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APPLICATION OF MULTI-CRITERIA OPTIMIZATION METHOD FOR DECISION-MAKING IN THE SPHERE FINANCIAL SUPPORT OF THE MILITARY TROOPS

The article considers the theoretical basis for the use of optimisation methods for managerial decision-making and search for an optimal solution. The article describes the methods of multi-criteria optimisation, which, based on the analysis of the relevant literature, are often used in various spheres of human activity, namely: simple additive weighting (SAW), elimination and choice expressing the reality (ELECTRE), preference ranking organisation method for enrichment evaluation (PROMETHEE), technique for order preference by similarity to ideal solution (TOPSIS), analytical hierarchy process (AHP), and analytical network process (ANP). The key characteristics of the decision-making environment in the field of military financial support are identified, based on the conditions and characteristics of such a decision-making environment, namely: a significant number of criteria to be taken into account, the presence of subjectivity in decision-making and the efficiency of such decisions, TOPSIS was chosen as the main method. In the methodological part of the article, the main characteristics, procedure of use and indicators of this method are considered. For practical application of the method, the article develops a case of decision-making by the military organisation A0001 regarding the optimal use of a limited financial resource out of 4 proposed options. In the article, a list of criteria was compiled, they were grouped, and a matrix was formed. In the final part of the article, a matrix of weighting coefficients for each of the 4 options is formed, its normalisation is carried out and the distance/closeness of the proposals of further solutions to the ideal solution is calculated. Based on the calculations, the author chose the optimal option for the use of financial resources, which, according to the TOPSIS method, had the smallest distance to the ideal solution, i.e., was the closest of the proposed options to the ideal option for the use of financial resources.

Keywords: budget, defense expediture, TOPSIS, multi-criteria optimization, making optimal management decisions, effectiveness of government expenditure.

Formulation of the problem. An important element of the concept of state budget policy is the assessment of the effectiveness of the use of budget funds. If we make a comparison with the commercial sector, we will face an increase in the number of evaluation criteria (in most cases, not economic) that need to be taken into account, numerous social, security, scientific, environmental and other components of the efficiency of spending public funds. The assessment of public spending should be preceded by the definition of the category of efficiency of the use of budget funds, the methods of measuring efficiency, the formulation of efficiency criteria, and the possibilities of applying the results of such an assessment in subsequent budget cycles.

In general terms, in the public sector, efficiency is characterised by the correlation between the results of the use of public funds and the costs of achieving them, which includes determining the economy, productivity and effectiveness of the use of public funds. Thus, the Budget Code of Ukraine defines budgetary funds management as a set of actions of a participant in the budget process in accordance with its powers related to the formation and use of budgetary funds, control over compliance with budget legislation, aimed at achieving the goals, objectives and specific results of its activities and ensuring the efficient, effective and targeted use of budgetary funds. Pursuant to Article 2 of the Budget Code of Ukraine, the concept of efficiency is correlated with effectiveness and is characterised as a set of actions of all participants in the budget process, in the preparation and execution of budgets, aimed at achieving the goals planned on the basis of the national system of values and objectives of innovative economic development, by ensuring the quality provision of public services while attracting the minimum amount of budgetary funds and achieving the maximum result when using the amount of funds determined by the budget. Thus, it can be concluded that when assessing the efficiency of the use of public funds and developing methods for measuring and formulating efficiency criteria, not only the economic component that relates the volume of public services to the costs of providing them should be taken into account, but also various other components of efficiency. Defence expenditures should be separated from all classifications of public expenditures [1, 2].

In the context of a full-scale armed Russian Federation waging an undeclared war against Ukraine, the issue of ensuring the security and defence of Ukraine as a sovereign, independent state that has embarked on the path of forming a democratic state system and is an active participant in the processes of Euro-Atlantic integration is particularly acute. At the same time, the Armed Forces of Ukraine and other elements of the security and defence sector play an important role as a guarantor of the state's independence and territorial integrity, as provided for in Article 17 of the Constitution of Ukraine: "The protection of the sovereignty and territorial integrity of Ukraine, ensuring its economic and information security are the most important functions of the state, the business of the entire Ukrainian people. The defence of Ukraine, protection of its sovereignty, territorial integrity and inviolability are entrusted to the Armed Forces of Ukraine. The level of expenditures of the State Budget of Ukraine on the security and defence sector has increased many times compared to previous years (before the full-scale invasion of the Russian Federation). In this situation, a controversial contradiction arises: the main thing is to ensure the sovereignty, territorial integrity and inviolability of the state by any means necessary (understood in the context of budget expenditures), and on the other hand, to ensure the effectiveness of such expenditures, compliance with the standards of efficiency and effectiveness set by the legislation. The above-mentioned issues were the main driving factor behind this study [3].

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Analysis of latest research and publications. In study of management activities, multi-criteria optimization methods are widely used, for example, such scientists as M. Haschuk, Yu. Shulga, Yu. Chibisov, and M. Naumova studied multi-criteria optimization methods in the management field, in particular to determine the degree of reliability of Ukrainian banks in conditions of multicriteria. The issue of the use of modern information technologies and scientific methods in the military sphere, in particular for making management decisions, was studied by foreign scientists such as: G. de Boisboissel, B. Bihan, as well as domestic specialists and scientists: P. Yanovskyi, V. Tkachenko, A. Grabovskyi, M. Tkachuk.

To be successful in Military Decision Making Process (MDMP), one need to assess many criteria, alternatives and factors simultaneously, to get satisfactory results at the end of the assessment process. Therefore, it is preferred to have approaches including objective and analytic methods as much as possible in decision-making process (Vowell, 2004). In Ukraine, such researchers and scientists as V. Pakholchuk, O. Ostapenko, I. Tkach, and O. Levchuk were engaged in the study of issues of financial support of the military, modeling of budget expenditures, as well as the issue of defense expenditure evaluation.

Purpose of the article is to study the possibilities and prospects of using multicriteria optimisation methods in the implementation of public expenditures in the area of ensuring the activities of the Armed Forces of Ukraine, to find the optimal method from the exhaustive list of multicriteria optimisation methods, and to test it on a modelled case of a military unit.

Main research material. Decision-making in the military sphere is usually characterized by a significant time limit, as well as possible consequences, that is, the significance of the decision made. This necessitates the development of the use of scientific methods in the military sphere, which facilitate decision-making. The work of making management decisions requires a high level of competence, time, energy, and experience from managers. One of the methods that is quite widely used for multi-criteria analysis of alternatives in the field of decision-making is the TOPSIS method, which is focused on evaluating the alternative relative to the best and worst of the adopted points. Therefore, the development of the methodological apparatus, in particular, the development of methods that allow to simplify, partially automate and minimize the subjective influence of the human factor, is, in our opinion, a relevant direction of research.

It is not an easy task to make a correct decision in a given time, by considering all the relevant criteria and by selecting the most plausible option among the present alternatives. This necessitates the development and application of the scientific methods that facilitate decision making. "Speed" is an aspect of decision making which is as important as correctness. Specifically in military decision making, a decision which is not taken as fast as it should be is often times a not a decision per se. The models to be developed by considering the act of decision making as a scientific activity will provide for the need to make fast decisions. All this makes multi-criteria decision-making evaluation methods relevant in this sphere [4, p. 406].

During the analysis of the literature on this issue, a list of methods that meet the requirements was formed: simple additive weighting, SAW, elimination and choice expressing the reality, ELECTRE, preference ranking organization method for enrichment evaluation, PROMETHEE, methods for assessing proximity to the ideal/anti-ideal, Technique for order preference by similarity to ideal solution, TOPSIS, as well as analytic hierarchy process, AHP, analytic network process, ANP. Based on the analysis of the above-mentioned methods, two main methods were formed that most fully correspond to the tasks: TOPSIS and ANP. In the context of this study, TOPSIS was preferred, based on the fact that the total number of criteria will not exceed 15. The decision-making process in the field of military financial support using the TOPSIS method was structurally differentiated into 8 processes (Fig. 1).

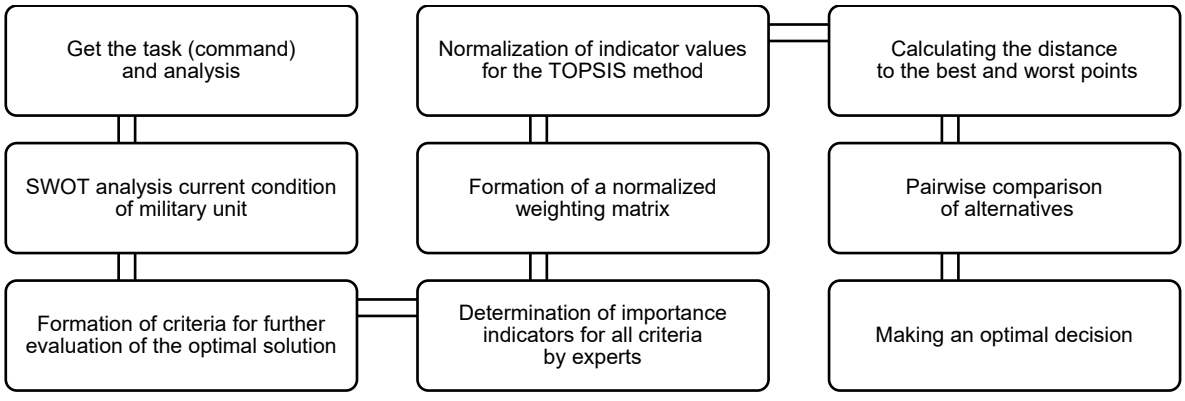

Fig. 1. Stages of making an optimal decision in the field of military financial support using the TOPSIS method

***Source*:** compiled by the author based on [5, p. 645–682].

The issue of determining the weight of the criteria requires separate consideration and research, because this stage has a critical impact on the entire subsequent process. One of the options to avoid subjectivity at this stage is to determine the weight of the criteria using the entropy method [6, p. 374]. However, given the importance of expert opinion in the field of military use, preference was given to the expert option of ranking the criteria, anouther variant with entropy method also possible and require anouther separate research.

In order to achieve the goal of the paper, we will simulate the use of multi-criteria optimisation methods on a pre-formed case of making a decision on the expenditure by the conditional military organisation A0001 in several directions. It is worth mentioning that the modelling of a military unit is conditional, and a similar methodology can be applied to higher-level spending units, including the main spending unit, when assessing the effectiveness of expenditures under a budget programme/subprogramme. The initial data are

4 options for using the same amount of financial resources. The task was defined – to evaluate such proposals and determine the best option. In order to solve the task, the main decision-making model was taken based on the TOPSIS multi-criteria optimization method, for which the next stage was the formation of groups of criteria:

Group A (budget)

- complete execution of the estimate by the direction of responsibility;
- response to changes in the process of execution of the estimate according to the direction of responsibility;
- implementation of the principles of planning the use of budget funds;

Group B (military)

- influence on the level of combat readiness of the military unit;
- influence on the moral and psychological state of personnel;
- the level of development of the direction of provision in view of the previous budget periods;
- expansion of the level of use of modern technologies by the used volume of financial resources;
- impact on the comprehensive provision of personnel;
- achievement of goals by the direction of responsibility by the used volume of financial resources;
- reducing the total volume of expenses by using economies of scale;
- consistency of expenditures for the past budget period with previous budget periods;

Group C (other)

- focus on counterparties, with a higher level of environmental friendliness of the production of the estimate according to the direction of responsibility;
- focus on domestic producers (counterparts) in the process of performing the estimate by direction of responsibility;
- corruption risks in the process of execution of the estimate by direction of responsibility;
- ensuring competitiveness during the selection of counterparties in the process of execution of the estimate

$$\{C_j, j = 1, \dots n\}. \quad (1)$$

The set consists of 15 criteria (Tables 1, 2). The next step was to form a matrix of criteria and determine a numerical option for each criterion, where 1 is the minimum score, 5 is the maximum, and a matrix was also formed for each of the 4 options:

$$X = |(x_{ij}),\ x_{ij} \in R, \quad (2)$$

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}, i = 1, \dots m; j = 1, \dots n \quad (3)$$

The total sum of the weighting coefficients of all criteria is equal to 1:

$$1 = \sum_{j=1}^{n} W_{x_j}. \quad (4)$$

Based on the built decision matrix, normalization was carried out according to the formula

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}. \quad (5)$$

Table 1. **Evaluation criteria for all options**

Criterion group name	A1	A2	A3	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4
Criterion	**X1**	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**	**X12**	**X13**	**X14x**	**X15**
Var1	5	4	2	5	5	5	4	5	2	5	3	5	5	4	4
Var2	5	4	2	5	4	5	5	4	3	2	4	4	4	5	3
Var3	4	3	3	4	3	3	3	5	3	3	5	3	4	5	5
Var4	5	5	4	5	4	4	3	3	4	2	3	3	3	4	4
Weight (W)	**0.05**	**0.08**	**0.08**	**0.09**	**0.09**	**0.09**	**0.08**	**0.07**	**0.08**	**0.08**	**0.08**	**0.03**	**0.04**	**0.03**	**0.03**

Source: compiled and calculated by the author.

Table 2. **Criteria normalized matrix of coefficients**

Criterion group name	A1	A2	A3	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4
Criterion	**X1**	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**	**X12**	**X13**	**X14x**	**X15**
Var1	0.524	0.492	0.348	0.524	0.615	0.577	0.521	0.577	0.324	0.772	0.391	0.651	0.615	0.442	0.492
Var2	0.524	0.492	0.348	0.524	0.492	0.577	0.651	0.462	0.487	0.309	0.521	0.521	0.492	0.552	0.369
Var3	0.419	0.369	0.522	0.419	0.369	0.346	0.391	0.577	0.487	0.463	0.651	0.391	0.492	0.552	0.615
Var4	0.524	0.615	0.696	0.524	0.492	0.462	0.391	0.346	0.649	0.309	0.391	0.391	0.369	0.442	0.492
Weight (W)	**0.05**	**0.08**	**0.08**	**0.09**	**0.09**	**0.09**	**0.08**	**0.07**	**0.08**	**0.08**	**0.08**	**0.03**	**0.04**	**0.03**	**0.03**

***Source*:** compiled and calculated by the author.

The next step is to form a matrix of weighting coefficients (Table 3), according to the formula

$$v_{ij} = W_j * r_{ij}. \quad (6)$$

Table 3. **Matrix of weighting coefficients**

Criterion	A1	A2	A3	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4
Var1	0.026	0.039	0.028	0.047	0.055	0.052	0.042	0.040	0.026	0.062	0.031	0.020	0.025	0.013	0.015
Var2	0.026	0.039	0.028	0.047	0.044	0.052	0.052	0.032	0.039	0.025	0.042	0.016	0.020	0.017	0.011
Var3	0.021	0.030	0.042	0.038	0.033	0.031	0.031	0.040	0.039	0.037	0.052	0.012	0.020	0.017	0.018
Var4	0.026	0.049	0.056	0.047	0.044	0.042	0.031	0.024	0.052	0.025	0.031	0.012	0.015	0.013	0.015

***Source*:** compiled and calculated by the author.

The TOPSIS method is a measure of similarity to the ideal solution, it is a method of classification by the degree of closeness, that is, alternative options are located on a scale of coincidence with the ideal, where 1 represents an ideal solution. The best alternative (S+) and the worst alternative (S-) are determined according to the weighted decision matrix through an equation that has the form

$$S^{+} = \sqrt{\sum_{j=1}^{n}(v_j^{+} - v_{ij})^2}\ , i\ = 1, \dots m, \qquad (7)$$

$$S^{-} = \sqrt{\sum_{j=1}^{n}(v_j^{-} - v_{ij})^2}\ , i\ = 1, \dots m. \qquad (8)$$

For each competitive alternative, the relative proximity of the potential location to the ideal solution was calculated using the following formula

$$C_i = \frac{S_i^{-}}{S_i^{+} + S_i^{-}}, 0 \le C_i \le 1. \qquad (9)$$

Using formula 9 matrix of distance/closeness of current solutions to the ideal solution vas formed (Table 4).

Table 4. **Matrix of distance/closeness of solutions to the ideal solution**

Criterion	S+	S-	C_i
Var1	0.045972	0.05522	0.545696
Var2	0.052945	0.039935	0.429962
Var3	0.054021	0.036052	0.40025
Var4	0.053980	0.046885	0.464825

Source: compiled and calculated by the author.

Based on the methodology of using the TOPSIS method, the maximum value is the best [7, p. 190].Thus, the Fig. 2 visualizes the distance between the options for using a financial resource and the ideal solution.

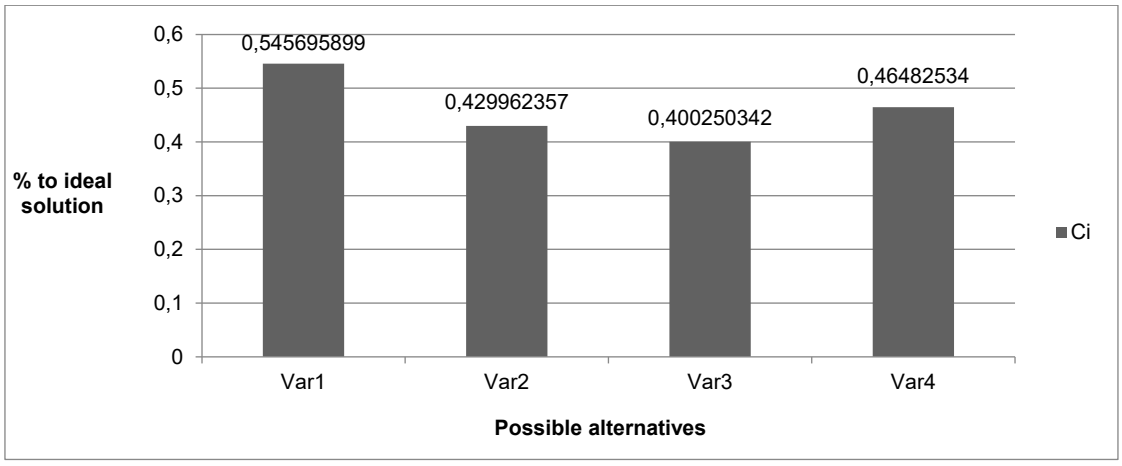

Fig. 2. Distance between variants and the ideal solution

***Source*:** compiled and calculated by the author.

According to the Fig. 2, the optimal solution is the option 1 (variant 1), the value of **Ci** for which corresponds to 0.5456, the worst (farthest from the ideal solution, 0.40025) of the possible variants is option 3.

Conclusion. The article describes the application of the TOPSIS method in the field of military financing, namely, to assess the effectiveness of expenditures in several areas. The study has answered the following questions: how to use the TOPSIS method in the field of military finance, and what criteria should be applied.

The described decision-making method can also be applied to more complex situations with a much larger number of criteria, and it should be noted that when a certain number of criteria is reached, the construction of matrices becomes unreasonably complicated, in which case it is worth considering the use of other methods, such as AHP. Further research will compare the methods of applying such methods in the field of military financing, as well as consider optimising the list of criteria used for evaluation.

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ЗАСТОСУВАННЯ МЕТОДУ БАГАТОКРИТЕРІАЛЬНОЇ ОПТИМІЗАЦІЇ ДЛЯ ПРИЙНЯТТЯ РІШЕНЬ У СФЕРІ ФІНАНСОВОГО ЗАБЕЗПЕЧЕННЯ ВІЙСЬК

Розглянуто теоретичні підґрунтя використання методів оптимізаії прийняття управлінських рішень, пошуку оптимального рішення. Описано методи багатокритеріальної оптимізаії, які, виходячи з аналізу відповідної літератури, часто використовуються в різних сферах діяльності людини, а саме: просте адитивне зважування (simple additive weighting, SAW); усунення і вибір, що виражає реальність (elimination and choice expressing the reality, ELECTRE); метод організації ранжування переваг для оцінювання збагачення (preference ranking organization method for enrichment evaluation, PROMETHEE); метод впорядкування переваг за схожістю з ідеальним рішенням (technique for order preference by similarity to ideal solution, TOPSIS); аналітичний процес ієрархій (analytic hierarchy process, AHP), а також аналітичний мережевий процес (analytic network process, ANP). Визначено ключові характеристики середовища прийняття рішень у сфері військового фінансового забезпечення, виходячи з умов та характеристик такого середовища прийняття рішень, а саме: значну кількість критеріїв, які необхідно враховувати; наявність суб'єктивності при прийнятті рішень та оперативність прийняття таких рішень, як основний метод обрано TOPSIS. У методологічній частині розглянуто основні характеристики, порядок використання та показники цього методу. Для практичного використання методу було сформовано кейс прийняття рішення військовою організацією A0001 щодо оптимального варіанта використання обмеженого фінансового ресурсу із 4 запропонованих. Сформовано перелік критеріїв, здійснено їхнє групування та сформовано матрицю. Також було сформовано матрицю вагових коефіцієнтів для кожного із 4-х варіантів, проведено її нормалізацію та розраховано відстань/наближеність пропозицій подальших рішень до ідеального рішення. Виходячи із проведених розрахунків, обрано оптимальний варіант використання фінансового ресурсу, який відповідно до методу TOPSIS мав найменшу відстань до ідеального рішення, тобто був найближчим із запропонованих варіантів, до ідеального варіанта використання фінансового ресурсу.

Ключові слова: бюджет, оборонні видатки, TOPSIS, методи оптимізації, багатокритеріальна оптимізація, прийняття оптимальних управлінських рішень, ефективність державних видатків.