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BATTLE PLANNING AND ORGANIZATION LOGISTICS SUPPORT IN THE FORMS AND METHODS OF NATO STANDARDS MILITARY MANAGEMENT TOOLS BASED ON THE USE OF THE GAME THEORY MATHEMATICAL APPARATUS

Abstract. The **subject matter** of the article is the analysis of the decision-making options for combat operations in the sphere of operation of the S-4 section of the headquarters of the military unit. The **goal** of the study is the development of the methodology of the military raffle according to NATO standards for the analysis of decision-making options for combat operations by applying the mathematical apparatus of game theory. **The tasks** to be solved are: to conduct an analysis of the methods recommended by NATO standards for a military draw; from the point of view their viability objectivity assessing to formulate a matrix game based on an a posteriori analysis of action options to make a decision on planning and organizing a battle in the field of the S-4 section operation. The **methodological basis** of the research was general scientific and special methods of scientific knowledge. General scientific and special **methods** of scientific knowledge are used. The following **results** were obtained: The adequacy of the mathematical apparatus of game theory for the formal description of the decision-making process for combat operations, taking into account all possible risks, has been clarified. **Conclusions** The method of analyzing options for making a decision on combat operations using the mathematical apparatus of game theory is one that is devoid of subjectivity. The solution of the matrix game compiled on the basis of data on combat operations in the sphere of operation of the S-4 headquarters section of the military unit is the basis of the methodology of logistical support for the planning and organization of the battle in the forms and methods of the military management toolkit according to NATO standards.

Keywords: decision-making options, S-4 section of the military headquarters, military raffle according to NATO standards, matrix game

Formulation of the problem and research tasks

Effective implementation of unit management procedures and coordination of available forces and means is impossible without taking into account risks, situational conditions, own capabilities and possible options for the enemy's actions. The analysis of possible options for actions, including with the help of a military raffle, is a promising toolkit of military management according to NATO standards. Modeling a military operation in the sense of considering the most likely and dangerous options for the enemy's actions and one's own involves drawing up a table of analysis of options for making a decision. Based on the selected evaluation criteria, the headquarters determines the relative effectiveness and objectivity of one course of action relative to others. The analysis of action options for decision-making is carried out on the basis of a matrix, the values of the elements of which are determined by an expert method, and during the briefing of the relevant officials. Expert evaluations are usually subjective, and the set of decision-making options with the help of "brainstorming" may not be complete enough. Therefore, the development of a methodology for the analysis of an action option for making a decision on combat operations based on scientific approaches is a **relevant** task.

Analysis of recent research and publications

Recommendations for planning and organizing a battle according to NATO standards provide that for each element of the method of conducting an operation (combat operations) the possibility is assessed and the necessity of carrying out appropriate security measures for the use of units is considered.

At the same time, the forecasting of probable measures of the enemy to mislead our units [1] is carried out. At the stage of comparing options for actions, the assessment is carried out in accordance with the predicted factors (the function of conducting the battle) and the expected factors (the ratio of the number of forces and means and combat potentials).

Usually, the developed action options are evaluated according to viability (realism) criteria:

− Suitable one consists in its adequacy to the nature of future actions, real and predicted conditions of the situation and the possibility of achieving the goal of the operation (combat operations) in the event of its implementation;

− Feasible one characterizes its compliance with the available (allocated) time and amount of material and technical resources for the operation;

− Acceptable one allows the rational use of forces and means, resources and compliance with established restrictions and acceptable risk, acceptable level of losses;

− Distinguishable one consists in the presence of characteristic features and its advantages and disadvantages compared to other options;

− Completed one involves full disclosure of the method of conducting the operation in all its components. According to the authors, these criteria are not devoid of subjectivity.

At the same time, the comparison of action options, taking into accounts all possible risks and ways of reducing them, is widely used in business through the application of the mathematical apparatus of game theory [2]. Game theory is part of a larger theory that studies optimal decision-making processes.

It provides a formal language for describing the processes of making conscious, purposeful decisions involving one or more people (options of action) under conditions of uncertainty and conflict caused by the clash of interests of each option.

The **goal** of the study is to formulate a matrix game based on the analysis of action options to make a decision on planning and organizing a battle in the field of the S-4 section.

This goal defined the following research **tasks**:

to conduct an analysis of the methods recommended by NATO standards for a military draw;

from the point of view of their viability objectivity assessing to formulate a matrix game based on an a posteriori analysis of action options to make a decision on planning and organizing a battle in the field of S-4 section operation.

Main material

1. The analysis of the methods recommended by NATO standards for a military draw from the point of view of the objectivity of assessing their viability. In the field of the S-4 section operation three methods recommended for military drawing are considered used: the belt method (Fig. 1), the avenue-in-depth method, and the fixed zone method (box). Thus, according to the method of belts, a strip (district) is divided into areas (belts) located in width. It is based on a sequential analysis of events in each belt. This method is based on a consistent analysis of the situation in each zone. In conditions of limited time, the commander can use the advanced belt method. The improved belt method divides the strip (region) of the operation into more than three consecutive belts.

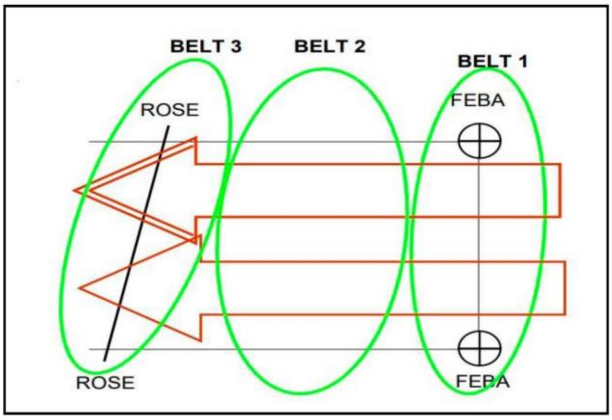

Fig. 1. Improved belt method

It is advisable to use this method under the following conditions:

– when actions in one part of the lane (district) affect actions in another part;

– when the terrain is clearly divided into different zones;

– during staged operations;

– when the enemy deploys in clearly defined belts or echelons.

Belts should include:

– the drawing of actions along the entire front and to the full depth of the task (the starting area, the starting line of forcing, the lines of deployment, the line of transition to the attack);

– introduction of a reserve / implementation of a counterattack;

– capture of the object / defeat of the enemy.

As you can see, each course of action is subject to analysis.

2. Forming a matrix (table) of analysis of options for making a decision. Comparison of options for action (CA) involves the analysis and evaluation of the advantages and disadvantages of each of them.

Evaluation criteria are indicators used by the headquarters to determine the relative effectiveness and objectivity of one intelligence agency relative to others.

The evaluation criteria developed prior to the draw are reflected in the matrix and are an analytical tool that the staff uses to prepare recommendations to the commander.

The evaluation criteria are chosen by the commander during a tactical meeting (briefing) on the consideration of the CA or a tactical meeting (briefing) on the analysis of the task.

Examples of evaluation criteria for offensive and defensive operations may include:

− performance of the task within the limits of acceptable losses;

− rules of hostilities;

− use of the requirements of the governing documents (battle statutes, guidelines, instructions, etc.);

− intention and instructions of the commander;

− risks.

The elements of such a table are usually certain arguments in favor of a particular course of action. Options for presenting the argument can be verbal (“BMPs operate together with tanks”) or in coded form according to a point or other defined scale. Staff officials can use their own matrix (table) of analysis of CA to make a decision, giving priority to their areas of operation.

An example of the matrix of the analysis of options for actions based on weighting factors is presented in Table 1.

The matrices reflect the evaluation criteria developed before the draw. They are an analytical tool that the staff uses to prepare recommendations to the commander. According to the existing methodology [1], each argument is expressed through the number points, which in ascending order reflects its influence on decision-making.

For further formulation of the problem of choosing the optimal course of action, it is proposed to arrange the elements of the matrix by means of two-dimensional indexing. An example of a generalized matrix (table) of the analysis of action options for decision-making is given in Table 1.

Table 1 – **A generalized matrix of analysis of options for making a decision**

Evaluation criterion	CA_1		CA_2		…	CAj		CAm	
	Strengths	Weaknesses	Strengths	Weaknesses	…	Strengths	Weaknesses	Strengths	Weaknesses
$Criterion_1$		$Argument_{11}$	$Argument_{12}$		…		$Argument_{11}$		$Argument_{11}$
$Criterion_2$	$Argument_{21}$			$Argument_{22}$	…	$Argument_{21}$		$Argument_{21}$	
...	…	…	…	…	…	…	…	…	…
$Criterion_i$	$Argument_{i1}$			$Argument_{i2}$		$Argument_{i1}$		$Argument_{i1}$	
…	…	…	…	…		…	…	…	…
$Criterion_n$	$Argument_{n1}$		$Argument_{n2}$			$Argument_{n1}$		$Argument_{n1}$	

At the same time, the selection of the optimal solution based on criteria with weighting coefficients tends to sequential consideration of action options, which in a certain sense reduce its effectiveness. It can be noted that if the set of criteria does not fundamentally affect the decision-making method, then the point evaluation of the arguments makes it possible to reduce the task of choosing the optimal CA to the classic problem of solving game theory.

3. A matrix game based on action options. Let us present the analysis matrix of action options as a payment matrix of game theory.

Let m options of actions are considered, which correspond to the set of strategies of the first player. Each action option has n criteria for evaluating the effectiveness of its strategy.

Arguments in favor of one or another criterion are presented in the form of points that reflect the strengths and weaknesses of each option.

We define the set of criteria by [2], i.e., m strategies with a profit $a_{ij}, \geq 0$ can be applied for each action option, respectively,

$$i = \overline{1, m}\ ,\ j = \overline{1, n}\ ,$$

which implement the strengths of the action option (the odd columns of Table 1 are expressed by the number of points and will be elements of the payment matrix).

Thus, the payment matrix is formed from the winnings of a conscious player, and the task of finding the best option for action, or a combination of several options for action, is to find the optimal strategy of the first player.

Since the actions of the second player are uncertain for us, we will define this game as a game with nature, and the corresponding evaluation criteria in terms of game theory − as states (strategies) of nature $П_j$ $j = \overline{1, m}$.

Thus, a payment matrix can be formed $A = \{a_{ij}\}$ ($i = \overline{1, n}$, n − the number of options evaluation criteria; $j = \overline{1, m}$, m − the number of action options) will determine the player's winnings when applying the j-th strategy in the state of the *i-th* criterion, the matrix itself will uniquely determine the decision-making situation (conflict situation) , and the optimal solution will be recognized through the winning of player A.

In this case, decision-making will consist in choosing some set $\{x_{ij}^*\}$, optimal in a certain sense. So, in terms of game theory, this game can be classified as a game with nature with a non-zero sum.

The game matrix or payment matrix will look like this:

$$A = \begin{bmatrix} a_{11} & a_{12} & ... & a_{1n} \\ ... & ... & ... & ... \\ a_{n1} & a_{n2} & ... & a_{nn} \end{bmatrix}. \qquad (1)$$

Similarly, a risk matrix formed as $R = \{r_{ij}\}$ ($i = \overline{1, n}$ − the number of options evaluation criteria); $j = \overline{1, m}$, m− the number of action options) will determine player A's risk in applying the *j-ї* strategy in the state of the *i-th* criterion *П*.

The elements of the mantissa R can be determined on the basis of data on the weaknesses of an action (paired columns of Table 2)

$$R = \begin{bmatrix} r_{11} & r_{12} & ... & r_{1n} \\ ... & ... & ... & ... \\ r_{n1} & r_{n2} & ... & r_{nn} \end{bmatrix}. \qquad (2)$$

The authors suggest using Wald's maximin criterion [3], according to which the game with nature is played as a game with an intelligent and aggressive opponent who does everything to prevent us from succeeding. The optimal strategy is considered to be the one in which the profit is guaranteed in any case not less than the specified one. The set of strategies of the first player will be defined as

$$X = \{x_{ij}\}\ ,\ \ i = \overline{1, n}\ ,\ \ j = \overline{1, m}\ . \qquad (3)$$

Then we will consider the optimal strategy which the average value of the winnings is the maximum:

$$A(X) = \sum_{i=1}^{n} \sum_{j=1}^{m} a_{ij} x_{ij} \Rightarrow \max\ . \qquad (4)$$

And the average risk according to each criterion satisfies the following restrictions:

$$\sum_{j=1}^{n} r_{ij} x_{ij} \leq r_i^{зад}\ ,\ \ i = \overline{1, n}\ ,\ \ j = \overline{1, m}\ , \qquad (5)$$

here n − the number of options evaluation criteria;

m − the number of action options.

In this case, the corresponding problem of linear programming is formulated as follows:

To find

$$X^{*} = \{x_{ij}^{*}\}$$

maximizes the objective function (4) under restrictions (5).

To get closer to the main theoretical provisions of classical game theory, the value of the risk matrix is proposed to be normalized by rows

$$r'_{i,j} = \frac{r_{i,j}}{\sum_{i-1}^{n} r_{i,j}}, \qquad (6)$$

thereby giving them a sense of probability

$$0 < r'_{i,j} < 1, \qquad (7)$$

where $$i = \overline{1,n},\ j = \overline{1,m} \qquad (8)$$

Then the values of marginal risks will be intuitive and will form a column vector

$$R^{зад} = \begin{bmatrix} r_1^{зад} \\ \dots \\ r_j^{зад} \\ \dots \\ r_m^{зад} \end{bmatrix}, 0 < r_j^{зад} < 1, i = \overline{1,n},\ j = \overline{1,m}. \qquad (9)$$

Methods of solving matrix games are known. For example, the problem can be reduced to a linear programming problem [4].

Conclusions

1. The method of analyzing options for making a decision on combat operations using the mathematical apparatus of game theory is one that is devoid of subjectivity.

2. The solution of the matrix game compiled on the basis of data on combat operations in the sphere of operation of the S-4 headquarters section of the military unit is the basis of the methodology of logistical support for the planning and organization of the battle in the forms and methods of the military management toolkit according to NATO standards.

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Логістичне супроводження планування та організації бою у формах і методах інструментарію військового менеджменту за стандартами нато на основі використання математичного апарату теорії ігор

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Анотація. Предметом вивчення в статті є аналіз варіантів прийняття рішення на бойові дії в сфері функціонування секції S-4 штабу військового підрозділу. **Метою статті є** розробка методики військового розіграшу за стандартами НАТО для аналізу варіантів прийняття рішення на бойові дій шляхом застосування математичного апарату теорії ігор. **Завдання дослідження**: Провести аналіз методів, рекомендованих стандартами НАТО для військового розіграшу, з точки зору об'єктивності оцінки їх життєздатності (реалістичності). Сформулювати задачу аналізу варіантів дій для прийняття рішення на планування та організацію бою у сфері функціонування секції S-4 військового підрозділу в термінах теорії ігор. Методологічною основою дослідження стали загальнонаукові та спеціальні **методи** наукового пізнання. **Отримані наступні результати:** З'ясована адекватність математичного апарату теорії ігор для формального опису процесу прийняття рішення на бойові дії з урахуванням усій можливих ризиків. **Висновки.** Методика аналізу варіантів прийняття рішення на бойові дії за допомогою математичного апарату теорії ігор є такою, що позбавлена суб'єктивності. Розв'язання матричної гри, складеної на основі даних секції S-4 штабу військового підрозділу про результати бойової операції є адекватним запропонованій методики логістичного супроводження планування та організації бою у формах і методах інструментарію військового менеджменту за стандартами НАТО.

Ключові слова: варіанти прийняття рішення, секція S-4 штабу військового штабу, військовий розіграш за стандартами НАТО, матрична гра.