ISSN Print 2414-0287
ISSN Online 2707-8426

ECONOMIC AND MATHEMATICAL MODELING AND INFORMATION TECHNOLOGIES IN ECONOMICS

UDC 332.142:504.61 https://doi.org/10.26661/2414-0287-2020-4-48-23

COGNITIVE APPROACH TO ENVIRONMENTAL SAFETY ASSESSMENT OF TERRITORY

O. Makarenko, T. Tatosian

Zaporizhzhia National University
Ukraine, 69600, Zaporizhzhia, Zhukovsky str., 66

olenamak@gmail.com, tar_arm@ukr.net

ORCID 0000 – 0003-1009-5122

Key words:
environmental safety, economic development, cognitive model, safety level, factor.

The article is devoted to the study of the impact of socio-economic development on the environmental safety of the territory. An analysis of scientific research on the environmental safety of the region and the country was carried out, during which factors of socio-economic development were taken into account. Socio-economic development of the region is characterized by qualitative changes and irreversibility, and as a complex and dynamic process by variability and uncertainty in the future. Qualitative changes in the economy can negatively or positively affect the level of environmental safety. It was determined that the assessment of the environmental safety condition is an important scientific and practical task, because global economic, social, political, climate changes, which affected Ukraine as well, require new tools for economic management. This paper offers a cognitive model for assessing the environmental safety condition of the territory, which takes into account the impact of economic and social factors. The procedure for building a cognitive model of the impact of factors on the environmental safety condition of the territory consists of several stages: a factor analysis of the impact of factors on the environmental safety condition is carried out; the implication of the impact of factors on each other is determined; a cognitive model of impact is built; the analysis of the model balance is carried out. This approach for assessing the environmental safety condition based on the cognitive modeling method can be applied in management decisions that relate to the viability of introducing environmental protection measures at the state and regional levels, since it allows you to quickly determine the current condition of safety, taking into account socio-demographic and production factors and anthropogenic environmental factors.

КОГНІТИВНИЙ ПІДХІД ОЦІНЮВАННЯ СТАНУ ЕКОЛОГІЧНОЇ БЕЗПЕКИ ТЕРИТОРІЇ

Макаренко О. І., Татосян Т. А.

Запорізький національний університет
Україна, 69600, м. Запоріжжя, вул. Жуковського, 66

Ключові слова:
екологічна безпека, економічний розвиток, когнітивна модель, рівень безпеки, фактор.

Стаття присвячена дослідженню впливу соціально-економічного розвитку на екологічну безпеку території. Проведено аналіз наукових досліджень щодо екологічної безпеки регіону, країни з урахуванням показників соціально-економічного розвитку. Соціально-економічний розвиток регіону характеризується якісними змінами та незворотністю, а як складний та динамічний процес мінливістю та невизначеністю стану у майбутньому. Якісні зміни в економіці можуть негативно або позитивно впливати на рівень екологічної безпеки. Визначено, що оцінювання стану екологічної безпеки є важливим науково-практичним завданням, адже глобальні економічні, соціальні, політичні, кліматичні зміни, які не обійшли й Україну, висувають нові умови господарювання. В роботі запропоновано когнітивну модель оцінювання стану екологічної безпеки території, яка враховує вплив економічних та соціальних факторів. Процедура побудови когнітивної моделі впливу факторів на стану екологічної безпеки території складається з декількох етапів: проводиться факторний аналіз впливів факторів на стан екологічної безпеки; встановлюється характер впливу факторів один на одного; будується когнітивна модель впливів та здійснюється аналіз її

ISSN Print 2414-0287
ISSN Online 2707-8426

збалансованості. Запропонований підхід для оцінювання стану екологічної безпеки на основі методу когнітивного моделювання може бути застосований у процесі підтримки прийняття управлінських рішень щодо доцільності впровадження природоохоронних заходів на державному та регіональному рівнях, оскільки дозволяє оперативно визначати поточний стан безпеки, з врахуванням соціально-демографічних та виробничих факторів та антропогенних чинників навколишнього середовища.

Problem statement

Ukraine's significant natural resource potential is the key element in securing economic development. The socio-economic development of the territory is characterized by aggregate changes in the socio-economic system (of the district, region, and country), which shape, under the influence of factors of the internal and external environment, acting in time and space, the transition of the system to a new qualitative and quantitative state [1]. The process of socio-economic development of the region is aimed at enhancing its economic potential, meeting people's needs, output growth, improving the competitiveness of products and, ultimately, growth in living standards for the regional population. In Ukraine, the ecological situation is in crisis reflecting a high level of anthropogenic pressure on the environment, i.e. the impact of factors posed by any human activity on the environment. That is why making strategic decisions in managing the socio-economic development of the country it is important to take into account the level of environmental safety of the territory.

For the purposes of the study, environmental safety is defined as "a condition of the environment which leads to the prevention of the ecological situation deterioration and of dangers to human health and safety" [2]. Assessing the condition of the environmental safety of a territory, it is necessary to comply with many factors which determine it. Using the tools of economic and mathematical modeling allows us to solve this problem.

Analysis of latest researches and publications

The works of many scientists are devoted to general issues of environmental safety, in particular, I. K Bystriakova, O. O. Veklych, Z. V. Herasymchuck, S. M. Iliashenko, O. V. Prokopenko, I. M. Syniakevych, Ye. V. Khlobystov and others.

Z. V. Herasymchuck proposed the mechanism for diagnosing and determining the level of ecological development of the region [3]. The researcher substantiated the methodology for assessing environmental risk in the region.

Threats to environmental safety within the national safety system of Ukraine are considered in the works of T. P. Kazachenko [4], M.I. Sokur and others. According to T.P. Kazachenko, the global problem of mankind is the ecological crisis, which mirrors differently in each country depending on the level of socio-economic development. The researcher determines how negative environmental changes affect the nation's health and the well-being of the country.

A fundamental research of the anthropogenic impact on the Environmental safety condition of territory is presented in the monograph by M.I. Sokur and co-authors [5]. Scientists proposed and substantiated measures to solve the environmental problems of the region, analyzed the issue of processing industrial waste and suggested for industrial enterprises directions for improving environmental marketing, taking into account anthropogenic and social factors.

A. V. Prokopenko in his works defined the relation between environmental safety and marketing [6]. The author grounded the concept of environmental marketing in the context of sustainable development, analyzed trends in the development of environmental marketing and defined the role of the condition in this process.

The problem of the ecological component in socio-economic development is studied in the works of: M. I. Nizhny, B. M. Danilishin, A. B. Kaczynski, I. S. Murashko, A. V. Shkarupa, M. I. Khylko and others. The authors use various approaches to assess environmental safety, in particular, probability methods, statistical analysis, scenario approach, simulation modeling, etc.

Environmental safety, according to A. B. Kachynski [7], is defined as the opposite condition of danger, the quantitative measure of which is risk. The researcher proposed to assess the risk of danger as a vector value of damage that may occur in the event of a threat.

I. S. Murashko [8] identified the principles of sustainable development, which should be aimed at establishing long-term, potential and short-term goals of the region, comparing the goals and objectives of each development subject not only with the availability of resources, but also with the principle of resource conservation and rational use of resources as a mandatory condition for achieving sustainable development region.

The problems of environmental safety as protection of the vital interests of individuals, society and the country from an excessive threatening danger are studied in the works of M. I. Khylko [9].

The researchers highlighted various aspects of environmental safety, however, among them there is no agreed opinion on the environmental safety assessment within a territory, therefore this issue is still relevant, which determined the choice of the research topic.

Statement of purpose

The purpose of the study is to develop a cognitive model for assessing the environmental safety condition, taking into account factors of the socio-economic development of the territory.

Presentation of basic material of the research

On the one hand, socio-economic development leads to economic growth, an increase in the standard of living of the population, and on the other hand, if low level of use of resource-saving, environmental technologies, a high level of anthropogenic impact, the formation of a large volume of production and consumption waste (at a low level of their processing, reuse, disposal), contributes to the growth of threats to environmental safety, which negatively affects the socio-economic situation within the territory. To assess the environmental safety condition,

ISSN Print 2414-0287
ISSN Online 2707-8426

taking into account the impact of socio-economic factors on the environment, the method of cognitive modeling was applied. The building of a cognitive model as a graph is carried out in stages: formation of a list of graph vertices - system elements that are important from the point of view of the problem under study; the formation of graph arcs - the establishment of relations between elements; graphical representation of the graph; highlighting target factors; determination of leverage; analysis into the effects and balance of the model; analysis of the results obtained and formulation of proposals for management decisions.

The proposed procedure is applied to assess the environmental safety condition in Ukraine. So, at the first stage of assessing the condition of the ecological safety of the territory, a factor analysis of the impacts was conducted, that is, the factors and the nature of the impact (stimulating or de-stimulating) were determined. At the next stage, a cognitive model of the influence of factors on the resulting indicator as a signed graph was built [10]. What is more, the vertices of the graph are elements of the system (factors) which are important from the point of view of the problem under study. The relationships between the vertices are reflected by arcs that determine the nature of the impact:

- stimulating impact (solid arc) indicates a direct relation between the vertices (the growth of the factor from which the arc exits leads to an increase in the factor into which it enters)
- de-stimulating impact (dotted arc) indicates an inverse relation between the factors (the growth of the factor from which the arc exits leads to a decrease in the factor into which it enters).

In addition, a target factor was determined: changing it in the desired direction is the goal of management and leverage: those factors which value we can change and thereby influence the target factor. As a target factor in the cognitive model, we propose to use a qualitative indicator "Environmental safety condition" (v1), which can take the following values: unsatisfactory, satisfactory and high.

As a result of the analysis of socio-economic factors that affect the environmental safety condition of Ukraine, three groups of factors were determined: socio-demographic (characterizes the social and demographic component), production (characterizing the production process), anthropogenic environmental factors (characterizes the impact of human activities on environment). The list of factors, their coding as the vertices of the cognitive model, and the type of impact on the environmental safety condition of the territory are shown in Table 1.

Table 1 Factors affecting Ukraine's environmental safety: coding and type

Type of factor	Notation	Factor	Type of factor
Socio-demographic factors	v_2	GDP per capita	stimulating
	v_3	Household income	stimulating
	v_4	Public health	de-stimulating
Production factors	v_5	Depreciation of fixed assets	de-stimulating
	v_6	Eenergy intensity of production	de-stimulating
	v_7	Renewable energy consumption	stimulating
Anthropogenic environmental factors	v_8	Environmental protection costs	stimulating
	v_9	Emissions of pollutants	de-stimulating
	v_{10}	Total waste generation	de-stimulating

Source: written by authors.

The cognitive model of assessing the environmental safety condition of Ukraine is presented in Fig.1.

ISSN Print 2414-0287
ISSN Online 2707-8426

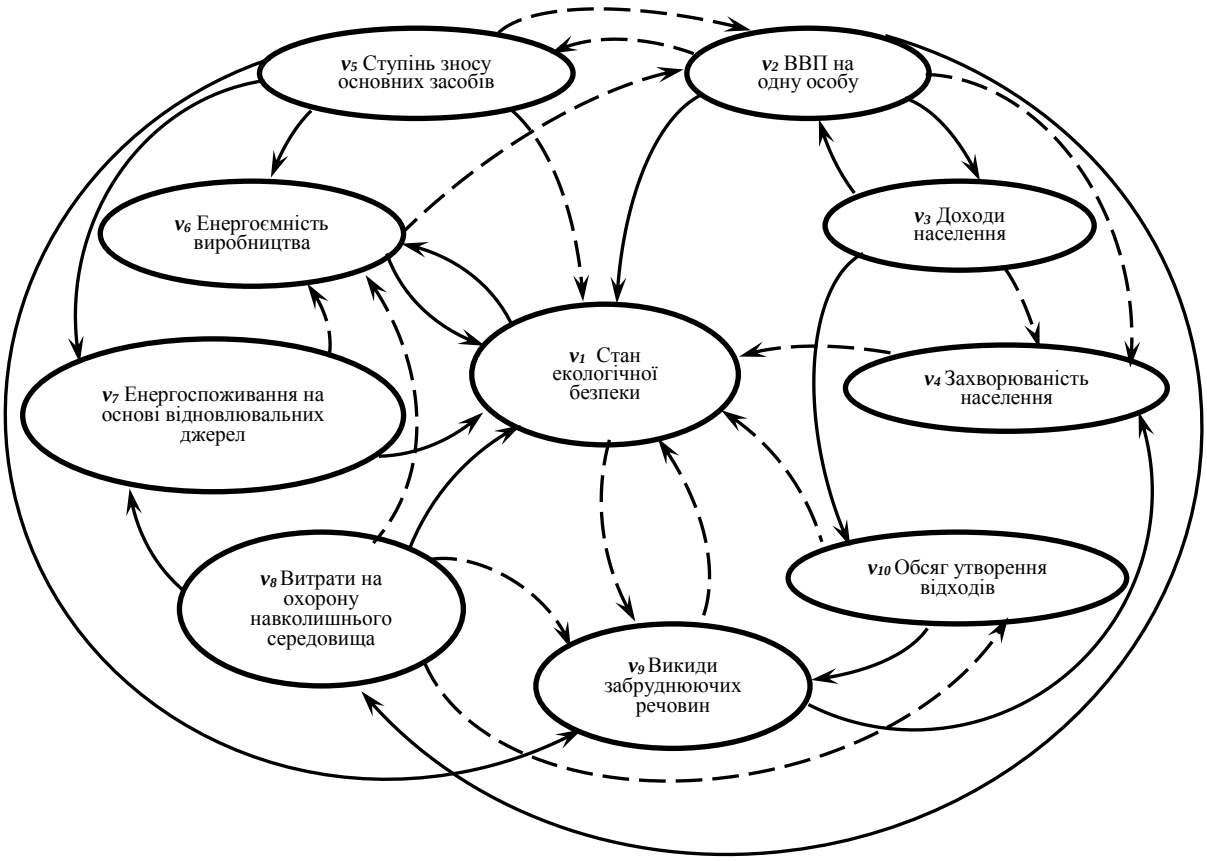

Figure 1 – Cognitive model of factors which impact on the environmental safety condition of the territory
Source: written by authors

These factors directly or indirectly impact on the environmental safety condition of the territory. By indirect impact we mean the influence that is determined by several arcs, for example, the relation between the vertices v_2 and v_1 can be both direct (path: $v_2 \xrightarrow{+} v_1$), and indirect (path: $v_2 \xrightarrow{-} v_5 \xrightarrow{-} v_1$ or $v_2 \xrightarrow{+} v_3 \xrightarrow{-} v_4 \xrightarrow{-} v_1$).

At the next stage of assessing the environmental safety condition of the territory, a statistical analysis of the balance of the cognitive model was carried out according to the method proposed by A.P. Kuznetsov [10].

The static analysis of the cognitive model is carried out using the indicator of total impact of the i factor on the j factor (s_{ij}), and the notation of consonance (c_{ij}), which is a measure of the difference between the positive and negative impact of the i factor on j factor [10].

The consonance (c_{ij}) of impact of the i factor on the j factor is determined by the ratio:

$$c_{ij} = \frac{p_{ij} - n_{ij}}{s_{ij}}, \qquad (1)$$

Where s_{ij} - the total impact of the i factor on the j factor, $s_{ij} = p_{ij} + n_{ij}$;

p_{ij} - the total positive impact of the i factor on the j factor, $p_{ij} = \sum_{m=1}^{\infty} f(m) E_{ij}^{(m)}$, $E_{ij}^{(m)}$ - the number of the positive (strengthening) paths of the length m;

n_{ij} - the total negative impact of the i factor on the j factor, $n_{ij} = \sum_{m=1}^{\infty} f(m) I_{ij}^{(m)}$, $I_{ij}^{(m)}$ - the number of negative (stabilizing) paths of length m;

$f(m)$ - monotone decreasing function of the path length m, which determines the degree of weakening impact on the route from the i factor to the j factor.

It is considered that the greater the value of the consonances, the more definite the impact of the i factor on the j factor. If $c_{ij} < 0$, then an increase of the i factor leads to a decrease of the j factor, if $c_{ij} > 0$, then an increase of the i factor leads to an increase of the j factor, and if $c_{ij} = 0$, then change of the i factor does not impact on the change of the j factor.

The analysis of the cognitive model of the impact of factors on the environmental safety condition of the territory makes it possible to determine the impact of the selected factor on the resulting indicator. For example,

consider the impact of the "GDP per capita" factor, the vertex v_2, on the target factor "Environmental safety condition", the vertex v_1. The existing paths from the"GDP per capita" factor to the "Environmental safety condition" factor are displayed in the table 2.

Table 2 Path from the "GDP per capita" factor to the "Environmental safety condition"

Path length (m)	Path	Path characteristics
m=1	$v_2 \xrightarrow{+} v_1$	strengthening
m=2	$v_2 \xrightarrow{-} v_5 \xrightarrow{-} v_1$	strengthening
	$v_2 \xrightarrow{-} v_4 \xrightarrow{-} v_1$	strengthening
	$v_2 \xrightarrow{+} v_8 \xrightarrow{+} v_1$	strengthening
m=3	$v_2 \xrightarrow{+} v_3 \xrightarrow{-} v_4 \xrightarrow{-} v_1$	strengthening
	$v_2 \xrightarrow{+} v_3 \xrightarrow{+} v_{10} \xrightarrow{-} v_1$	stabilizing
	$v_2 \xrightarrow{-} v_5 \xrightarrow{+} v_6 \xrightarrow{+} v_1$	stabilizing
	$v_2 \xrightarrow{-} v_5 \xrightarrow{+} v_7 \xrightarrow{+} v_1$	stabilizing
	$v_2 \xrightarrow{-} v_5 \xrightarrow{+} v_9 \xrightarrow{-} v_1$	strengthening
	$v_2 \xrightarrow{+} v_8 \xrightarrow{+} v_7 \xrightarrow{+} v_1$	strengthening
	$v_2 \xrightarrow{+} v_8 \xrightarrow{-} v_6 \xrightarrow{+} v_1$	stabilizing
	$v_2 \xrightarrow{+} v_8 \xrightarrow{-} v_9 \xrightarrow{-} v_1$	strengthening
	$v_2 \xrightarrow{+} v_8 \xrightarrow{-} v_{10} \xrightarrow{-} v_1$	strengthening
m=4	$v_2 \xrightarrow{+} v_3 \xrightarrow{+} v_{10} \xrightarrow{+} v_9 \xrightarrow{-} v_1$	stabilizing
	$v_2 \xrightarrow{-} v_5 \xrightarrow{+} v_7 \xrightarrow{-} v_6 \xrightarrow{+} v_1$	strengthening
	$v_2 \xrightarrow{+} v_8 \xrightarrow{+} v_7 \xrightarrow{-} v_6 \xrightarrow{+} v_1$	stabilizing
	$v_2 \xrightarrow{+} v_8 \xrightarrow{-} v_9 \xrightarrow{+} v_4 \xrightarrow{-} v_1$	strengthening
	$v_2 \xrightarrow{+} v_8 \xrightarrow{-} v_{10} \xrightarrow{+} v_9 \xrightarrow{-} v_1$	strengthening
m=5	$v_2 \xrightarrow{+} v_3 \xrightarrow{+} v_{10} \xrightarrow{+} v_9 \xrightarrow{+} v_4 \xrightarrow{-} v_1$	stabilizing

Source: written by authors.

It is worth noting that the longer the path, the weaker the impact, so the impact of the "GDP per capita" factor on the "Environmental safety condition" factor was calculated from the assumption that $f(m)$ - monotone decreasing function, $f(m)=\frac{1}{m}$. Then the total positive impact is equal to:

$p_{21}=1+\frac{3}{2}+\frac{5}{3}+\frac{3}{4}\approx 4{,}92$; the total negative impact – is equal to: $n_{21}=\frac{4}{3}+\frac{2}{4}+\frac{1}{5}\approx 2{,}03$.

The total impact is respectively equal to: $s_{21}=4{,}92+2{,}03=6{,}95$. So, the consonance of the impact of "GDP per capita" on the "Environmental safety condition" is determined by the ratio: $c_{2,1}=\frac{4{,}92-2{,}03}{6{,}95}=0{,}416$.

Since $p_{21}>n_{21}$, then we can conclude that the positive impact of GDP per capita on the Environmental safety condition is greater than negative, and the consonance value ($c_{2,1}$) indicates that such an impact is sufficiently definite.

The calculated values of consonance indicators in the cognitive model of factors which impact on the environmental safety condition of the territory are presented in Table 3.

Table 3 The value of consonance indicators in the cognitive model of the influence of factors on the state of ecological safety of the territory

Consonance values	Interpretation
$c_{3,1}$=0,33	positive impact, the relation is sufficiently definite
$c_{4,1}$=-1	negative impact, the relation is strong
$c_{5,1}$=-0,36	negative impact, the relation is sufficiently definite
$c_{6,1}$=-0,22	negative impact, the relation is insufficiently definite
$c_{7,1}$=0,55	позитивний вплив, the relation is sufficiently definite
$c_{8,1}$=0,4	позитивний вплив, the relation is sufficiently definite
$c_{9,1}$=-1	negative impact, the relation is strong
$c_{10,1}$=-1	negative impact, the relation is strong

Source: written by authors.

As a result of the analysis of consonances absolute values of the cognitive model it is possible to conclude that the greatest impact on the environmental safety of the territory is imposed by the following factors: public health, emissions of pollutants, waste generation; the least impact is imposed by energy intensity of production.

Conclusions

So, environmental safety is the subject of many scientific studies not only of domestic but also of world politics. The environmental safety condition of a territory depends on the level of economic development. The authors proposed to determine the environmental safety condition of Ukraine through the prism of socio-economic development using the method of cognitive modeling. Thus, on the basis of the consonances values of the cognitive model, it has been proved that the following factors have a negative impact on the environmental safety condition: public health, emissions of pollutants, waste generation; the least impact is imposed by energy intensity of production.

The proposed approach for assessing the environmental safety condition based on the cognitive modeling method can be applied in management decisions that relate to the viability of introducing environmental protection measures at the state and regional levels, since it allows you to quickly determine the current condition of safety, taking into account socio-demographic and production factors and anthropogenic environmental factors. The prospect for further research is the development of a methodology for a quantitative assessment of the condition of the environmental safety of the territory.

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