosti ekolohichnoi polityky / N.P. Yavorska // Pidpryiemnytstvo ta innovatsii. 2019. № 10. S. 114–120.

State service of statistics of Ukarine (2022) URL: http://www.dneprstat.gov.ua/

Khilchevskyi V.K Zabokrytska M.R. Kravchynskyi, R.L. 2016. Environmental standardization and prevention of waste impact on the environment. Kyiv, "Kyiv University".

Zakhozhai O.I. (2018) Concept of improvement of theretical and methodological base of synthesis of the Information technologies for automated processing of the information and complex systems management. Bulletin of the Volodymyr Dahl East Ukrainian National University. № 6 (246). pp. 49-55

Horal, L., Khvostina, I., Shyiko, V., Radin, M., Korol, S., & Panevnyk, T. (2021). Sustainable development of forest recreation management as a basis for environmental safety. In IOP Conference Series. Earth and Environmental Science (Vol. 628, No. 1). IOP Publishing.

Zelinska, H., Andrusiv, U., Fedorovych, I., Khvostina, I., & Astafiev, O. (2021). Rational resource in the context of forming a model of using fuel and energy resources expenditure. In IOP Conference Series: Earth and Environmental Science (Vol. 628, No. 1, p. 012003). IOP Publishing.

Kiv, A., Hryhoruk, P., Khvostina, I., Solovieva, V., Soloviev, V. N., & Semerikov, S. (2020, January). Machine learning of emerging markets in pandemic times. In M3E2-MLPEED (pp. 1-20).

Derbentsev, V., Semerikov, S., Serdyuk, O., Solovieva, V., & Soloviev, V. (2020). Recurrence based entropies for sustainability indices.

Tkachenko O. (2019) Cognitive modelling of complex systems. Digital platform: information technologies in socio-cultural sphere. Edition 2, № 1 pp. 11-19. URL: http://infotech-soccult.knukim.edu.ua/article/view/175650/176888

Law of Ukraine on insurance from 18.11.2021. URL: https://zakon.rada.gov.ua/laws/show/1909-20

Yelisieieva O.K. Vasylieva O.O. 2018. Theoretical aspects of environmenral taxation: national and international experience. Economics. Finances. Law. –№10/1. pp. 33-36.