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MODELING THE SYSTEMS OF ENSURING THE STATE SECURITY

Abstract. The model of ensuring the system of the state security is proposed as an effective tool for realizing the interests of the citizens and society, taking into account internal and external factors of influence. Possibilities of application of the mathematical methods for the optimal choice of the means of protection against threats and dangers in the public administration are investigated.

Ways of using the artificial intelligence to establish the state security criteria have been studied. In particular, the optimization-simulation methods are considered, which allow, due to a certain number of iterations, to obtain an approximate value of the studied parameters. Their practical importance has been determined for the purpose of further application in the fields of: analysis of the national security threats; analysis of the market for protection against such threats; processing of the information on the characteristics of the threats (opportunities for manifestation and harm); processing of the information on possibilities of prevention of the threats; development of the algorithms for the optimal choice of the protection options.

The theoretical aspects of the use of artificial neural networks that can be used in the process of the state security modeling are investigated. The peculiarity of their use can be considered that a large number of input indicators characterizing the level of the national security can be analyzed by machine method, using machine learning algorithms. This makes it possible to classify different states, such as threats, risks and dangers. And while the problem of the influence of the input parameters of the neural network remains unsettled, their self-study, combined with simulation methods of the mathematical modeling, can further resolve the optimization of the state security assessment.

Keywords: modeling, security, state, threats, risks.

МОДЕЛЮВАННЯ СИСТЕМ ЗАБЕЗПЕЧЕННЯ ДЕРЖАВНОЇ БЕЗПЕКИ

Анотація. Запропоновано модель системи забезпечення державної безпеки, як дієвого інструменту реалізації інтересів громадян і суспільства, з урахуванням внутрішніх та зовнішніх факторів впливу.

Досліджено можливості застосування математичних методів для оптимального вибору засобів захисту від загроз та небезпек в державному управлінні.

Вивчено способи застосування штучного інтелекту для встановлення критеріїв безпеки держави. Зокрема, розглянуто оптимізаційно-імітаційні методи, які дають можливість завдяки певній кількості ітерацій, отримати приближене до оптимального значення показників, що досліджуються. Визначено їх практичне значення, з метою подальшого застосування у сферах: аналізу загроз національної безпеки; аналізу ринку засобів захисту від таких загроз; оброблення інформації про характеристики загроз (можливості прояву та шкоди); оброблення інформації про можливості запобігання загроз; розроблення алгоритмів оптимального вибору варіантів захисту.

Досліджено функціональні залежності рівня безпеки держави від низки факторів впливу, що можуть бути застосовані при моделюванні безпеки держави, що дає можливість визначити рівні безпеки.

Досліджено теоретичні аспекти застосування штучних нейронних мереж, які можуть використовуватись в процесі моделювання безпеки держави. Особливістю їх використання можна вважати, те, що велика кількість вхідних показників, які характеризують рівень держаної безпеки, може бути проаналізована машинним способом, з використанням алгоритмів машинного навчання. Це дає можливість проводити класифікації різних станів, наприклад, загроз, ризиків та небезпек. І, хоча, не вирішеним аспектом залишається вибір певної ваги впливу вхідних параметрів нейронної мережі, їх самонавчання у поєднанні із імітаційними методами математичного моделювання, в подальшому можуть вирішити питання оптимізації оцінювання рівня безпеки держави.

Ключові слова: моделювання, безпека, держава, загрози, ризики.

МОДЕЛИРОВАНИЕ СИСТЕМ ОБЕСПЕЧЕНИЯ ГОСУДАРСТВЕННОЙ БЕЗОПАСНОСТИ

Аннотация. Предложена модель системы обеспечения государственной безопасности, как действенного инструмента реализации интересов граждан и общества, с учетом внутренних и внешних факторов воздействия. Исследованы возможности применения математических методов для оптимального выбора средств защиты от угроз и опасностей в государственном управлении.

Изучены способы применения искусственного интеллекта для установления критериев безопасности государства. В частности, рассмотрены оптимизационно-имитационные методы, позволяющие благодаря определенному количеству итераций, получить приближенных к оптимальному значению показателей исследуемых. Определено их практическое значение, с целью дальнейшего применения в сферах: анализа угроз национальной безопасности; анализа рынка средств защиты от таких угроз; обработки информации о характеристиках угроз (возможности проявления и ущерба); обработки информации о возможности предотвращения угроз; разработки алгоритмов оптимального выбора вариантов защиты.

Исследованы функциональные зависимости уровня безопасности государства от ряда факторов влияния, которые могут быть применены при моделировании безопасности государства, что в свою очередь дает возможность определить уровни безопасности.

Исследованы теоретические аспекты применения искусственных нейронных сетей, которые могут использоваться в процессе моделирования безопасности государства. Особенностью их использования можно считать, то, что большое количество входных показателей, характеризующих уровень государственной безопасности, может быть проанализирована машинным способом, с использованием алгоритмов машинного обучения. Это дает возможность проводить классификации различных состояний, например, угроз, рисков и опасностей. И, хотя, нерешенным аспектом остается выбор определенного веса влияния входящих параметров нейронной сети, их самообучения в сочетании с имитационными методами математического моделирования, в дальнейшем могут решить вопрос оптимизации оценки уровня безопасности государства.

Ключевые слова: моделирование, безопасность, государство, угрозы, риски.

Formulation of the problem. TThe problem of reproduction of the real processes in the state, reflecting the state of security, must be solved by the use of effective models that characterize the ability to assess the protection against external, internal, potential and real threats.

Given that the existing approaches provide only a general level of security,

to reproduce a comprehensive assessment, there are a number of obstacles in the system of its provision: volatility of the economic, social, political and geopolitical processes; not perfect national security modeling tools; and, most importantly, the lack of political will to really evaluate the administration actions in the country. The existing models ignore the internal political, inter-ethnic and other problems of the development of our country. Therefore, the insufficient level of detail is a major obstacle to the optimal reproduction of the state's security status and its components.

Analysis of the previous research and publications. The problems of evaluating the efficiency of the public administration were addressed by I. Ansoff, J. Bryson, M. Zhurovsky, O. Kokoshyn, I. Pranhishvyly, H. Atamanchuk, V. Bogdanovych, R. Griffin, R. Kinney, and others.

However, despite the significant scientific contribution, the complexity of reproducing the real processes taking place in the country and abroad, which directly or indirectly affect the level of the national security of Ukraine, uncertainty and unpredictability, volatility and impartiality of the events occurring, impede the creation of an effective model government that can be used to simulate security-creative issues in the country.

The purpose of the article is analysis of the state security system as an effective tool for realizing the interests of citizens and society.

Outline of the main research material. The urgency of the problems related to the effectiveness of the public administration, the development of the methods for improving the effectiveness of the administrative decisions and the definition of the effective criteria for evaluating the work of the public authorities is constantly increasing. And the lack of effective approaches leads to a deterioration of the effectiveness of the political decisions, which eventually turn into potential threats and then into real risks for the country.

Also, given the considerable number of components that affect the level of the national security that also have a number of dependencies: the existing information processing facilities are not able to reproduce the full range of threats, so it is advisable to use models from which you can form integral indicators of the country security. On the other hand, it is also not possible to obtain data from all the sources characterizing the country's security.

This implies the need to establish statistical dependencies using the artificial neural networks, that, similar to human neurons, are constructed on the basis of the organization and operation of the biological neural networks based on machine algorithms that can learn, that is, memorize the states of the output parameters, which can subsequently serve the threat classifier, criteria for a certain state of security, recognition of danger patterns, etc.

To date, machine learning technologies are quite advanced, and the criteria for the effectiveness of the administrative decisions in the public administration are also being improved. For example, the Common Assessment Framework (CAF) methodology [1] used in the European Union countries to assess public sector quality administration can be seen as a tool to help

some public authorities monitor the organizations' performance. The Common Assessment Framework includes data from 2382 public sector organizations in 43 different countries.

Considering the peculiarities of the economic, social and political nature, each country stands out in the formulation of the national security assessment indicators. For example, the officially recognized models of assessing the level of security in Ukraine should include the Methodology for Calculating the Level of Economic Security [2] developed by the Ministry of Economy of Ukraine. The contribution to the assessment of the environmental component of the national security was made by Ye. Romanenko, proposing the mechanisms of the legal regulation of the methods of environmental safety assessment [3] and G. Wright, using the methods of Q-analysis and analysis of the environmental security hierarchies, suggesting ways to determine the quantitative level of the environmental security [4, p. 436–451].

Among the large number of papers describing the possibilities of modeling the national security, considerable attention is paid to the hierarchical methods that are generally effectively used to evaluate the various components of the state security. The use of hierarchy analysis methods includes:

- research of the state security variables and their generalization;
- creation of the matrices of separate comparative priorities (weights);
- scenario analysis;
- interpretation of the calculated state variables of the system.

Such techniques differ in the number, sequence and content of the steps, the set of methods on the basis of which they were developed, the degree of formalization of the processes, as well as the participation of the experts in the research, etc.

Therefore, in the absence of universal methods of modeling the national security, the problem of scientifically sound choice of methods that best correspond to the content and nature of the processes of protection of the national interests in the public administration is exacerbated.

It should be noted that the methodology for assessing the effectiveness of the national policy of protection of the national interests is due to the need to increase the level of scientific substantiation of the strategic decisions and their correction, clarification of the goals, principles, priorities, tasks, etc. Thus, the complexity and versatility of the national security category reflects the dynamism of such a system. All its elements are focused on ensuring the protection of the national interests and creating safe conditions for the effective socio-economic development, which are the main objects of the modeling.

The formation of this system is influenced by many factors of the external and internal environment: historical, geopolitical, ethnic, demographic, political, social, economic and other components of the national security the study of which deals with a considerable number of works.

Not dwelling in detail on the results of these studies, it should be noted that in most cases the obvious connection and interdependence of such components can be traced, and their action may be multidirectional. As a result, the structural links between the ele-

ments of the national security system are further complicated. Considering the possibilities of modeling the national security, most authors identify as components of the model such areas as: military, economic, social, environmental, political, information, etc. Some are trying to devise ways to highlight the modeling levels. Thus, in particular H. Vechkanov and Ye. Kuznetsova, in their works propose to divide the process of the national security research into "vertical" and "horizontal" spheres of analysis. Vertical — this is international, global, regional, national and anthropogenic security, at the horizontal level distinguish the economic, social, environmental, spiritual and information security [5].

It is possible to graphically represent the model of the communication of the elements of the national security system, which, conditionally, but adequately reflects the complexity of the interaction of the most important elements: objects, interests and spheres (Fig. 1).

The model displays links between the main elements of the national security system that apply to all the research objects.

Such objects can and should be considered as areas of the national security research, and they should form the security module as a whole. The investigation of such objects will allow to set critical limits of the permissible threats and risks for the state. Therefore, the artificial neural networks can be used in the formation of the national security models, as they are shown in Fig. 1, the links have different functional dependencies among the vast number of input parameters of such models in order to reproduce the complex social, political, geopolitical and economic structures.

To address these issues, the following groups of the national security assessment methods should be identified: comparison of a number of the external and internal socio-economic indicators with the marginal estimates; setting key indicators for the each component of the national security, assessing the pace

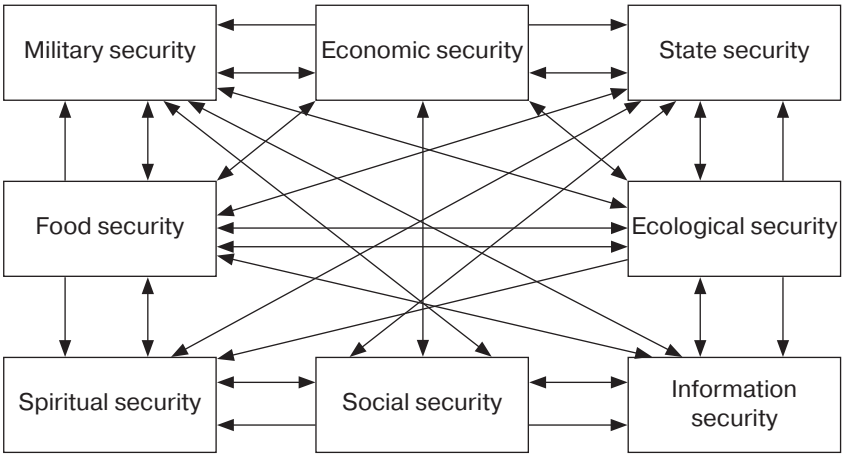

Fig. 1. **Structural – logical model of the national security system**
Developed by the author.

and dynamics of the economic growth; assessment of the national security on the basis of a point grade; expert assessment and ranking of the threats and dangers; applied mathematical methods for the quantitative measurement of a number of the state security indicators.

Given that, at present, the most effective approach to complex systems modeling is neural network modeling, the process of assessing the level of the national security can consider the functional dependence of the key indicators in the state and a number of factors that affect their effectiveness. As input parameters of the neural network, it is advisable to evaluate the level of the development of the scientific and technological progress, the ability of the economy to sustainable growth, the state of the financial-credit system, the martial law, the political component, the social component, which will allow to assess the state of the national security qualitatively. And these proposals to establish the functional dependence of the national security on a number of factors at the fixed values of input variables will allow to quantify the administration decisions.

The very process of forming an artificial neural network (Fig. 2) can be represented as a set of artificial neurons connected by arrows, as well as in a real, biological neural network, an electrical signal is transmitted from inputs to outputs. And as you go through the network, it may change, depending on the weight setting (w) of each neuron. After the inputs (x) are given signals in the form of certain data, they are multiplied by weights, then summed, and, as a result, a functional dependence is formed, which outputs the result that depends on further adjustment of the weighting factors w and the recognition accuracy of a specific trait, or set of traits that can be represented by the equation:

$$x_1 w_1 + x_2 w_2 + \ldots + x_n w_n = \sum_{i=1}^{n} x_i w_i, \quad (1)$$

where $x_1 \ldots x_n$ — input network parameters; $w_1 \ldots w_n$ — weights of the corresponding input signals.

And the neural network approach itself makes it possible to detect the nonlinear relationships between such

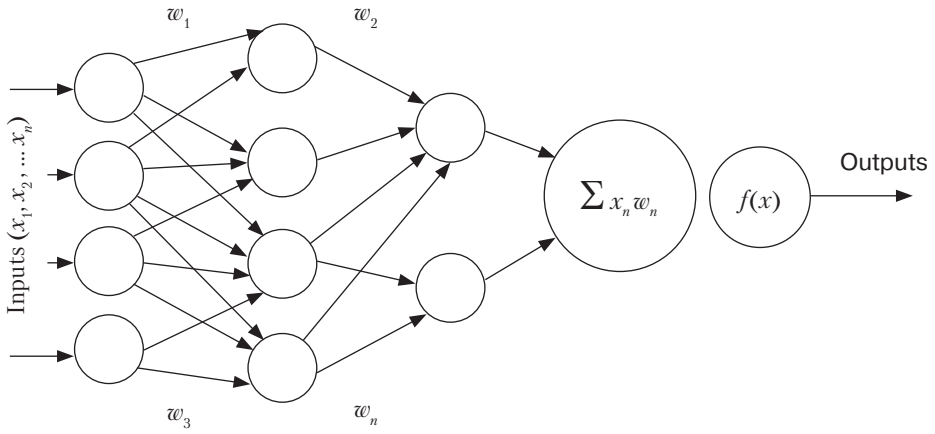

Fig. 2. **Artificial neural network**

inputs and outputs. Therefore, it is very important in this case to choose a neural network structure that would fully meet the national security modeling objectives.

If we consider the security of the state as a functional dependence of a number of factors with its quantitative level, it is advisable to introduce several variables. Let these be the following input indicators: the normative level of the economic development (x_1), the existing level of the economic development (x_2), the ability of the economy to sustainable development (x_3), the state of the financial-credit system (x_4). In this case, the desired national security function can be represented as a system of differential equations (2):

$$\begin{cases} \dfrac{dF_s}{dx_1} = f(x_2, x_3, x_4)\left(F_s - F_s^{\min}\right)\left(F_s - F_s^{\max}\right); \\ \dfrac{dF_s}{dx_2} = f(x_1, x_3, x_4)\left(F_s - F_s^{\min}\right)\left(F_s - F_s^{\max}\right); \\ \dfrac{dF_s}{dx_3} = f(x_1, x_2, x_4)\left(F_s - F_s^{\min}\right)\left(F_s - F_s^{\max}\right); \\ \dfrac{dF_s}{dx_4} = f(x_1, x_2, x_3)\left(F_s - F_s^{\min}\right)\left(F_s - F_s^{\max}\right); \end{cases}$$

where $F_s^{\min}$, $F_s^{\max}$ — current minimum and maximum national security values; F_s — national security function.

The research of the function F_s will identify the critical points that can be considered threatening states and establish security levels on the basis of which the administration decisions are usually made intuitively.

Thus, in this case, the important aspect remains the correct determination of the input parameters of the model, since it is their choice that determines the specificity of the mathematical modeling.

This example shows that there are opportunities to describe the functional dependency of a country's security with a number of factors that influence it. The only unsolved aspect that can be further developed is the process of selecting the weight of each influencing factor and identifying the factors that can be measured by thousands and even tens of thousands of factors for the national security. And to some extent, it requires the use of expert, scientific and professional potential.

Although the author's scientific work is connected with conducting expert studies in the automatic mode, where the approximate number of the respondents, currently reaches 100 people, for a comprehensive study of the impact of the factors on the security situation in the country this is not enough, since the vulnerability of the state security objects is essential and exceeds the ways to protect them. This is due, first of all, to the scale and heterogeneity of the national security objects themselves. The main causes of this vulnerability include the shortcomings of the information technology and the steady increase in the number of impacts on the state of security. Therefore, a thorough analysis of all the possible threats is required to effectively address the national security concerns.

In the analysis of threats it is necessary to assess the possibility of their manifestation, as well as the damage that will be inflicted on the state in case of the realization of these threats.

Although, to counteract the same threat, there are usually several remedies, to create a model, it can be assumed that each remedy protects exactly the same threat. Then, the problem

of the optimal choice of the protection options can be solved by means of Boolean programming, for which there are many algorithms [6–8]. However, it is also possible to build a model where each remedy can counteract a number of threats, and when the possibility of preventing each threat is different.

So, let the set of possible national security threats be presented as $A = \{a_1, a_2, ..., a_n\}$. The set of threat indexes is $N = \{1, 2, ..., n\}$. The set of protection means $B = \{b_1, b_2, ..., b_n\}$. Multiple indices of security options $M = \{1, 2, ..., m\}$.

Threat functioning period $T = [t_0, t_{max}]$ is considered the functioning period.

We denote the probability of occurrence of the i-th threat at the time interval T as: $p_i, \forall i \in N, p_i \in [0, 1]$, which is determined by the experts. The average i-th non-threat damage can be represented as, $u_i, \forall i \in N$.

The cost of j-th remedy — $c_j, \forall j \in N$.

The probability of preventing the effects of an i-th threat using the j-th security can be represented as: $v_{ij}, \forall i \in N, \forall j \in M, v_{ij} \in [0, 1]$, which can also be determined by statistics or expertly.

By marking the inputs and objects of the study, the task of optimizing the choice of the means of protection can be represented in two variants of modeling:

• maximizing the possible average cost of preventing certain negative consequences of the threat, while limiting the overall security measures;

• minimizing the overall costs of the security measures, while limiting the cost of preventing the individual losses.

An important aspect here is to optimize the costs of preventing the threats. It is much cheaper and then eliminating their effects. And, optimization, in the conditions of the economic development of our country, is the most important component for such development, because, in the conditions of war, economic and political reforms, etc., there is no unnecessary money and resources, and consequently the right to error.

Let us consider the first version of the national security modeling problem statement. To do this, we introduce a Boolean variable to simulate the means of protection $x_j \in \{0, 1\}, \forall j \in M$. In that case, if $x_j = 1$, then the j-th remedy will be stuck in state security measures, $x_j = 0$, it will be in the passive state, i.e. it will not be used. In this case, we create a vector of Boolean variables $\vec{x} = x_j, \forall j \in M$.

An indicator of the quality of the choice of the remedy, that is parallel and an indicator of the effectiveness of the administration decision, for the authorized person, can be represented as a function where the vector of Boolean variables is specified as an argument:

$$U(\vec{x}) = \sum_{i \in N} u_i p_i \max_{j \in M} \left(v_{ij} x_j \right). \qquad (3)$$

Given that this indicator is used to potentially prevent harm when using vector-defined protection $\vec{x}$, its value should be maximized with the following constraint:

$$\sum_{j \in M} c_j x_j \le C. \qquad (4)$$

The corresponding condition limits the cost of the selected remedies, where C is the maximum possible cost allocated to the defense.

Thus, the state of security, subject to maximization of the possible costs for the prevention of certain negative

consequences, with restrictions on carrying out general security measures can be presented as follows:

$$U(\vec{x}) = \sum_{i \in N} u_i \, p_i \max_{j \in M} \left(v_{ij} \, x_j \right) \to \max_{\vec{x} \in \Delta_{\text{альт}}};$$
$$\Delta_{\text{альт}} : \sum_{j \in M} c_j \, x_j \le C, \quad (5)$$

where $\Delta_{\text{альт}}$ — the set of admissible vector values $\vec{x}$.

The solution to this problem in the optimal choice of the protection means to find all the unknown components of the vector $\vec{x}$ and the choice of those remedies for which component of the vector x_j ($\forall j \in M$) is 1.

Considering the following variant of minimization of the general expenses for carrying out of safety measures at limitation of the level of expenses for the prevention of separate losses, also the Boolean variable is entered $x_j \in \{0, 1\}$, $\forall j \in M$, $x_j = 1$. If the j-th remedy is used, $x_j = 0$, if not used. Then $\vec{x}$ — vector of the Boolean variables is x_j, $\forall j \in M$.

The cost of threat and dangers protection options can be summarized as follows:

$$C(\vec{x}) = \sum_{j \in M} c_j \, x_j. \quad (6)$$

The value of this indicator should be minimized under restrictions where the possible loss would be at least as specified:

$$\sum_{i \in N} u_i \, p_i \max_{j \in M} \left(v_{ij} \, x_j \right) \ge U_{\text{зад}}, \quad (7)$$

where $U_{\text{зад}}$ — setpoint of the value of possible harm prevention.

Thus, the mathematical model, while minimizing the overall cost of the security measures, while limiting the likely level of cost to prevent individual losses, looks like:

$$C(\vec{x}) = \sum_{i \in N} c_i \, x_i \to \min_{\vec{x} \in \Delta_{\text{альт}}};$$
$$\Delta_{\text{альт}} : \sum_{j \in M} u_i \, p_i \max_{j \in M} \left(v_{ij} \, x_j \right) \ge U_{\text{зад}}. \quad (8)$$

In this case, the solution of the problem is to find all the unknown components of the vector $\vec{x}$ and the choice of such remedies b_j, for which the corresponding component of the vector x_j is 1. Which, in general, can be realized through powerful computing tools using simulation modeling techniques.

To summarize, it should be noted that the proposed models for optimizing the choice of the national security threats have certain difficulties, since it is difficult to determine the weight of a particular security impact factor, it is quite problematic to establish the cost of the threat prevention measures, which in turn also depend from many factors, both economic and other. In general, expert methods are often used to solve this problem.

Conclusion. The mathematical formulation of the problem of the optimal choice of means of protection against threats and dangers, which can be called optimization-simulation method, is that when restrictions or index cannot be calculated or given in the form of a certain formula, there are simulation modeling methods for their calculation, and modifications thereof, using the example below, can be applied to: analysis of the national security threats; analysis of the market for protection against such threats; processing of the information on the characteristics of the threats (opportunities for manifestation and harm); processing of the information on possibilities of prevention of the threats; development of the algo-

rithms for the optimal choice of protection options.

The study of the functional dependencies of the state security level on a number of factors of influence can also be applied in modeling the security of the state, which makes it possible to determine the security levels. However, an important aspect remains the correct determination of the input parameters of the model, since it is their choice that determines the specificity of the mathematical modeling.

When using the artificial neural networks in the process of the state security modeling, the choice of the weight of each influencing factor and determining the factors of influence on the state of the national security are not resolved.

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