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THE NEWEST METHOD FOR OPTIMIZING CLUSTERS OF SPECIAL-PURPOSE STRUCTURES THROUGH BIM MODELING

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In the articlea method of cluster geometric modeling is proposedand the results of this method application were consideredto optimize resources when solving defense issues.An example of the necessary solution to the problem of reforming the placement of special-purpose facilities and structures in the light of the new concept of Ukrainian defense has been chosen, and on this basis an algorithm for quantitative and qualitative solution of the problem has been developed using modern neural networks.
Keywords: special-purpose facilities and structures, cluster geometric modeling, neural networks.

Introduction

The article proposes a general method of cluster geometric modeling in resource optimization, which will be an urgent need to solve the problems facing Ukraine. For the effective formation and functioning of the Armed Forces of Ukraine and their development, it is necessary to maintain their material and technical support at a high level, which must meet modern requirements and world standards. The current relevance of the problem indicates an urgent need to study the problems of norming and standardization and the creation of territorial planning and urban planning solutions for property defense complexes under the conditions of the transition to a new concept of defense construction in Ukraine, close to world standards.

The purpose of the study is to create a toolkit to optimize the solution of problems that will arise in the process of developing the concept of complex modeling of the characteristics of special-purpose structures and related issues of territorial planning and urban development solutions.

According to the authors, currently, complex, mainly anthropological, expert methods are mostly used when planning resources. Creating mathematical models requires a lot of time, which is unacceptable under current conditions, but if an already developed algorithm is used, which will be operated by a modern neural network, this drawback can be eliminated.

The topic of decision optimization is currently a poorly structured multi-criteria problem. In addition, the existing correlations between influencing factors require the development of a complex apparatus for making urgent decisions.

Relevance of the researchand Formulation of the problem

One of the conclusions of the study of the optimization methodology, including defense issues, was the statement about its complex organizational structure, which is based on various criteria. Multi-criteria is a feature of modern defense. Accordingly, the widespread view of special construction through the monetary dimension (involvement of private structures through tenders) does not justify itself. The emergence of many certification systems – energy efficiency, green building, etc. emphasizes this. Even the use of FIDIC contracts in the case of the construction of special structures will not have the desired effect. Finding a balance between influencing factors is a pressing scientific problem that is most likely to be solved by creating a powerful state structure that will take on the task of solving the scientific, educational, and construction aspects of the problems of norming and standardization and creating territorial planning and urban development solutions for defense property complexes.

An analysis of literary sources shows that the development of new technical and technological solutions for the placement of special-purpose facilities is based on the principles of the territorial formation of armed groups.

The formation of security in the field of special-purpose facilities and capital construction depends

on many factors:

- progressive standards developed at the level of modern achievements of world science;
- the latest design and construction solutions;
- the use of modern standardized construction technologies and construction equipment.

To achieve maximum productivity and the greatest economic effect, a skillful combination of advanced engineering and technology with advanced construction organization is required. The correct choice of organizational scheme largely determines the technology of construction and installation work.

The organization and implementation of work on international, regional, and national standardization will make it possible to gradually bring the regulatory and technical framework into line with EU directives and international technical regulations, which will contribute to approximation to the standards of EU countries, involve the country in the collective security system in Europe, and have a positive impact on the economic and social aspects of the functioning of the Ukrainian economy.

Modern scientists are engaged in the search for an optimal mathematical model to determine the optimal characteristics of complex property clusters, which are defense objects. The method of cluster geometric modeling is considered in modern research as one of the most effective methods of resource optimization and decision-making. It allows you to clearly and rationally structure a complex decision-making problem in the form of a hierarchy, compare and quantitatively express alternative solutions, taking into account not only the material or intangible quantitative qualities of objects, but also the subjective qualities or processes of the so-called "hybrid war" (Badyul and Kramarenko, 2013). In addition, the research of the Kyiv National University of Construction and Architecture presents algorithms for procedures for determining weighted indicators of the quality of city projects based on the qualimetric method of expert assessments. An important basis for forming an optimal management decision is a theoretical algorithm associated with the development of a universal method for quantitatively assessing the quality of the country's defense capabilities, which allows evaluating any object.

It should be noted that the use of a neural network using the cluster geometric modeling method is also possible when planning other defense tasks - the supply of material resources, real-time regrouping and planning of special operations, etc.

Scientific hypothesis

The algorithm for obtaining scientific results consists of 3 stages:

Analytical stage:

- Studying of existing methods of multi-criteria analysis and optimization of indicators to improve the result;
- Systematization of modern criteria for assessing the quality of a construction defense facility;
- Conducting analytics of existing software to identify available automatic means of obtaining indicators from the model;

Methodological and theoretical stage:

- Determination of the main groups of criteria for optimizing solutions in planning and placing special-purpose objects or other special tasks;
- Description of the neural network model as a system with the interaction of subsystems and supersystems;
- Definition of the paradigm of the cluster geometric modeling method as a system for managing the input database of the model;
- Formation of a property tree. Development of a mathematical and analytical apparatus for obtaining research results.

Practical stage:

- Flowchart of creating a network structure and its templates of management decisions;
- Structural diagram of a software module for determining a set of indicators, their aggregation and weight distribution;
- Technical description of the software implementation of the mathematical and analytical apparatus of the study.

The aim of the work and research tasks

The object of research is the network model as a system of heterogeneous data types at the input and output.

The subject of the study is multi-criteria analysis of a neural network model operating on the basis of the

cluster geometric modeling method.

The purpose of the study is to develop a methodology for applying automatic multi-criteria analysis to a building information modeling product to manage the creation of the modeling product.

Method implementation

The method is implemented by determining the indicators of the main assessment categories; obtaining aggregated quality indicators of different categories from the BIM model; comparison with reference indicators from the electronic technical specifications; automation of multi-criteria comparison of model indicators with reference values.

The practical significance is investigated on the example of designing a special modular town using BIM technology. The development of a software tool based on the developed method of quantitative and qualitative analysis of the BIM model will allow managing the qualitative characteristics of the project according to existing regulatory parameters and conditions specified by the customer at the initial stage of the life cycle of the object - its project. The tool described in the study improves both the economic, technical, environmental and social efficiency of the design and planning product.

The use of the method of quantitative-qualitative analysis of the BIM model is advisable when introducing standardization, in particular in the field of designing special structures. The Technical Committee for Standardization TC-320 "Special Purpose Structures" has expressed its intention to use this method after its final development.

In addition, the use of this method allows you to more accurately determine the material intensity and total cost of construction of structures. This allows you to save significant funds and prevent corruption when conducting tenders for the design and construction of buildings and structures under state order. The practical significance of the project exists both at the national level, from the help of regulating public procurement and public hearings, and in the private construction sector: for assessing business risks and mutual control of the customer and the contractor.

The approval of the Concept of BIM Implementation in Ukraine at the state level at the end of 2019 allowed us to continue working on proposals for amendments to The State Construction Standard of Ukraine N 2.2.3 regarding the implementation of BIM in Ukrainian regulatory acts. According to this study, ISO 22263: 2008, dedicated to quality management. In addition, amendments were made to the Law of Ukraine “On Construction Standards” to improve standardization in construction: “the method of parametric standardization in construction is a method of establishing requirements for a standardization object in construction, which involves determining the goals and/or parameters of safety, functionality and quality of a standardization object in construction (criteria, requirements for performance and/or its indicators)”.

However, it should be noted that according to the analysis of modern research, determining the quality of the model is quite relevant, and not a problem for the global design community. Today, a comprehensive tool of this kind for BIM technology is available for designers. The use of the survey results can be widely represented in various aspects of construction, architecture, and economic spheres of activity:

- A tool for improving the public procurement system. It is from this sector that the implementation of BIM at the state level began in many developed countries. Optimizing transparent decision-making helps improve the economic performance of the construction industry and the return on investment in the public construction sector.
- Application of decisions during public hearings. The clarity of the method helps to compare the effectiveness of different projects and make appropriate independent decisions.
- A method for improving the assessment of private investment risks, which is carried out by modeling quality indicators according to criteria important for a specific business plan.
- Quality control of the project team for both its leader and the investor. Transparency in adhering to the schedule and the quality of work that meets the ETR improve the economic effect of cooperation for both parties.
- Grounds for legal assessment of actions to change the technical task during the design process, which entail a second revision of the project, and, accordingly, the financial obligations of the parties.

Scientific novelty

The study describes for the first time the analysis of quantitative and qualitative characteristics of the design model for optimizing clusters of special structures regardless of their functional purpose. It assumes strategic, economic, environmental and technological properties of the project. The methods are implemented using:

1) determination of indicators of 4 main categories of assessment: strategic, economic, technical, environmental;

2) obtaining from the neural network model aggregate indicators of various categories in planning and managing defense processes;

3) comparison of reference indicators for a comprehensive decision submitted to the command;

4) automation of multi-criteria comparison of model indicators with reference values.

It should be noted that at present it is impossible toconfirm the presence or absence of documents regulating the quality of individual aspects of decision-making processes in solving defense problems. But it is assumed that all these documents do not have requirements for the necessary quality and construction aspects of defense, which are reproduced by the cluster model. The paper concludes that it is possible to adopt a neural network model as a qualimetric standard, provided that it determines the values of the weights and formulates reference indicators of properties on this basis. The conclusion is based on existing modern theses on the numerical values of the characteristics of the reference sample. They are established as accepted reference values, which are used as agreed reference values for comparison and are defined as:

a) a theoretical or established value based on scientific principles;

b) an established or certified value based on experimental data by certain national or international organizations;

c) an agreed (consensus) or certified value based on collaborative experimental work conducted by a scientific or engineering group (Motalo,A. and Stadnyk,B. and Motalo,C., 2020).

Significance of the study

The practical significance is investigated on the example of designing a residential area of a functional-spatial cluster of special-purpose objects using BIM technology. The development of a software tool based on the developed method of quantitative and qualitative analysis will allow at the initial stage of the object's life cycle to manage the qualitative characteristics of the project in accordance with existing regulatory parameters and conditions set by the customer and to optimize all solutions when creating it.The tool described in the study improves the economic, technical, environmental and social efficiency of the construction design product. The use of the method of quantitative and qualitative analysis is appropriate for the implementation of standardization, in particular in the field of design of special structures. The Technical Committee for Standardization TC-320 "Special Purpose Buildings" has expressed its intention to use this method after its final development. In addition, the use of this method makes it possible to more accurately determine the implementation time, resource optimization, material consumption and total construction cost.This allows you to save significant funds and eliminate corruption during the directive appointment by the State Service for Special Construction of contractors for the design and construction of buildings and structures under a state order. It should be noted that an integral part of the model is the regulatory framework that corresponds to the type of defense facility or planned process. In the example given in the article, these are standards that always provide for actions within the described framework (Sandbook. Base Camp Facilities Standards, 2004). These are the initial limitations in the data fields of the model. But according to the modern method of parametric inspection of the facility, which is gradually being replaced by fixed The State Construction Standard of Ukraine, it is such a flexible system of setting the initial parameters as the proposed model that allows you to combine the wishes of the customer with permanent construction. standards. In addition, the parametric method of standardization is practiced in countries with already implemented at the state level technology of Building Information Models (BIM).

The cluster geometric modeling method

The issue of effective formation of cluster organizational structures is very acute, since, in most cases, increasing the efficiency of production processes is prevented not by technological shortcomings of the equipment used and the material and technical base as a whole, but by suboptimal (and sometimes ill-considered) management decisions(Mykytas, 2019).Creating a model for the formation of organizational clusters, the elements of which will be united according to certain key characteristics and will ensure the most efficient and economically feasible implementation of production processes focused on energy saving in construction.This task in mathematical formulation can be presented as follows.

Let there be a certain set of m projects that need to be implemented. Let there be a certain set of “x” key features that characterize the projects and reflect the specifics of the consequences of their implementation. Let there be “n” stakeholders - potential performers of work on all existing projects - each of whom has known experience and the degree of effectiveness of implementing different types of projects, which are

assessed by the key features inherent in them above (the type of effect from the implementation of projects should be considered as features). It is necessary to determine which of the stakeholders should be entrusted with the implementation of which of the set of m projects.

Problem solving

Let us divide all m projects into "x" subsets, combining projects into subsets according to the principle of choosing one of "x" key features as the most significant effect of the implementation of each project from this subset.

Let us evaluate each of the n potential performers of certain works in terms of the experience of performing projects with which main features the corresponding performer has the most. Let us denote the numerical indicator of such h-th experience for some i-th performer as bi,h. After each of the potential performers receives the corresponding value for each characteristic, it is necessary to convert these values into percentage indicators in such a way that the sum of all indicators of all projects equals 100%. The reduction from natural (numerical) bi,h to percentage indicators ai,h should be carried out according to the following formula:

$$a_{i,h} = \frac{b_{i,h}}{\sum_{g=1}^{n} b_{g,h}} \cdot 100\%, \quad h = 1,2,\ldots,\Omega.$$

In this case, the following requirement is also met:

$$\sum_{i=1}^{n} a_{i,h} = 100\%, \quad h = 1,2,\ldots,\Omega. .$$

For example, if there are three performers, each of whom has experience in implementing 10, 7, and 5 projects with the same key features, then in percentage terms their relative (relative to each other) efficiency in implementing these projects will correspond to the indicators given in Table 1.

Table 1

Performance indicators of projects with the same features by three different performers with different experience

Performers	bi,h, pcs.	ai,h, %
No1	10	45.45 %
No2	7	31.82 %
No3	5	22.73 %

Having a percentage assessment of the effectiveness of the implementation of different types of projects, combined according to different key characteristics, it could be constructed a sectoral diagram with the number of sectors corresponding to the number of characteristics and subsets "x", with the possibility of additional internal division of individual sectors into subsectors of individual projects (Fig. 1).

That it could have beencloser or further from neighboring enlarged sectors. Accordingly, such a division can be performed both evenly and in percentage terms by the number of projects in subsets that will be included in the subsectors. In the latter case, the sectors will have not the same, but different angles.

The graph has been built that illustrate the connection between potential performers and projects that need to be implemented.The corresponding graph is presented in Figure 2.

Let us specify the coordinates of the a priori fixed vertices of the graph

$A(xA, yA), B(xB, yB), C(xC, yC):\ xA = 14.1;\ yA = 11.5;\ \ xB = 8.0;\ yB = 1.0;\ xC = 1.9;\ yC = 11.5.$

To reflect the mutual external influence of vertices on each other, it could beused the vector-free hypothesis, assuming that only the interaction forces between vertices act.

Let's determine indicators of the conditional intensity of interaction ki,j between all potential performers, as between the vertices of the constructed graph. As a result of the calculations, it could beobtained percentage indicators.

By projecting the vector components of the system equations onto the coordinate axes, it could beobtained a system of equations of the type:

$$-(k_{1,A} + k_{1,B} + k_{1,C} + k_{1,2} + k_{1,3} + k_{1,4} + k_{1,5} + k_{1,6} + k_{1,7}) \cdot x_1 + k_{1,A} \cdot x_A + k_{1,B} \cdot x_B + k_{1,C} \cdot x_C +$$
$$+k_{1,2} \cdot x_2 + k_{1,3} \cdot x_3 + k_{1,4} \cdot x_4 + k_{1,5} \cdot x_5 + k_{1,6} \cdot x_6 + k_{1,7} \cdot x_7 = 0.$$

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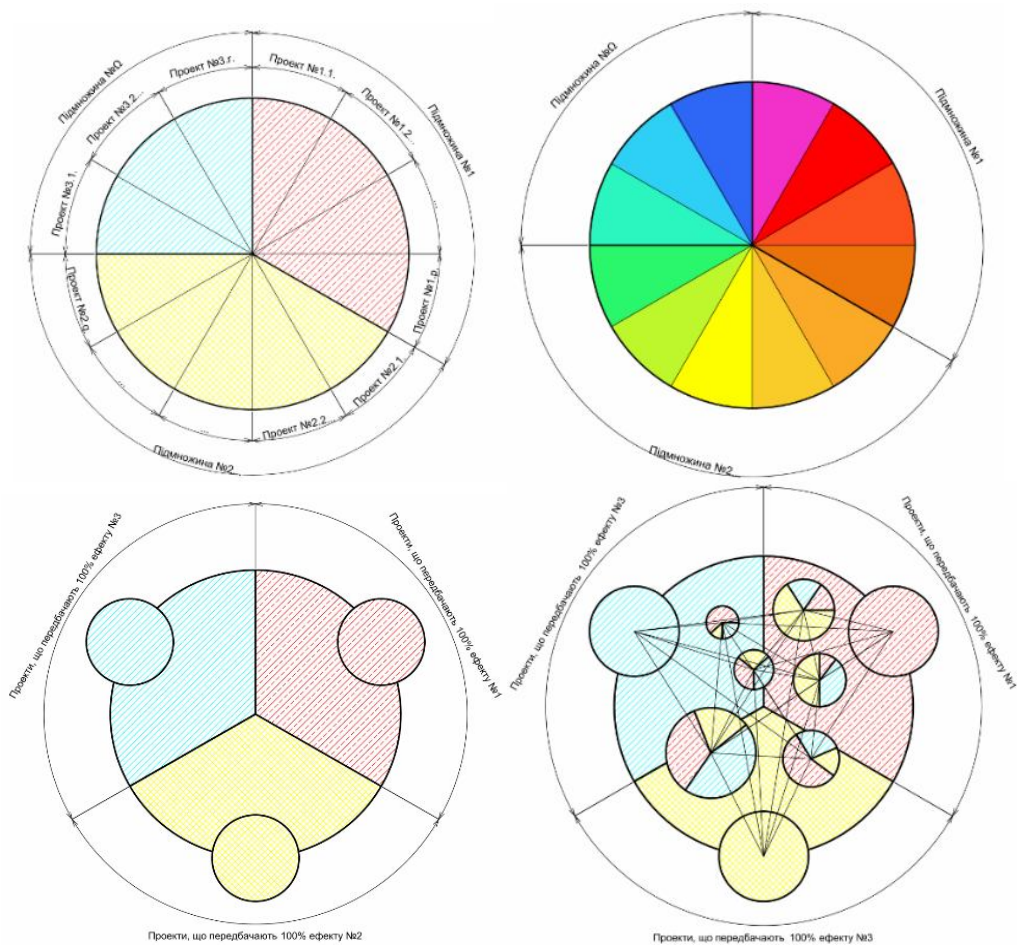

Fig. 1. Examples of undirected graphs on corresponding pie charts

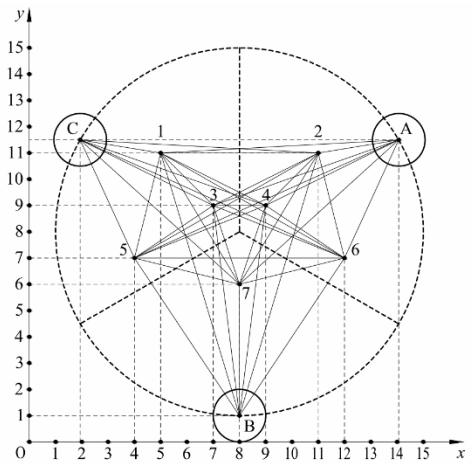

Fig. 2. Relationship between potential performers and projects

Solving the system of equations with respect to the coordinates of the 1st and 2nd vertices of the graph, it could beobtainedthe calculated coordinates from which clusters are formed, which include the corresponding performers.

The graphical representation of the results is shown in Figure 3. This figure clearly shows the position of the vertices of the graph on the sectors of the diagram.

Research results and prospects

The use of the qualimetric method of cluster geometric modeling using neural network resources in a comprehensive approach takes up more hardware resources and time due to a large, branched system of indicators for four groups of criteria, each of which has its own subgroups. However, the result formed by this method allows for a detailed description of the customer's needs and is easier to align with standards. Graphing using a system approach is a fast method for conceptual modeling of process effects.

Aggregation of indicators helps to more easily adjust the project to achieve the optimal picture. In the

example given in this article, it is advisable to use a systematic approach to determining the quality of the project. This is especially convenient in the case of developing a typical model. For further application of the model for a specific task, it is possible to supplement the models and recalculate the indicators using a comprehensive method. During the implementation of the process, a so-called self-learning neural network is created. In fact, it can be used as a conceptual template for objects of a similar typology. In the process of developing management decisions and comparing their success with previous real examples, machine learning can occur (Kysil and Levchenko, 2018). The prospects of such software are difficult to overestimate in the context of the multifacetedness and complexity of modern defense.

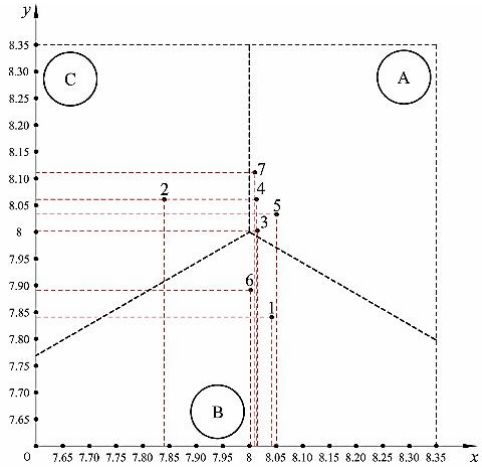

Fig. 3. Graphical representation of cluster formation

Conclusion

As the experience of builders, managers and logisticians involved in solving defense problems shows, a significant problem is outdated standards for making and optimizing decisions and applying paper documentation rules to modern projects. Defense process models have the entire range of relevant information in electronic form. But now there is a conflict between new technologies and generally accepted management processes. The proposed model is an element of such a conflict, since it is one of the initial defining criteria that exclude anthropogenic influence, and therefore corruption.In addition, to achieve maximum economic and social impact, the manager must be able to control quality indicators at any stage of the project (Prusov, et al, 2024). The research described in the article is part of a project to develop software tools for all stakeholders in the process of strengthening Ukraine's defense capabilities. Previous surveys have shown a high level of interest in such software from professionals. Thus, a mathematical apparatus has been developed that allows optimizing the use of resources, at least when placing special-purpose facilities. When developing BIM models and corresponding software and using a neural network, it can have a significant, significant positive impact on solving strategic and current defense problems.

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НОВІТНЯ МЕТОДИКА ОПТИМІЗАЦІЇ КЛАСТЕРІВ СПОРУД СПЕЦІАЛЬНОГО ПРИЗНАЧЕННЯ ЧЕРЕЗ BIM-МОДЕЛЮВАННЯ

Запропоновано метод кластерного геометричного моделювання і результати дослідження можливим застосування цього метода для оптимізації ресурсів при вирішенні оборонних питань. Вибрано приклад необхідного вирішення проблеми реформування розміщення об’єктів і споруд спеціального призначення в світлі нової концепції оборони України і на цій основі розроблено алгоритм кількісного і якісного вирішення проблеми з застосуванням сучасних нейромереж.У статті пропонується загальний метод кластерного геометричного моделювання при оптимізації ресурсів, яка становитиме нагальну потребу для вирішення проблем, що постають перед Україною. Для ефективного формування та функціонування Збройних Сил України та їх розвитку необхідно підтримувати їх матеріально-технічне забезпечення на високому рівні, який повинен відповідати сучасним вимогам і світовим стандартам. Сучасна актуальність проблеми свідчить про нагальну потребу в дослідженні проблем нормування і стандартизації та створення територіального планування та містобудівних рішень для майнових комплексів оборони за умов переходу до нової концепції побудови оборони в Україні, наближеної до світових стандартів.

Метою дослідження є створення інструментарію для оптимізації розв’язання проблем, що постануть в процесі опрацювання концепції комплексного моделювання характеристик споруд спеціального призначення та пов’язаних з цим питаннях територіального планування та містобудівних рішень. На припущення авторів, наразі використовуючи ресурси при плануванні здебільше застосовуються комплексні переважно антропозалежні експертні методи. Створення математичних моделей вимагає багато часу, що за сучасних умов недопустимо, але за умов застосування вже розробленого алгоритму, яким оперуватиме сучасна нейромережа, ця вада може бути усунена.Тема оптимізації рішень на сьогодні є погано структурованою багатокритеріальною задачею. Крім того, існуючі кореляції між факторами впливу вимагають розробки складного апарату прийняття невідкладних рішень.

Ключові слова: об'єкти та споруди спеціального призначення, кластерне геометричне моделювання, нейронні мережі.

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Запропоновано метод кластерного геометричного моделювання і результати дослідження можливим застосування цього метода для оптимізації ресурсів при вирішенні оборонних питань. Вибрано приклад необхідного вирішення проблеми реформування розміщення об'єктів і споруд спеціального призначення в світлі нової концепції оборони України і на цій основі розроблено алгоритм кількісного і якісного вирішення проблеми з застосуванням сучасних нейромереж.
Іл. 3. Бібліогр. 19 назв.

UDC355.7: 721.01: 725.1: 711.5
Mykhalchenko S.V., Prusov D.E. **The Newest Method for Optimizing Clusters of Special-Purpose Structures through BIM Modeling** // Strength of Materials and the Theory of Structures.– K.:KNUCA, 2025. – Issue 114. – P. 319-327.
A method of cluster geometric modeling is proposed and the results of this method application were considered to optimize resources when solving defense issues. An example of the necessary solution to the problem of reforming the placement of special-purpose facilities and structures in the light of the new concept of Ukrainian defense has been chosen, and on this basis an algorithm for quantitative and qualitative solution of the problem has been developed using modern neural networks.
Fig. 3. Refs. 19.

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