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IMPROVING THE SCIENTIFIC AND METHODOLOGICAL APPARATUS FOR DETERMINING THE OPTIMUM STRATEGY WHEN SELECTING A GROUPING ELEMENT FOR PERFORMING THE TASK

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The object of this study is the process of determining the optimal strategy for choosing a certain element of the grouping to perform a certain task.

The problem solved was the contradiction between the need to take into account various types of adverse conditions when determining the optimal strategy for assigning a certain type of forces and means for a certain task to the existing approach to maximizing the result.

The improved scientific and methodical apparatus includes optimal selection criteria and an improved procedure for optimal selection of a certain grouping element.

Existing approaches to the selection of optimal strategies for assigning forces and means to perform tasks were analyzed, in particular the criteria of Wald, Hurwitz, and Savage.

The peculiarity of this analysis is the examination of the criteria in view of the types of adverse conditions they take into account. The application of these criteria will make it possible to take into account the conditions of uncertainty of the input data and minimize the influence of adverse conditions during distribution.

The field of practical use of the analysis results is management processes during preparation for the operation.

A procedure of optimal selection of a certain element of the grouping for the performance of a certain task has been improved by using several criteria for choosing the optimal strategy and harmonizing the results of this selection in accordance with the conditions. The proposed procedure guarantees the performance of tasks, and the increase in the value of the objective function can reach 40 %.

A feature of the proposed procedure is that the result of choosing the optimal strategy is determined according to the conditions of a certain operation and takes into account various types of adverse conditions. This makes it possible to take into account the factors that significantly affect the uncertainty and minimize the expenditure of resources when performing a certain set of combat tasks.

The scope of practical use of the methodology is the process of planning and allocation of forces and means among tasks in the operation

Keywords: optimal strategy, Wald criterion, Hurwitz criterion, Savage criterion, combat tasks

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1. Introduction

Analysis of management processes related to modern military (combat) operations testify to a significant transformation of decision-making algorithms associated with the expansion of the capabilities of forces and means of armed struggle [1–3]. Thus, the capabilities of forces and means in many types and kinds of troops have changed as a result of internal transformations of kinds and types of troops, as well as caused by the conditions of modern military conflicts.

Moreover, it should be noted that the transformation of management processes took place both at the tactical level during the organization of hostilities, and at the operational and strategic level during the planning of operations.

The change in the capabilities of forces and means as a result of internal transformations is related to the structure of training and the order of equipping the relevant units and military personnel [4]. In particular, the structure of modern training of all types and kinds of troops, especially missile forces and artillery, special operations forces, and military intelligence began to include a greater number of tactical procedures. For example, actions in the environment, maneuverable defense, raid actions, information and psychological operations, etc. [5–7]. This leads to the expansion of opportunities for actions in a wider range of conditions than was previously foreseen both at the tactical level and at the operational and strategic levels.

At the same time, the increase in technology and the change in the capabilities of weapons and military equipment affects both the training of units and the expansion of the capabilities of these units to perform tasks [8, 9]. Thus, the depth and efficiency of the performance of these tasks, the accuracy of defeating the enemy and its reconnaissance have increased. Accordingly, the requirements for military specialists in terms of the ability to control weapons and military equipment and make decisions under appropriate conditions have increased. Moreover, it should be noted that if at the tactical level it is possible to take into account changes in weapons capabilities due to internal organizational influences, then at the operational (strategic) level, a change in approaches to planning is necessary.

Considering the conditions of modern military conflicts, it is necessary to note their rapidity, the increased capabilities of means of destruction and intelligence, the network-centricity of hostilities [4, 10]. The specified features significantly affect the management process, in particular the stage of decision-making regarding combat operations both during the operation itself and during planning.

One of the main stages of decision-making on the conduct of hostilities (operations) is the assignment of forces and means to tasks. The importance of this stage is due to the need to preserve the resource because, as a rule, the resource for performing tasks is limited, and its non-rational allocation can lead to the failure of the task. At the same time, a change in the capabilities of forces and means and the conditions of the operation affects the performance of tasks.

Thus, the management processes of complex systems of military assignment have a problem related to the need for optimal allocation of disparate forces and means between disparate tasks and the absence of a suitable adapted methodical apparatus. Therefore, taking into account the expansion of the range of forces and means and the tasks assigned to them and the difficulty of determining the optimal strategies of choice under the specified conditions, overcoming this problem is urgent.

2. Literature review and problem statement

In paper [11], a new concept of the Wald criterion is proposed, which is based on the optimization (according to Pareto) of minimum payments, which is called the optimin criterion. Optimin criterion makes it possible to generalize and unify the results in different areas. This criterion coincides with maximin strategies in zero-sum games, the core of cooperative games. It also generalizes Nash equilibria in games with a constant sum of n-persons. However, the specified criterion does not allow taking into account the factor associated with additional adverse conditions that arise during the operation.

Study [12] presents a new decision concept for a graph model of conflict resolution for situations with uncertainty caused by the absence or non-use of information on the priority of strategies. The cited article examines how the degree of optimism and the conflict horizon affect the stability of states (strategies). It is also analyzed how the stability of optimism and pessimism is related to other stabilities that are commonly used in the process of choosing an optimal strategy. However, this strategy does not take into account the impact of differences between the maximum and minimum possible value of the objective function on the overall result of choosing a certain strategy.

Study [13] considered the decision-making process in the antagonistic digital communication of users of Internet services. The cited article presents approaches to decision-making by administrators of the online community under the conditions of antagonistic behavior of online services, which ensures an increase in the effectiveness of online communication. The article provides examples of the use of the considered Wald and Savage criteria for making optimal decisions, confirmed by many experiments. However, the approaches proposed in the article do not allow taking into account various types of adverse conditions that may arise during the execution of tasks.

Paper [14] discusses the approach to the allocation of a certain amount of combat equipment between two combat units for the performance of various combat tasks. It is proposed to carry out such a division into three stages, and the stages of hostilities are determined by the total efficiency of their conduct by the appropriate means of the units. The basis for determining the combat effectiveness is the determination of the probability of completing the task under the condition that the functioning of the weapons units is subject to the exponential law of the distribution of random variables. However, the cited article does not take into account the possibility of choosing the optimal strategy when changing the set of tasks or the conditions for performing these tasks.

Work [15] proposed a methodical approach to solving the problem of synthesis of a rational program for the development of the weapons system based on the criterion of achieving the maximum possible level of combat capabilities under the condition of limited resource provision. The specified problem is proposed to be solved as a multi-vector optimization problem, as a search for the time distribution function of the number of new aircraft supplied to the troops. Methodical approaches to solving this class of problems are considered, in particular, criteria scalarization, the main criterion method, and some other approaches. The need to introduce an additional suitability criterion for studies of found solutions to the multi-criteria optimization problem is substantiated. However, the cited paper does not consider the issue of taking into account the risks of the occurrence of additional (not taken into account) criteria of influence on the process of choosing the optimal strategy.

Paper [16] substantiates the indicator of evaluating options for the rational allocation of forces and means of the troops by direction in the defense lane of the operational-tactical grouping of troops. The article also covers the content of this indicator, the procedure for calculating its value, and its further use in the interests of evaluating variants of the method of conducting a defense operation. The probability of keeping the entire defense strip is proposed as an indicator for evaluating options for the distribution of forces and means by direction in the defense strip of the operational-tactical grouping of troops. However, the proposed indicator does not take into account the influence of such factors that become important during the execution of tasks, which can affect the accuracy of the assessment of distribution options.

Study [17] proposed an approach to determining the optimal strategy for deploying repair bodies of a military group during hostilities. Also, the study offers indicators of the effectiveness of strategies for deploying repair bodies of a military group. Mathematical programming approaches with continuous and Boolean variables were used to formalize the problem of synthesis of optimal strategies. The specified approach allows choosing the optimal strategy for deploying repair bodies of a military group during hostilities, however, on the condition that these bodies react equally to changing conditions. However, the proposed approach does not take into account the entire range of possible adverse conditions, especially adverse conditions directly related to each strategy.

Paper [18] presents an approach to determining optimal strategies for joint decision-making by a pilot and an air traffic controller as a problem of solving a «conflict» between them using game theory methods. In the article, based on the example of the conflict situation model «pilot – air traffic controller», in a special case in flight, the procedure for determining the optimal strategy is shown. However, the specified approach does not take into account the degree of competence of the conflicting parties and the degree of possible influence of the specified factor on the result of choosing a certain strategy.

Study [19] shows the peculiarities of the theoretical aspects of determining the criteria of military and economic efficiency in the tasks of substantiating the choice of rational variants of complex samples of weapons and military equipment. In the study, the main requirements for military-economic criteria are formed, an approach to their classification is given, and the features of their application are revealed. On the basis of the theoretical aspects of the military-economic analysis method, during the justification of technical solutions, the order of formation of the sequence of hierarchical optimization according to the selected criteria, taking into account the peculiarities of their application, is proposed. However, the proposed approach does not allow taking into account various types of adverse conditions that may appear during the implementation of the chosen strategy.

In study [20], a procedure of substantiating the need for weapons samples and target distribution in the application of a reconnaissance-fire system was considered. This procedure is based on a modified method of nonlinear programming (two functions). It was established that the specified procedure allows taking into account the features of weapons samples and their suitability for hitting a certain target. This will prevent the emergence of problems related to overspending of resources, failures in the cycle of detection-injury, non-fulfillment (incomplete fulfillment) of tasks during enemy fire damage. However, the proposed approach does not take into account the uncertainty caused by different types of adverse conditions.

In article [21], the task of evaluating the effectiveness of the interaction of law enforcement forces during the protection of important objects from the subversive actions of the enemy's subversive forces is formulated. The article also defines the procedure for choosing a decision-making criterion for the organization of interaction depending on the information situation. Methods of solving the problem of multi-criteria selection of an effective method of interaction of law enforcement forces during the cover of important objects from subversive actions of the enemy's subversive forces are also considered. In general, the specified approach allows choosing the optimal strategy for the interaction of forces and means during the execution of combat tasks but does not allow determining the optimal strategy for the assignment of these tasks.

In paper [22], the process of competitive selection of samples of weapons and military equipment is analyzed with the aim of determining the best in terms of quality from a number of alternatives. An analysis of the existing methodical apparatus for solving the given problem was carried out and the use of the apparatus of the Bayesian trust network for solving the problem of choosing a high-quality sample of weapons and military equipment was proposed. An analysis of software tools for modeling Bayesian trust networks is given. A proposed decision-making procedure for sample selection based on probabilistic criteria under conditions of insufficient certainty. However, the proposed procedure is focused on taking into account the tactical and technical characteristics of the sample, not taking into account the change in the capabilities of the unit in general depending on the training of personnel.

Thus, the generalization of the results of research on the selection of optimal strategies in the military sector allows us to identify an unresolved problem related to the consideration of uncertainty. Thus, a significant factor that increases uncertainty are factors that change their importance during the execution of a combat mission and are difficult to formalize. That is, the unresolved problem of the theoretical plan is the contradiction between the need to take into account various types of adverse conditions when determining the optimal strategy for assigning a certain type of forces and means for a certain task to the existing approach to maximizing the result.

3. The aim and objectives of the study

The purpose of our research is to improve the scientific and methodological apparatus for determining the optimal strategy for choosing a certain element of the group to perform a certain task under the conditions of hostilities. This will make it possible to minimize the consumption of resources when performing a certain set of combat missions.

To achieve the goal, the following tasks were set:

– to analyze existing approaches to choosing optimal strategies for assigning forces and means to perform tasks;

– to improve a procedure of optimal selection of a certain element of the grouping for the performance of a certain task.

4. The study materials and methods

The object of this study is the process of determining the optimal strategy for choosing a certain element of the grouping to perform a certain task.

The main hypothesis assumes that the optimal assignment of forces and means of military formations to tasks is possible when choosing an appropriate strategy for assigning a certain type of forces and means to a certain task. To choose the appropriate strategy, it is necessary to apply a criterion that takes into account both possible gains and losses.

The main assumptions adopted in the research: the basis of uncertainty when choosing the optimal strategy for assigning a certain element of a group to perform a certain task are factors caused by various types of adverse conditions. The study deals with the distribution of elements of a military group to perform a combat task in such a way that this area contains the greatest degree of uncertainty in decision-making.

The main simplifications adopted in the work include factors that lead to uncertainty caused by three types of adverse conditions, in particular: general adverse conditions, additional adverse conditions, adverse conditions relative to each strategy.

The study was conducted in relation to the grouping of troops corresponding to the operational (strategic) level of planning. Also, the study combines the operational and strategic levels because the detailed allocation of forces and resources is carried out at the operational level, and at the strategic level, assignment carried out at the operational level is used. Moreover, the case study was conducted on the basis of the use of an operational-tactical grouping of troops in a counteroffensive operation with extensive use of special actions of the Special Operations Forces.

Our work uses approaches from game theory, in particular the selection criteria of Wald, Hurwitz, and Savage for dealing with optimization problems [23–25].

The essence of the Wald criterion (maximin criterion) is to choose the best result among the worst ones [23–25]. That is, it is necessary to determine the smallest values of the objective function $a_{ij}=F(x, y)$ for each condition and subsequently choose the largest of these values. In general, this expression can be written in the form of a formula [23–25]:

$$K_V = \max_i \min_j a_{ij}, \quad (1)$$

The next is the Hurwitz criterion (criterion of pessimism – optimism) [23–25]. The essence of the choice based on this criterion is to choose the best value from the sum of the minimum and maximum values, taking into account the subjective pessimism-optimism constant. The general expression of the choice can be represented in the form of a formula [23–25]:

$$K_H = \max_i \left(C \min a_{ij} + (1-C) \max_j a_{ij} \right), \quad (2)$$

where C is a constant satisfying the condition $0 \le c \le 1$. When $c=1$, the Hurwitz criterion turns into a maximin criterion; when $c=0$, it turns into a gambler's criterion (choice based on the best value of the objective function).

As the next criterion, it is proposed to consider the Savage criterion (or the criterion of minimax regrets) [23–25]. The essence of the choice according to this criterion is to choose the minimum value of the action option among the maximum values of the difference between the maximum and current values according to the conditions. The general expression of such a choice can be represented by the following formula [23–25]:

$$K_S = \min_i \left(\max_j \left(\max_i a_{ij} - a_{ij} \right) \right). \quad (3)$$

Calculations in the study were carried out in the Microsoft Excel 2010 software environment as it is universal and easy to use while the calculations are relatively simple.

5. Results of improving the approach to determining the optimal strategy for selecting a grouping element

5. 1. Analysis of existing approaches to the selection of optimal strategies for assigning forces and means to perform tasks

In general, the allocation of forces and means of military formations between tasks in an operation can have several options, and the results of the execution of these tasks can be represented by some matrix. For further analysis, it is proposed to formalize such a distribution through a matrix of gains [23–25] (Table 1). The essence of this matrix is that the fitness to perform a certain task (y) by a certain element of forces and means (x) is determined through the fitness function $F(x,y)$.

Table 1

Matrix of gains when performing certain tasks in operation (y) with certain forces and means (x)

$F(x,y)$		Tasks in operation (y)				
		y_1	...	y_j	...	y_m
Forces and means (x)	x_1	$F(x_1,y_1)$	...	$F(x_1,y_j)$	...	$F(x_1,y_m)$
	...	...	...	...	...	...
	x_i	$F(x_i,y_1)$	...	$F(x_i,y_j)$	...	$F(x_i,y_m)$
	...	...	...	...	...	...
	x_n	$F(x_n,y_1)$	...	$F(x_n,y_j)$	...	$F(x_n,y_m)$

The analysis of the problem of assignment of forces and resources to tasks in the operation, formalized through the matrix of gains, reveals that it is possible to have several solutions that will depend on the conditions of choice. The best tools for working with such optimization tasks are criteria for choosing optimal strategies.

The analysis of existing criteria for choosing optimal strategies is proposed to be carried out based on the condition of incomplete certainty in the initial data. That is, to analyze the criteria that allow taking into account a certain «pessimism» in calculations. Such criteria include Wald's criterion (maximin criterion), Hurwitz's criterion (pessimism-optimism criterion), Savage's criterion (minimax regret criterion).

Considering the essence of the Wald criterion, which implies choosing the best result among the worst ones [26], this criterion allows determining the best strategy in the worst-case scenario. That is, with the help of this criterion, it is possible to determine the best assignment of the appropriate forces and means of a military formation to perform a certain task with guaranteed execution. Taking into account formula (1), the procedure for working with this criterion is to determine the smallest values of the objective function $a_{ij}=F(x, y)$, that is, the suitability of certain forces and means to perform a certain task. In the future, the largest of these values is selected, which allows determining the best strategy under the worst conditions (1). In other words, the specified criterion makes it possible to choose such forces and means to perform the task, which will give the maximum effect under the most unfavorable conditions.

The general view of the matrix of gains (Table 1) transformed for the conditions of application of the Wald criterion is given in Table 2.

The advantage of such an approach is the selection of such an element of the asset force that will not best perform the task under favorable conditions but will perform it best in unfavorable conditions, in particular, enemy countermeasures. The disadvantage of this approach is the possibility of incomplete use of the potential of forces and means.

Table 2

Matrix of gains when certain tasks are performed by certain forces and means (x) in the operation (y) according to the Wald criterion

$F(x, y)$		Task in operation (y)					min	max
		y_1	...	y_j	...	y_m		
Forces and means (x)	x_1	a_{11}	...	a_{1j}	...	a_{1m}	min(a_1)	max(min(a_{ij}))
	...	...	...	...	...	...	...	
	x_i	a_{i1}	...	a_{ij}	...	a_{im}	min(a_2)	
	...	...	...	...	...	...	...	
	x_n	a_{n1}	...	a_{nj}	...	a_{nm}	min(a_n)	

A general analysis of the Hurwitz criterion (criterion of pessimism – optimism) [23–25] shows that it takes into account both the pessimistic scenario (worst conditions) and the optimistic one (best conditions). According to the essence of the criterion, which implies choosing the best value from the sum of the minimum and maximum values, taking into account the subjective pessimism-optimism constant (C). That is, one of the features of this criterion is taking into account the subjective opinion of the decision-maker. Regarding the problem of allocation of forces and resources, this opinion is the opinion of the commander (chief). That is, the commander (chief) can take into account certain influences that were not formalized before and thus increase the accuracy of the forecast. The general procedure for applying the Hurwitz criterion (2) includes determining the minimum and maximum value of the adaptability of forces and means to a specific task, setting the value of the constant C, finding the maximum value of the sum of these values (2).

The general view of the matrix of gains (Table 1) transformed for the conditions of application of the Hurwitz criterion is given in Table 3.

The advantages of this criterion are the ability to take into account both pessimistic and optimistic scenarios, as well as taking into account the experience of the commander who conducts the allocation of tasks in the operation. The disadvantage of the Hurwitz criterion is the lack of a methodical approach to determining the constant C, i.e., if the experience of the commander conducting the assignment is insufficient for an adequate determination of this constant, significant errors can be obtained.

According to the essence of Savage's criterion [26, 27], the choice of the optimal assignment of forces and means to perform a certain task depends on the difference between the maximum and the current value of the objective function for the task. That is, its essence implies choosing the minimum value among the maximum values of the difference between the maximum and current values for the task. In other words, the criterion makes it possible to take into account the worst conditions in relation to the best and minimize their impact. The procedure for applying the criterion includes finding the difference between the maximum and current value of the objective function for the task, determining the maximum value of these differences for each task, and choosing the minimum of them.

The general view of the matrix of gains (Table 1) transformed for the conditions of application of the Savage criterion is given in Table 4.

The advantage of this criterion is taking into account the maximum losses when a certain element of forces and means is not assigned to perform other tasks. The disadvantage of this criterion is that it does not take into account the total losses when performing these tasks.

Table 3

Matrix of gains when performing certain tasks in the operation (y) by certain forces and means (x) according to the Hurwitz criterion

$F(x,y)$		Task in operation (y)					max	min	C	$1-C$	$\Sigma = C\min(a_{ij}) + (1-C)\max(a_{ij})$	max
		y_1	...	y_j	...	y_m						
Forces and means (x)	x_1	a_{11}	...	a_{1j}	...	a_{1m}	max(a_1)	min(a_1)	C	$1-C$	Σ_1	max Σ
	...	...	...	...	...	...	...	...			...	
	x_i	a_{i1}	...	a_{ij}	...	a_{im}	max(a_2)	min(a_2)			Σ_i	
	...	...	...	...	...	...	...	...			...	
	x_n	a_{n1}	...	a_{nj}	...	a_{nm}	max(a_n)	min(a_n)			Σ_n	

Table 4

Matrix of gains when certain tasks are performed by certain forces and means (x) in the operation (y) according to the Savage criterion

$F(x,y)$		Task in operation (y)					max	The difference between the maximum and current values $\Delta_{ij}=\max(a_i)-a_{ij}$					max	min
		y_1	...	y_j	...	y_m		y_1	...	y_j	...	y_m		
Forces and means (x)	x_1	a_{11}	...	a_{1j}	...	a_{1m}	max(a_1)	Δ_{11}	...	Δ_{1j}	...	Δ_{1m}	max Δ_1	min(max Δ_{ij})
	...	...	...	...	...	...	...	...	...	...	...	...	...	
	x_i	a_{i1}	...	a_{ij}	...	a_{im}	max(a_2)	Δ_{i1}	...	Δ_{ij}	...	Δ_{im}	max Δ_i	
	...	...	...	...	...	...	...	...	...	...	...	...	...	
	x_n	a_{n1}	...	a_{nj}	...	a_{nm}	max(a_n)	Δ_{n1}	...	Δ_{nj}	...	Δ_{nm}	max Δ_n	

The analysis of existing approaches to the selection of optimal strategies for the assignment of forces and means for the performance of tasks shows that the criteria for choosing the optimal strategies, in particular the criteria of Wald, Hurwitz, and Savage, are the most appropriate. The specified criteria make it possible to take into account the conditions of uncertainty of input data and minimize the impact of adverse conditions during distribution. However, it should be noted that the analyzed criteria take into account various unfavorable conditions, the Wald criterion takes into account the general unfavorable situation, the Hurwitz criterion – additional unfavorable conditions, the Savage criterion – unfavorable conditions directly related to each strategy.

5. 2. Improving a procedure of optimal selection of a certain element of the grouping for the performance of a certain task

It is proposed to improve a procedure of optimal selection of a certain element of the grouping for the performance of a certain task, taking into account the selection of the appropriate strategy according to criteria that take into account both possible gains and losses. In particular, it is proposed to apply the criteria of Wald, Hurwitz, and Savage. Moreover, it is proposed to take into account the mechanism of selection of the criterion appropriate to the situation.

The input data (module 2) for the procedure of assignment of forces and means of military formations to tasks are the number of separate elements of the military formation (x), the number of tasks in the operation (y). Also, input data are the values of indicators that characterize the suitability function of a certain element of a military formation to perform a certain task [28]. Moreover, the fitness function $F(x,y)$ can be determined both by the probability of completing the task (P) and by other indicators that will reflect the essence of the task itself.

The next group of input data is the coefficients of conditions, in particular the general coefficient of conditions (C_c), the coefficient of uncertainty (C_{un}), and the coefficient of stability of strategies (C_s) [29]. The specified coefficients are proposed to be determined in the range from 0 to 1. Moreover, 0 means the least influence of this coefficient, and 1 – the largest. Accordingly, the coefficients of conditions reflect the general influence of conditions on the implementation of a certain strategy (task performance). The coefficient of uncertainty reflects the influence of additional (not taken into account) factors on the implementation of a certain strategy. The coefficient of stability of strategies reflects the impact of adverse conditions directly on a certain strategy, that is, it takes into account the difference between the maximum and minimum value of the fitness function indicator.

Another input indicator is the pessimism-optimism constant (C), which reflects the subjective judgment of the person conducting the distribution regarding the degree of certainty of adverse conditions.

At the first stage (module 3), it is proposed to build a matrix of gains when performing certain tasks in the operation with certain forces and means (Table 1). Moreover, it is necessary to take into account that within the limits of one matrix of gains, the suitability function must be represented by one type of indicator to ensure the possibility of applying the relevant criteria. The most appropriate and convenient indicator is the probability of completing the task. Such an indicator makes it possible to take into account the adaptability of a certain element to a certain task due to the degree of achievement of the goal of this task.

The next stage (module 4) is to determine the maximum and minimum value of the objective function for each strategy. These values are required for use in further calculations.

The next stages (modules 5.1–5.3) are the determination of the resulting value of the best strategy according to the criteria of Wald (1), Hurwitz (2), and Savage (3).

The next module (module 6) is the selection of the optimal strategy in the case of at least two results. The general selection condition is displayed as follows:

$$K_V = K_H = K_S \vee K_V = K_H \neq \neq K_S \vee K_V \neq K_H = K_S \vee K_H \neq K_V = K_S. \quad (4)$$

To use the specified condition in the block diagram, it is suggested to take the reverse condition from (4):

$$K_V \neq K_H \neq K_S. \quad (5)$$

If condition (4) is met, we choose the appropriate strategy that is optimal for the accepted conditions (module 7.2). Otherwise, it is necessary to go to the module of comparison of coefficients (module 7.1) of conditions (C_c), uncertainty (C_{un}), and sustainability of strategies (C_s). If the value of the condition coefficient is the smallest, then the optimal strategy is the strategy chosen using the Wald criterion (module 8). If the coefficient of uncertainty has the smallest value, then the strategy chosen according to the Hurwitz criterion (module 10.2) is optimal. In the case of the lowest value of the coefficient of stability of strategies – the strategy according to the Savage criterion (module 10.1).

The general view of the block diagram of the improved methodology for the optimal selection of forces and means of military formations for the performance of a certain task is shown in Fig. 1.

Verification of the above procedure (Fig. 1) was carried out by simulating its use with certain input data. The case study was conducted on the basis of the use of an operational-tactical grouping of troops in a counteroffensive operation with a wide application of special operations of the Special Operations Forces.

Setting the task: it is necessary to conduct an optimal selection of a special purpose group (SPG) of the Special Operations Forces to perform a certain set of tasks. The total number of variants of special purpose groups x=5.

Variants of recruitment of forces and means (SPG) by specialization are given in Table 5.

The number of combinations of sets of tasks in operation y=5 is given in the form of a table (Table 6).

The definition of filling options for combinations of tasks (Table 6) by their types with an indication of their number is given in Table 7.

The value of indicators that characterize the function of the suitability of a certain special purpose group to perform a certain task is expressed in terms of a relative decrease in the combat potential of the enemy (P) and is represented in the form of a table (Table 8).

The next group of input data is general coefficient of conditions C_c=0.6, coefficient of uncertainty C_{un}=0.4, and coefficient of constancy of strategies C_s=0.5, pessimism-optimism constant C=0.4.

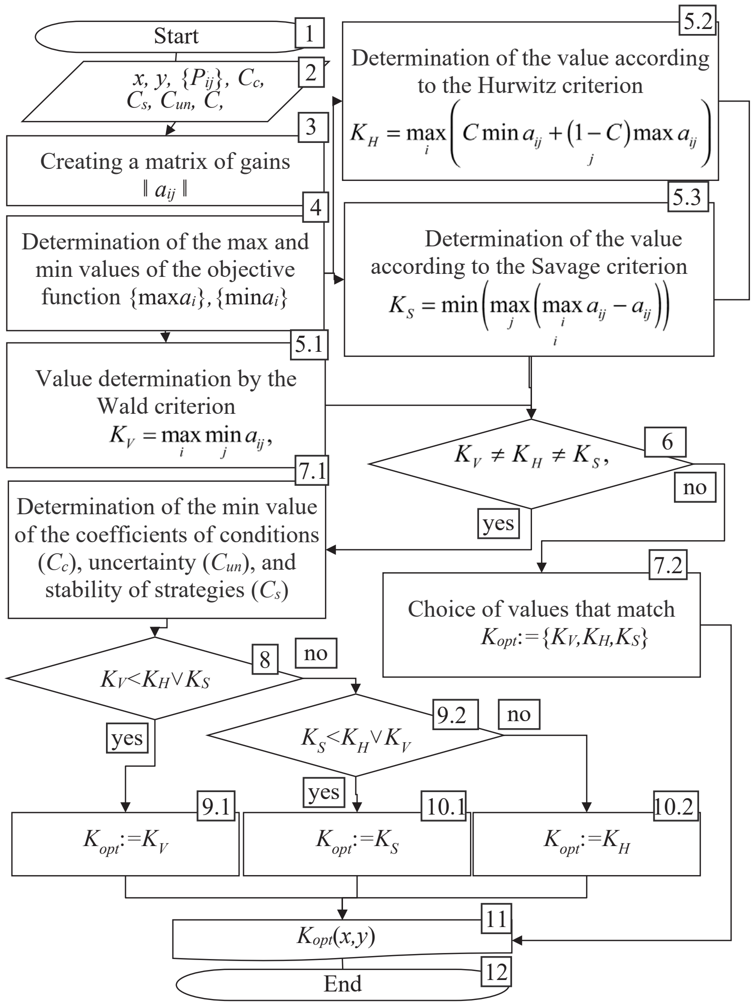

Fig. 1. General view of the block diagram of the improved procedure of optimal selection of a certain element of the grouping for the performance of a certain task

Table 5

Variants of involvement of SPG to perform tasks in the operation

Variants of SPG (x)	Type of specialization			
	Intelligence	Sabotage	Fire damage	Universal
1	3	1	1	–
2	–	2	2	1
3	1	1	–	3
4	1	1	1	2
5	2	1	1	1

Table 6

Combinations of accepted tasks in the operation

A variant of combinations of tasks (y)	Task in operation			
	Detection	Sabotage	Fire damage	Universal
1	3	1	1	–
2	–	2	2	1
3	1	1	–	3
4	1	1	1	2
5	2	1	1	1

Table 7

Filling options for combinations of tasks according to their types

Types of tasks in operation	A variant of combinations of tasks (y)				
	1	2	3	4	5
Combat actions and raids	2	1	3	2	4
Psychological operations	2	3	1	4	2
Work of «civil administration»	3	2	2	4	1
Acquisition of intelligence information on the front line	3	4	4	1	2
Creation of agency networks	4	1	1	3	3
Search, evacuation and delivery of prisoners, hostages	1	2	1	1	2
Introduction into the structure of enemy organizations	2	2	1	2	1
Espionage	3	2	1	2	2
Destruction of officials and objects of the enemy	4	3	5	2	2

Table 8

Matrix of gains when certain special purpose groups (x) perform certain tasks in the operation (y)

SPG (x)	A variant of combinations of tasks (y)				
	1	2	3	4	5
1	0.42	0.81	0.56	0.24	0.32
2	0.54	0.27	0.75	0.55	0.63
3	0.82	0.56	0.26	0.67	0.78
4	0.31	0.73	0.92	0.35	0.4
5	0.28	0.46	0.62	0.78	0.93

In accordance with the improved methodology for the optimal selection of forces and means of military formations for the performance of a certain task, a matrix of gains has already been built (Table 8). The next step is to determine the max and min value of the objective function, which is represented in the table (Table 9).

Table 9

Determination of the max and min values of the objective function

SPG (x)	A variant of combinations of tasks (y)					maxa_i	mina_i
	1	2	3	4	5		
1	0.42	0.81	0.56	0.24	0.32	0.81	0.24
2	0.54	0.27	0.75	0.55	0.63	0.75	0.27
3	0.82	0.56	0.26	0.67	0.78	0.86	0.26
4	0.31	0.73	0.92	0.35	0.4	0.92	0.31
5	0.28	0.46	0.62	0.78	0.93	0.93	0.28

The next steps are to determine the resulting value of the objective function of the optimal strategy according to the criteria of Wald (Table 10), Hurwitz (Table 11), and Savage (Table 12).

The results of determining the resulting value of the objective function of the optimal strategy according to the Wald criterion indicate that the optimal value is the choice of the 4th option of SPG for performing the first variant of combinations of tasks.

The results of determining the resulting value of the objective function of the optimal strategy according to the Hurwitz criterion indicate that the optimal value is the choice of the 4th option of SPG for performing any variant of combinations of tasks.

The results of determining the resulting value of the objective function of the optimal strategy according to the Savage criterion indicate that the optimal value is the choice of the 2nd option of SPG for performing the second variant of combinations of tasks.

The next step is to check the coincidence of the resulting values obtained by different criteria. According to condition (5), there is a match between the results of selection according to the Wald and Hurwitz criteria.

Table 10

Matrix of gains when certain tasks are performed by certain forces and means (x) in the operation (y) according to the Wald criterion

SPG (x)	A variant of combinations of tasks (y)					min	max (min(a_{ij}))
	1	2	3	4	5		
1	0.42	0.81	0.56	0.24	0.32	0.24	0.31
2	0.54	0.27	0.75	0.55	0.63	0.27	
3	0.82	0.56	0.26	0.67	0.78	0.26	
4	0.31	0.73	0.92	0.35	0.4	0.31	
5	0.28	0.46	0.62	0.78	0.93	0.28	

Table 11

Matrix of gains when performing certain tasks in the operation (y) by certain forces and means (x) according to the Hurwitz criterion

SPG (x)	A variant of combinations of tasks (y)					max	min	C	1−C	$\Sigma = C\min(a_{ij}) + (1\text{-}C)\max(a_{ij})$	max
	1	2	3	4	5						
1	[	0.81	0.56	0.24	0.32	0.81	0.24	0.4	0.6	0.582	0.676
2	0.54	0.27	0.75	0.55	0.63	0.75	0.27			0.558	
3	0.82	0.56	0.26	0.67	0.78	0.86	0.26			0.62	
4	0.31	0.73	0.92	0.35	0.4	0.92	0.31			0.676	
5	0.28	0.46	0.62	0.78	0.93	0.93	0.28			0.67	

Table 12

Matrix of gains when certain tasks are performed by certain forces and means (x) in the operation (y) according to the Savage criterion

SPG (x)	A variant of combinations of tasks (y)					max	$\Delta_{ij}=\max(a_i))-a_{ij}$					max	min
	1	2	3	4	5								
1	0.42	0.81	0.56	0.24	0.32	0.81	0.39	0	0.25	0.57	0.49	0.57	0.48
2	0.54	0.27	0.75	0.55	0.63	0.75	0.21	0.48	0	0.2	0.12	0.48	
3	0.82	0.56	0.26	0.67	0.78	0.82	0	0.3	0.6	0.19	0.08	0.6	
4	0.31	0.73	0.92	0.35	0.4	0.92	0.61	0.19	0	0.57	0.52	0.61	
5	0.28	0.46	0.62	0.78	0.93	0.93	0.65	0.47	0.31	0.15	0	0.65	

Thus, the optimal choice of the option of SPG has 4 variants. Moreover, it should be noted that when choosing this option, we can expect, with a high degree of probability, a decrease in combat potential by an average of 39 percent more than with other results (Fig. 2).

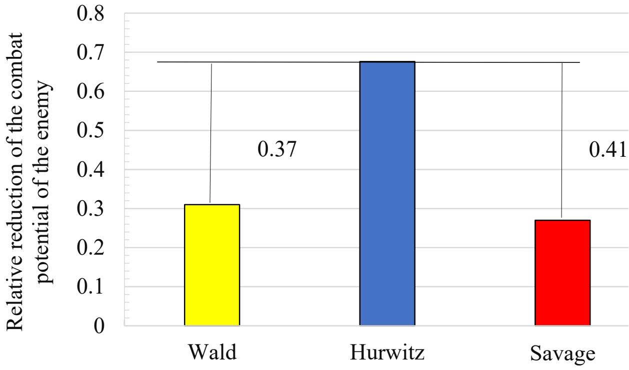

Fig. 2. Results of determining the possible relative reduction of the combat potential of the enemy depending on the choice of criterion

Analysis of our results (Fig. 2, Tables 10–12) reveals that the proposed procedure allows one not only to minimize the possible risk of not completing the task but also choose a strategy with the greatest effect. In particular, in the proposed example, choosing a strategy based on the Hurwitz criterion will allow the task to be performed with approximately 40 % more efficiency.

The main assumption of the methodology is that the uncertainty during the selection of the optimal strategy for assigning a certain element of the group to perform a certain task is caused by factors associated with various types of adverse conditions.

The main simplification is that the factors that lead to uncertainty are due to three types of adverse conditions, in particular: general adverse conditions, additional adverse conditions, adverse conditions relative to each strategy.

The limitation of this procedure is that the indicator of the objective function must be the same for all types of strategies (combat missions) within the scope of this procedure.

6. Discussion of results of improving the approach to determining the optimal strategy for selecting a grouping element

Existing approaches to the selection of optimal strategies for assigning forces and means to perform tasks have been analyzed ((1) to (3), Tables 2–4). It was found that the criteria for choosing optimal strategies are the most appropriate, in particular the criteria of Wald (Table 2), Hurwitz (Table 3), Savage (Table 4). The application of these criteria will make it possible to take into account the conditions of uncertainty of the input data and minimize the influence of adverse conditions during assignment.

The essence of the Wald criterion is to choose the best result among the worst ((1), Table 2). This criterion makes it possible to determine the best strategy in the worst-case scenario.

The essence of the Hurwitz criterion is to choose the best value from the sum of the minimum and maximum values, taking into account the subjective pessimism-optimism constant. General analysis of the Hurwitz criterion (criterion of pessimism – optimism) ((2), Table 3). The specified criterion takes into account both the pessimistic scenario (worst-case conditions) and the optimistic (best-case conditions).

The essence of the Savage criterion ((3), Table 4) is that the choice of the optimal strategy depends on the difference between the maximum and the current value of the objective function subject to conditions. In other words, its essence implies choosing the minimum value among the maximum values of the difference between the maximum and current values according to conditions. The specified criterion allows taking into account the worst conditions in relation to the best and minimizing their impact.

It was established that the specified criteria ((1) to (3)) take into account various unfavorable conditions, the Wald criterion takes into account the general unfavorable situation, the Hurwitz criterion takes into account additional unfavorable conditions, the Savage criterion takes into account unfavorable conditions directly related to each strategy. This is explained by the fact that the specified criteria were developed for use under certain conditions.

A feature of our analysis is the consideration of the criteria in view of the types of adverse conditions that they take into account, in contrast to existing studies [15, 18, 19], where only certain types of adverse conditions were analyzed. The analysis makes it possible to take into account the features of the criteria and types of adverse conditions (Tables 2–4).

The specified feature of our analysis closes the problematic part related to taking into account a wide range of uncertainty when determining the optimal strategy for assigning a certain type of forces and means for a certain task to adverse conditions. This allows us to proceed to the improvement of the procedure of optimal selection of a certain element of the grouping for the performance of a certain task, taking into account its adaptation to a wide range of adverse conditions.

Regarding the limitations of this analysis, it should be noted that its results can be used under conditions where a list of strategies and conditions is known (Table 1). This is taken into account when applying the results of the analysis in practice (Table 8), as well as in further theoretical studies (Fig. 1).

The shortcomings of the proposed analysis include the lack of other criteria that would expand the range of adverse conditions that could be taken into account. However, it should be noted that the proposed list of adverse conditions caused by uncertainty covers those types of adverse conditions that have the greatest impact on uncertainty.

The development of the analysis of the criteria for choosing the optimal strategy can be continued in the direction of determining the possibility of using them when using dynamic programming problems. This will significantly expand the limits of application of the proposed analysis and allow the development of a more advanced scientific and methodological apparatus.

The procedure of optimal selection of a certain grouping element for the performance of a certain task has been improved (Fig. 1). The essence of the improvement is the use of several criteria for choosing the optimal strategy (modules 5.1–5.3 of Fig. 1) and the coordination of the results of this selection in accordance with conditions ((4), (5), module 6 of Fig. 1). The specified procedure makes it possible to select such an element of the grouping that will allow one to perform a combat task with the maximum possible, given the accepted conditions. Also, the proposed procedure (Fig. 1) makes it possible to maximize the result, taking into account accepted conditions. Moreover, according to the conditions adopted within the example (Tables 5–8), the increase in the value of the objective function is on average 39 % (Fig. 2).

This is explained by the fact that the application of the criteria of Wald (Table 10), Hurwitz (Table 11), Savage (Table 12) makes it possible to take into account various types of adverse conditions when performing a task.

The peculiarity of the proposed procedure is that the result of choosing the optimal strategy is determined according to the conditions of a certain operation ((4), (5)). Unlike existing approaches [14–17, 21, 22], which take into account constant conditions and, accordingly, unfavorable factors, the proposed procedure allows taking into account various types of unfavorable conditions. Also, it will make it possible to minimize the consumption of resources when performing a certain set of combat missions.

The proposed procedure closes the problematic part of the high degree of uncertainty in the existing scientific and methodological apparatus due to the indirect consideration of factors that significantly affect the specified uncertainty. This makes it possible to reduce the negative impact of factors that can change their importance in the process of performing a combat mission.

The limitation of this procedure is that the value of the objective function for different strategies, conditions and, accordingly, different types of combat tasks should be expressed by one indicator (Table 8).

The disadvantage of the improved procedure of optimal selection of a certain grouping element for the performance of a certain task is the impossibility of determining the optimal strategies for several consecutive stages of the operation. However, it should be noted that such an approach can be implemented by combining the improved methodology with dynamic nonlinear programming approaches. It is proposed to tackle it in further research.

7. Conclusions

1. Existing approaches to the selection of optimal strategies for assigning forces and means to perform tasks have been analyzed. It was established that the criteria for choosing optimal strategies are the most appropriate, in particular the criteria of Wald, Hurwitz, and Savage. A feature of this analysis is the examination of the criteria in view of the types of adverse conditions they take into account. A distinctive feature of this analysis is the consideration of various types of adverse conditions. Thus, Wald's criterion takes into account general unfavorable conditions, Hurwitz's criterion – additional unfavorable conditions, Savage's criterion – unfavorable conditions relative to each strategy. The results of the analysis allow us to take into account a wider spectrum of uncertainty when determining the optimal strategy, which covers part of the problem related to the complexity of choosing the appropriate selection criterion. The application of these criteria will make it possible to take into account the conditions of uncertainty of the input data and minimize the influence of adverse conditions during assignment. The field of application of the proposed analysis is the processes of managing a group of forces during preparation for an operation by control bodies.

2. A procedure of optimal selection of a certain element of the grouping for the performance of a certain task has been improved. The improvement was carried out by using several criteria for choosing the optimal strategy and matching the results of this choice according to conditions. The proposed procedure provides the maximum probability of completing tasks in the operation, and the increase in the value of the objective function can reach 40 %. The peculiarity of the proposed procedure is that the result of choosing the optimal strategy is determined according to the conditions of a certain operation. A distinctive feature of this procedure is the consideration of various types of adverse conditions that may accompany the performance of tasks in the operation. The above allows solving part of the problem of a high degree of uncertainty in the existing scientific and methodological apparatus through the indirect consideration of factors that significantly affect the specified uncertainty. This will make it possible to minimize the consumption of resources when performing a certain set of combat missions. The field of application of the proposed methodology is management processes related to the planning and assignment of forces and resources to tasks in operations by military management bodies.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

All data are available in the main text of the manuscript.

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