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DEVISING A PROCEDURE FOR JUSTIFYING THE NEED FOR SAMPLES OF WEAPONS AND WEAPON TARGET ASSIGNMENT WHEN USING A RECONNAISSANCE FIRING SYSTEM

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This paper proposes an algorithm to substantiate the need for weapons samples, as well as targeting when using a reconnaissance firing system taking into consideration the peculiarities of functioning of such systems. The algorithm essentially implies streamlining the stages in determining the magnitude of the reduction of the enemy's combat potential and, on its basis, the formation of the need for the number of weapons by type. The algorithm makes it possible to take into consideration the nonlinearity of functions that describe both different types of weapons and targets. In addition, this algorithm is based on a modified method of nonlinear programming (two functions). The modification involves the use of a normalized share of the weight of each target as weight coefficients. This allows for targeting while taking into consideration the established level of the combat potential of an enemy.

A procedure for determining the need for samples of weapons and targeting in the use of reconnaissance firing systems has been devised. It was determined that in order to achieve the goal of enemy fire damage, it is not typically necessary to use all weapons samples. In general, the procedure makes it possible to take into consideration the peculiarities of the samples of weapons and their suitability to hit a certain target. That could prevent problems with overspending of resources, failures in the detection-defeat cycle, non-fulfillment (not fully performing) tasks during enemy fire damage.

In general, the algorithm and procedure for determining the need for the samples of weapons and targeting when using a reconnaissance firing system testify to devising a methodology for justifying the need for weapons samples and targeting. The performance and adequacy of this procedure have been tested by considering an example of determining the need for weapons samples and targeting and obtaining the result confirmed by the experience in the use of reconnaissance firing systems

Keywords: reconnaissance firing systems, methods of nonlinear programming, method of two functions, combat potential

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1. Introduction

As a result of the transformation of the goals, objectives, and limitations of armed struggle in recent military conflicts, the role of reconnaissance firing systems (RFS) has significantly increased. After all, the use of such systems makes it possible to minimize the time of the detection-defeat cycle, move from hitting targets over areas to hitting targets by points, minimize the likelihood of hitting civilians and civilian infrastructure. RFSs also ensure increased control over the capabilities and stability of the functioning of the entire structural-functional scheme of forces and means of the grouping of troops.

The results of analyzing the use of RFSs show that quite often the results of planning the use of RFSs do not coincide with the actual results. This is due to many reasons. These reasons include weak situational awareness of unit commanders, late processing and sending the necessary information [1, 2]. Additionally, the reasons include the lack of information about the enemy, the difficulty of coordinating joint actions of aviation and ground components [3, 4], the inability to determine the real ratio of forces [5].

Such problems also include the imbalance of various subsystems of RFSs (intelligence, control, fire activity). That is, quite often the capabilities of these subsystems to perform functional tasks over a certain time do not coincide [6]. This causes subsystem resources to be overspent, or tasks not completed (not fully completed).

Another issue is the use of capabilities that do not always correspond to the level of influence that is required to perform the task. That is, sometimes it is necessary to use the forces and means of RFSs, which are ready to perform the task immediately, to replace those that are more consistent with the level of the task [7]. This can also lead to overspent resources, as well as failures in the detection-defeat cycle.

However, the main reason for a mismatch between the predicted and real results of the use of RFSs, according to the authors of [8, 9], is the difficulty in executing the targeting [8, 9]. After all, it is not always possible to predict the number of targets of the enemy, the degree of suitability of weapons to hit a particular target. Moreover, it is difficult to optimally distribute the existing weapons among targets because the functions of the dependence of the damage caused on the spent efforts are nonlinear. In addition, these functions depend both on the characteristics of weapons and the characteristics of the target. That is, it is necessary to assign a sample of weapons to defeat a target taking into consideration both the probable win-loss when hitting this target by other samples and the likely win-loss in the case of hitting other targets by this sample.

The results of the analysis of the combat use of RFSs show that these problems are associated with the complexity of the allocation of forces and means of RFS subsystems among tasks. That is, the problems are caused by the imperfection of the scientific and methodological apparatus on the targeting and distribution of intelligence tasks. The main factors that predetermine imperfection are the implementation of the targeting and distribution of intelligence tasks as two independent tasks; the nonlinearity of functions that describe both means of reconnaissance, fire activities, and goals, directions of reconnaissance.

In addition, it is quite common that the functions of distribution of the source and/or resources are approximated to linear ones. That is, they lead to typical objects (calculated fire, single target, etc.). This simplification leads to a significant distortion of the distribution results.

Thus, in the practice of using RFS, there is an urgent need to find such an approach to targeting, which would make it possible to determine the optimal number of weapons samples to achieve the predefined effect.

In general, these problems are inherent in the “classic” approaches to fire damage to the enemy. However, the specificity of RFS use predetermines a more critical attitude to these issues. Therefore, overcoming these problems is a relevant task.

2. Literature review and problem statement

Paper [11] reports an approach to assess the effectiveness of the use of weapons, to determine the need for them. This approach is based on the application of approaches to decision theory, in particular, determining the weapon effectiveness index/weighted (WEI/WUV) based on the linear function of the number of each type of weapon. However, a significant limitation of that approach is the need for a subjective choice of numerical coefficients to represent different types of weapons, which are given by linear functions.

In study [12], a combat operation is divided into stages where three models are used. The first is a mathematical programming model for optimizing the targeting. Next is a Lanchester simulated model to predict whether targets could be hit over the targeting process. The next is a model for determining the effectiveness of weapons from one stage to the next. These models interact with each other within the framework of a decision support system. However, that approach does not take into consideration the possibility of determining the need for weapons in accordance with the established level of reduction in the enemy’s combat potential.

Paper [13] proposed an approach based on the use of so-called “combat capabilities”. The essence of this method is to assign certain coefficients to groups of troops, which indirectly reflect the potential ability to perform tasks. This significantly simplifies the calculations but reduces the conditions for using that approach and reduces the accuracy of the results.

Similar in the approach used is study [14] in which the coefficient of “combat potential” is applied to a weapon sample. However, that approach has significant drawbacks, in particular, the combat potential of a particular weapon sample is determined relative to a specific target, and it is not taken into consideration that this potential may change. In particular, the potential may vary depending on the characteristics of the target; stage of the operation; conditions of the combat activity.

Work [15] addresses the issue of targeting, that is, assigning and planning targets for weapons samples. This approach is based on the decomposition of a nonlinear function, linearization methods, and a simulation approach. Such an approach makes it possible to take into consideration the peculiarities of different types of weapons but does not take into consideration the change in the importance of targets in the process of hitting them.

Study [16] focuses on solving the task of interpreting the time of failure of the weapons sample as a random variable with a fixed (constant) shutter speed factor in existing stochastic models of combat collisions. This approach is based on the implementation of the Bayesian stochastic model. However, the study did not take into consideration the possibility of determining the level of reduction in the combat potential, taking into consideration the options of targeting.

Paper [17] reports an improvement to the method of targeting. In particular, the authors proposed that non-integer variable quantities in a continuous solution should be truncated to derive an entire solution. A whole program of targets is executed for the redistribution of weapons and targets available in the process of truncation. Then the truncated solution is combined with the results of the entire target program to derive a possible integer solution to the initial task. However, that approach does not imply determining the need for samples of weapons of a certain type.

The peculiarities of the specified areas indicate that it is important to study the issue of determining the need for samples of weapons and targeting in modern combat operations. Moreover, such trends in the use of RFS in modern combat operations as the speed of change in a situation, large volumes of tasks across a wide front, the use of information and communication technologies predetermine the use of a more accurate mathematical apparatus. The methods of nonlinear programming represent such an apparatus. After all, these approaches make it possible to take into consideration the different effectiveness of weapons in terms of hitting targets with different characteristics.

Thus, the need to conduct a study into the specified issues is due to the need to take into consideration a change in the combat potential during a combat operation, as well as the characteristics of various types of weapons, the optimization of the costs for achieving the established level of functional tasks.

3. The aim and objectives of the study

The purpose of this research is to devise a methodology for justifying the need for samples of weapons and targeting when using a reconnaissance firing system, taking into consideration the peculiarities of the functioning of such systems. This would make it possible to make informed decisions on determining the need for weapons samples and their targeting, which could ensure optimal execution of combat missions.

To accomplish the aim, the following tasks have been set:

– to build an algorithm for justifying the need for samples of weapons and their targeting when using a reconnaissance firing system;

– to devise a procedure for determining the need for samples of weapons and their targeting.

4. The study materials and methods

The software suite Microsoft Excel 2010 (Microsoft Corporation, USA) was used for calculations.

As for the choice of an optimization method, then, given the accepted conditions, in particular, one should argue about the allocation of heterogeneous resources among heterogeneous consumers. The methods of nonlinear programming [18] are quite simple and accurate. One of the methods is the so-called two functions method, which makes it possible to take into consideration both the heterogeneity of weapons samples and the heterogeneity of targets [17, 19–21]. In addition, this method makes it possible not only to maximize the effect of hitting targets but also to minimize the cost of achieving this effect (an economic component). Moreover, the use of the method could make it possible to establish the required degree of execution of a certain task, that is, the degree of hitting an enemy.

The essence of the method is to find a purpose matrix $\|\vartheta^0\|$, (where ϑ is the indicator of the purpose of a certain sample for a specific target), which would maximize the function of suitability of the samples of weapons of a certain type for hitting certain targets (F) [18–21].

$$F=\sum_{l=1}^{S}\Theta_l\left(1-\prod_{k=1}^{N}\left(1-\omega_{kl}\right)\right), \tag{1}$$

where l is the target number indicator; S – the number of goals; Θ – importance factor of a particular target; k – an indicator of the number of weapons of a certain type; N – the number of types of weapons; ω – the probability of hitting a target.

With restrictions, when one weapon sample is assigned per target at one step and the destination indicator acquires values from 1 to N.

$$\sum_{l=1}^{S}\vartheta_{kl}=1,\quad k=1.....N.$$

Under such additional conditions as the constituents of the purpose matrix acquiring values of 1 or 0, the probability of not hitting the target is between 0 and 1, the importance factor of the target is greater than 0.

$$\left.\begin{array}{l}\vartheta_{kl}\in\{1,0\},\\ 1\geq\left(\varepsilon_{kl}=1-\omega_{kl}\right)\geq 0,\\ \Theta_l>0.\end{array}\right\}\begin{array}{l}k=1...N,\\ l=1...S.\end{array}$$

A characteristic feature of the method of two functions is that the characteristics describing the hitting of a target by a certain type of weapon are characterized by their probability of hitting a target specified by the $\|\omega_{kl}\|_{NS}$ matrix [18–21]. Accordingly, the decision on assigning a certain type of weapon must be made for each target. To this end, each type of weapon is assigned the number k (k=1... N), and the fact of assigning a certain type of weapon for hitting γ target is registered by the indicator ϑ_{kl}=1(ϑ_{kl}=0) – otherwise). Under such conditions, the matrix of assignment would include information about assigning each type of weapon for hitting a specific target.

Thus, a given approach to the distribution of weapons to hit targets is based on the allocation of heterogeneous types of weapons to targets.

Of course, when distributing a clearly defined number of types of weapons among targets, it would suffice to apply the classical method of two functions [18–21]. At the same time, the use of a given method is problematic to determine the need for the number of types of weapons and distribute them among targets in accordance with the specified degree of hitting the targets. In this case, for the specified method, it is proposed using, instead of weight coefficients, their normalized particles, which makes it possible to determine the relative "weight" of each target. That, in turn, could determine the relative decrease in the total "weight" of targets at a certain stage of optimization [19]. Such an improvement in the method of two functions makes it possible to determine the need for the number of weapons, including the types involved in hitting the targets.

Our research involved RFSs of the tactical level, which implied considering up to five targets and five types of weapons [22]. However, it should be noted that the procedure given in this paper could be adapted for other levels of planning, in particular, operational and strategic.

Additionally, the limitation in this study is to accept the values of the probabilities of hitting certain targets for certain conditions, which requires clarification for other conditions. Regarding the concept of the "probability of defeat" in this study, it should be noted that the probability is considered as a numerical characteristic of the possibility that the combat potential of the target would decrease by a certain value under certain conditions. The conditions here are understood as a single shell (MLRS shot) hitting the target. At the same time, these conditions can be reproduced an unlimited number of times. It is clear that the accuracy, range, striking effects from the use of various types of barrel artillery, MLRS are different. However, based on the interpretation of the probability of hitting the target, in particular, regarding the possibility of reducing the combat potential, it can be assumed that such an indicator would be appropriate for both barrel artillery and MLRS. In general, determining such probabilities requires devising a separate procedure to take into consideration the entire range of possible conditions.

Another limitation of this study is the peculiarities of hitting group targets. In this study, the target is understood as a single target. However, taking into consideration group targets when using this procedure is possible by splitting it into elementary single targets. In cases where it is impossible, a group target is conditionally accepted as a single target, and the probability of hitting it with barrel artillery is about 0. On the other hand, this restriction brings some benefit to the procedure because, in the case of breaking the group target into single targets, one can take into consideration the features of each type of weapon.

Regarding the conditions under which the present study is carried out, it should be noted that it is performed for the stage of planning a combat operation. This means that planning involves only the first fire raid (strike). It is clear that the enemy's influence, such as electronic suppression, fire damage, could make significant adjustments to the initial data. Therefore, the limitation of this procedure is its use only at the stage of planning and executing the initial targeting.

In addition, it should be noted that the awareness of the parties in our study is defined for the conditions for solving the problem of dual conflict. That is, it is assumed that one party knows some information about the other side's goals, and the other party receives information during the first firing raid (strike).

It is also proposed to take into consideration the technical condition of weapons samples. Accept it as one that does not affect the results of calculations. However, it should be noted that taking into consideration the technical condition of weapons can be done through the introduction of appropriate coefficients and dividing the types of weapons during calculations into subgroups according to the level of technical suitability for tasks. It is also possible to take into consideration the technical condition of the weapon through the probability of hitting certain targets. That is, to take into consideration this condition at the stage of determining these probabilities.

Another limitation is indirect consideration of the enemy's counteraction due to the likelihood of hitting a certain target with a certain type of weapon.

5. Results of studying the process of justifying the need for weapons samples and targeting

5. 1. Building an algorithm for justifying the need for samples of weapons and targeting when using a reconnaissance firing system

The input data for this algorithm is the number and nature of the targets, the number of types of weapons, and the number of weapons samples by type, the established level of value of the objective function (the degree of hitting the targets).

The first step is to calculate the normalized shares of significance coefficients of the entire set of targets [18–21]:

$$R_l^{(t)} = \frac{\Theta_l^{(t)}}{\sum_{l=1}^{S} \Theta_l^{(t)}}, \qquad (2)$$

where t is the number of the calculation step, l – the number of targets in a certain step of calculations.

In the second step, one determines the elements in the current matrix of winning values when a certain type of target is struck by a certain type of weapon, taking into consideration the loss in the case of non-hitting other targets [18–21]:

$$\Delta_{kl}^{(t)} = R_l^{t-1}\omega_{kl} - \sum_{l=1}^{S} \frac{R_l^{(t-1)}\omega_{kl}}{\varepsilon_{kl}} a_l^{(t-1)}, \qquad (3)$$

where $a_l^{(0)} = \prod_{k=1}^{N} \varepsilon_{kl}$, $l=1...S$, $k \in N^{(t)}$, $N^{(t)}$ is the set of numbers of types unused to the t-th step of calculations; k – the number of weapons samples at a certain step of calculations.

The next step is to assign a certain type of weapon to a specific target $\left(\vartheta_{kl}^{(t)} = 1\right)$ in accordance with the condition $\Delta_{kl}^{(t)} = \max_{k,l} \Delta_{kl}$, $k \in N^{(t)}$.

The next step is to calculate the current value of the objective function [18–21]:

$$F^{(t)} = F^{(t-1)} + \max \Delta_{kl}^{(t)}, \qquad (4)$$

where $F^{(0)}=0$.

Next, the condition of reaching the level of the objective function to the established level is checked $F^{(t)} \geq F_{set\ level}^{(t)}$.

Next, new values of normalized shares of significance coefficients $R^{(t)}$ are calculated, as well as the product of the probabilities of not hitting the target $a_l^{(t)}$ [18–21]:

$$R_l^{(t)} = \begin{cases} R_l^{(t-1)}, \text{ if } \vartheta_{kl}^{(t)} \neq 1, \\ R_l^{(t-1)}\varepsilon_{kl}^{(t)}, \text{ if } \vartheta_{kl}^{(t)} = 1, \end{cases} \qquad (5)$$

$$a_l^{(t)} = \frac{a_l^{(t-1)}}{\varepsilon_{kl}^{(t)}}. \qquad (6)$$

The operation of the method of two functions regarding the optimal distribution of types of forces and means is shown in Fig. 1.

<table>
<tr><td rowspan="6">Step number</td><td rowspan="6">Weapon number</td><td colspan="3">Target number</td><td rowspan="6">The maximum value of the function for each type of weapon</td><td rowspan="6">The assigned type of weapon to the target</td><td rowspan="6">The maximum value of the objective function</td></tr>
<tr><td>1</td><td>.....</td><td>l</td></tr>
<tr><td colspan="3">Target "weight"</td></tr>
<tr><td>$\Theta_1^{(0)}$</td><td>…</td><td>$\Theta_l^{(0)}$</td></tr>
<tr><td colspan="3">Target "weight" normalized share</td></tr>
<tr><td>$R_1^{(0)}$</td><td>…</td><td>$R_l^{(0)}$</td></tr>
<tr><td rowspan="5">1</td><td>1</td><td>$\Delta_{1,1}^{(1)}$</td><td>…</td><td>$\Delta_{1,l}^{(1)}$</td><td>$\max_{1,l} \Delta_{1,l}^{(1)}$</td><td rowspan="3">$\vartheta_{kl}^{(1)}$</td><td rowspan="3">$\max \Delta_{kl}^{(1)}$</td></tr>
<tr><td>…</td><td>…</td><td>…</td><td>…</td><td>…</td></tr>
<tr><td>k</td><td>$\Delta_{k,1}^{(1)}$</td><td>…</td><td>$\Delta_{kl}^{(1)}$</td><td>$\max_{kl} \Delta_{kl}^{(1)}$</td></tr>
<tr><td rowspan="2">$R_l^{(1)}$</td><td colspan="3">The normalized fraction of the "weight" of the target in the first step of calculations</td><td colspan="3">The current value of the objective function</td></tr>
<tr><td>$R_1^{(1)}$</td><td>…</td><td>$R_l^{(1)}$</td><td colspan="3">$F^{(1)} = \max \Delta_{kl}^{(t)}$</td></tr>
<tr><td colspan="8">.</td></tr>
<tr><td rowspan="5">t</td><td>1</td><td>$\Delta_{1,1}^{(t)}$</td><td>…</td><td>$\Delta_{1,l}^{(t)}$</td><td>$\max_{1,l} \Delta_{1,l}^{(t)}$</td><td rowspan="3">$\max \vartheta_{kl}^{(t)}$</td><td rowspan="3">$\max \Delta_{kl}^{(t)}$</td></tr>
<tr><td>…</td><td>…</td><td>…</td><td>…</td><td>…</td></tr>
<tr><td>k</td><td>$\Delta_{k,1}^{(t)}$</td><td>..</td><td>$\Delta_{kl}^{(t)}$</td><td>$\max_{kl} \Delta_{k,l}^{(t)}$</td></tr>
<tr><td rowspan="2">$R_l^{(t)}$</td><td colspan="3">The normalized fraction of the "weight" of the target at step t of the calculations</td><td colspan="3">The current value of the objective function</td></tr>
<tr><td>$R_1^{(t)}$</td><td>…</td><td>$R_l^{(t)}$</td><td colspan="3">$F^{(t)} = F^{(t-1)} + \max \Delta_{kl}^{(t)}$</td></tr>
</table>

Fig. 1. Tabular technique for determining the optimal option for the distribution of types of weapons among targets

Based on the tabular solution, a matrix of assignments $\|\vartheta_{j\gamma}\|_{NS}$ is determined (the variant of which is shown in Fig. 2).

(weapon type number)	(target number)		
	1	…	l
1	$\vartheta_{1.1}$	…	$\vartheta_{1.l}$
…	…	…	…
k	$\vartheta_{k.1}$	…	$\vartheta_{k.l}$

Fig. 2. Matrix of assignment of specific types of weapons to a specific target

The general view of the flowchart of the algorithm for justifying the need for samples of weapons and targeting when using RFS is shown in Fig. 3.

Thus, we have built an algorithm in the form of a flowchart for justifying the need for samples of weapons and targeting when using RFS (Fig. 3). This algorithm makes it possible to determine the required number of weapons of certain types to achieve the established level of the value of the objective function $\left(F^{(t)}_{set\ level}\right)$. Additionally, this algorithm makes it possible to optimize targeting according to the available types of weapons.

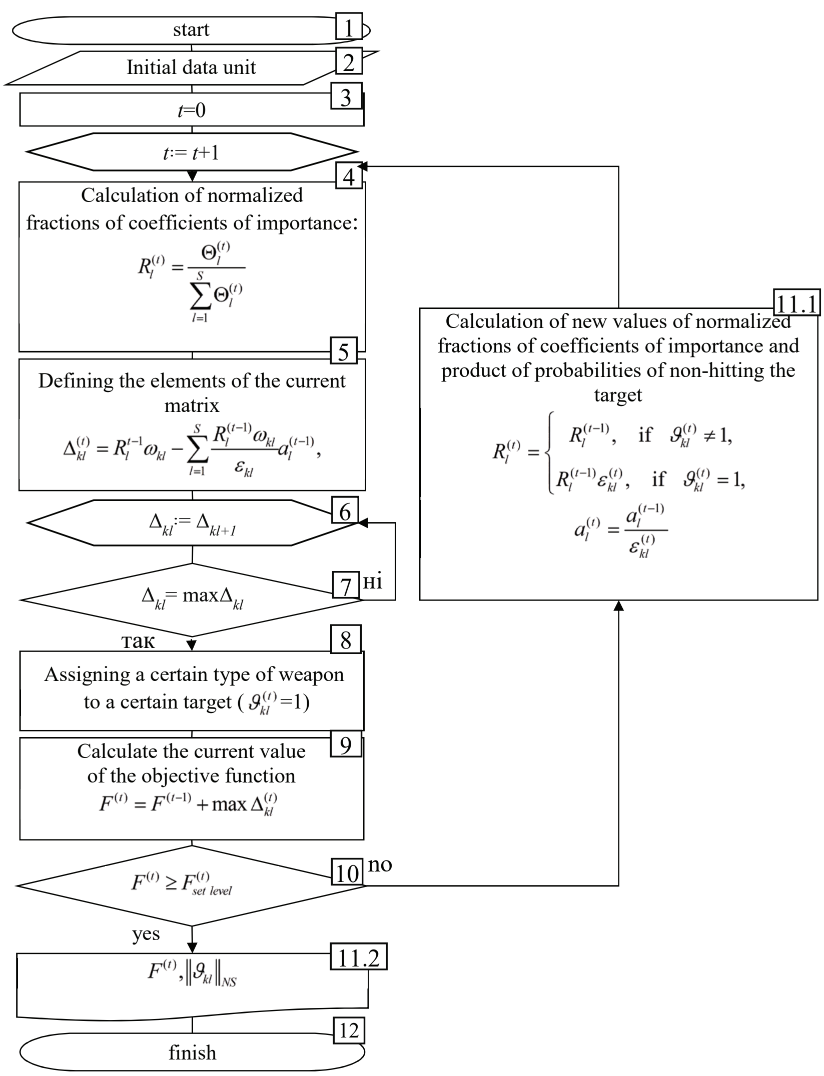

Fig. 3. General view of the flowchart of the algorithm for justifying the need for weapons samples and targeting when using a reconnaissance firing system

5. 2. Devising a procedure for determining the need for samples of weapons and targeting when using a reconnaissance firing system

The initial data for devising a procedure for determining the need for samples of weapons and targeting when using RFS under specific conditions of combat operations includes information on our troops, an enemy, and the conditions of the situation.

The basis is the tactical level combat operations.

Data on our troops: the number of types of weapons (means of fire influence on the enemy) N – 5 types. The first type, the multiple launch rocket system Smerch – 1 unit. The second, the multiple launch rocket system BM-21 Grad – 2 units. The third, the 152 mm gun-howitzer D-20 – 4 units. The fourth, the 122 mm howitzer D-30 – 6 units. The fifth, the 203 mm self-propelled gun 2S7 "Pion" – 2 units.

Data on an enemy: enemy objects S – 5 units were detected. The first object is the 23 mm anti-aircraft gun ZU 23-2, with a coefficient of importance Θ_1 – 4. The second object is the automated obstacle station R-330Zh "Zhitel", with a coefficient of importance Θ_2 – 7. The third object is the 1B75 "Penicillin" sound-thermal artillery reconnaissance system with a coefficient of importance Θ_3 – 6. The fourth object is the launcher of the missile system 9K79-1 "Tochka-U", with a coefficient of importance Θ_4 – 10. The fifth object is the command and staff vehicle R-142, with an importance factor Θ_5 – 5.

Data on the situation: in accordance with the physical and geographical conditions, season, and day, the mutual location of the target and weapons sample, the probability of hitting certain types of targets by certain types of weapons: they are given in Table 1. The required enemy defeat level $\left(F^{(t)}_{set\ level}\right)$ is 0.6.

At the first stage, we calculated the normalized fractions of importance coefficients using formula (2) for each target and entered their values in Table 2, the "normalized fractions" column.

At the second stage, one calculates the value of the win when a certain type of weapon hits a certain type of target, taking into consideration the loss in the case of non-hitting other targets according to formula (3). The calculations are carried out in relation to each type of weapon and target and are entered in the corresponding columns in Table 2.

Next, the maximum value of the win $\max\limits_{k,l}\Delta_{k,l}^{(1)}$ is determined when a certain type of weapon hits a certain type of target, taking into consideration the loss in the case of non-hitting other targets. For the first step, the maximum value corresponds to the first type of weapon (Smerch MLRS) and the fourth target (Launcher). The corresponding objective function value for the first step is 0.25.

To move to the next step, it is necessary to recalculate the normalized fractions of coefficients of importance. To this end, it is necessary to deduct from the normalized share of the importance factor of the target, which was taken prior to hitting, the already implemented value of the increase in the objective function. In a given case, it is necessary to subtract 0.25 from 0.31, which yields 0.06.

Table 1

Probability of hitting certain types of targets with certain types of weapons (ω_{kl})

Weapon type	Number of weapons	Target type (S)				
		Anti-aircraft installation	Interference station	Intelligence complex	Launcher	CSM
		Coefficient of importance of some type of target (Θ_l)				
		4	7	6	10	5
MLRS Smerch (USSR)	1	0.90	0.90	0.50	0.80	0.90
MLRS BM-21 (USSR)	2	0.98	0.75	0.67	0.74	0.95
ACS 2C7 Pion (USSR)	2	0.63	0.54	0.42	0.63	0.90
Howitzer D20 (USSR)	4	0.56	0.32	0.40	0.60	0.87
Howitzer D30 (USSR)	6	0.23	0.54	0.50	0.53	0.23

Similarly, calculations are carried out for the remaining steps until the maximum value of the objective function reaches the desired level of enemy defeat $\left(F^{(t)}_{set\ level}\right)$. In accordance with the initial conditions, this level is 0.6 and is achieved in the fourth step.

In line with the proposed procedure, a tabular method of implementation of the method of two functions was used. All calculated data are entered in Table 2, which makes it possible to increase the clarity of the application of this procedure.

In accordance with the procedure for determining in a tabular way the need for samples of weapons and targeting when using RFS (Table 2), a table of assignments of certain means to defeat certain targets was compiled (Table 3).

Analysis of the results of the assignment of certain means to defeat certain targets (Table 3) indicates that in order to achieve the desired level of enemy defeat ($F^{(t)}_{set\ level}$ – 0.6), 4 weapons should be used.

Table 2

Procedure for determining the need for samples of weapons and targeting in a tabular way when using RFS

Step number	Weapon type	Number of samples of weapons	Target type					Select the maximum value of the function	Assign weapon to task		The maximum value of the objective function at a given step
			Anti-aircraft installation	Interference station	Intelligence complex	Launcher	CSM				
			Target importance factor								
			4	7	6	10	5				
			Normalized fractions								
			0.13	0.22	0.19	0.31	0.16				
1	MLRS Smerch	1	0.11	0.20	0.09	0.25	0.14	0.25	1	4	0.25
	MLRS BM-21	2	0.12	0.16	0.13	0.23	0.15	0.23	0	0	
	ACS 2C7 Pion	2	0.07	0.11	0.07	0.19	0.14	0.19	0	0	
	Howitzer D20	4	0.05	0.05	0.06	0.17	0.13	0.17	0	0	
	Howitzer D30	6	–	0.08	0.05	0.13	–	0.13	0	0	
2	Weapon type	N	Normalized fractions					$\max\limits_{k,l} \Delta^{(2)}_{k,l}$	$\vartheta^{(2)}_{kl}$		$\max \Delta^{(2)}_{kl}$
			0.13	0.22	0.19	0.06	0.16				
	MLRS Smerch	–	0.11	0.20	0.09	0.05	0.14	–	0	0	0.41
	MLRS BM-21	2	0.12	0.16	0.13	0.05	0.15	0.16	2	2	
	ACS 2C7 Pion	2	0.07	0.11	0.07	0.03	0.14	0.14	0	0	
	Howitzer D20	4	0.06	0.06	0.06	0.02	0.13	0.13	0	0	
	Howitzer D30	6	–	0.10	0.07	–	0.00	0.10	0	0	
3	Weapon type	N	Normalized fractions					$\max\limits_{k,l} \Delta^{(3)}_{k,l}$	$\vartheta^{(3)}_{kl}$		$\max \Delta^{(3)}_{kl}$
			0.13	0.05	0.19	0.06	0.16				
	MLRS Smerch	–	0.11	0.05	0.09	0.05	0.14	–	0	0	0.56
	MLRS BM-21	1	0.12	0.04	0.13	0.05	0.15	0.15	2	4	
	ACS 2C7 Pion	2	0.07	0.02	0.07	0.03	0.14	0.14	0	0	
	Howitzer D20	4	0.06	–	0.06	0.02	0.13	0.13	0	0	
	Howitzer D30	6	–	0.01	0.07	–	0.00	0.07	0	0	
4	Weapon type	N	Normalized fractions					$\max\limits_{k,l} \Delta^{(4)}_{k,l}$	$\vartheta^{(4)}_{kl}$		$\max \Delta^{(4)}_{kl}$
			0.13	0.05	0.19	0.06	0.01				
	MLRS Smerch	–	0.11	0.05	0.09	0.05	0.01	–	0	0	0.63
	MLRS BM-21	–	0.12	0.04	0.13	0.05	0.01	–	0	0	
	ACS 2C7 Pion	2	0.07	0.02	0.07	0.03	0.00	0.07	3	1	
	Howitzer D20	4	0.06	–	0.06	0.02	0.00	0.06	0	0	
	Howitzer D30	6	0.02	–	–	–	–	0.02	0	0	

Table 3

Table of specific means to defeat certain targets

Weapon type	Number of weapons	Anti-aircraft installation	Interference station	Intelligence complex	Launcher	CSM
MLRS Smerch	1	–	–	–	1	–
MLRS BM-21	2	–	1	–	–	1
ACS 2C7 Pion	2	1	–	–	–	–
howitzer D20	4	–	–	–	–	–
howitzer D30	6	–	–	–	–	–

It should be noted that the reconnaissance system is not to be hit. This is explained by the fact that the weight of this target without means of management and means of destruction is significantly reduced. It should also be noted that 10 samples of weapons (howitzer D20 – 4 units, howitzer D30 – 6 units) remained unused. This is explained by the fact that the use of these samples would require an increase in resources (time, ammunition) to achieve the desired level of enemy defeat.

To verify the adequacy of the procedure and reliability of our results, a well-known approach to the targeting and determining the need for weapons samples was applied, namely a weapon target assignment method. The initial data taken for the proposed methodology and procedure based on the "transport problem" are as follows: the targets and their importance from this section, and the means of influence – of the same type (howitzer D20 – 4 units). Such initial data are due to the fact that these approaches can work with such data without additional formalization.

Our analysis of the results in Table 4 indicates the assignment of two howitzers to target No. 4 (Launcher), one to target No. 3 (Reconnaissance system), and one to target No. 5 (CSM). These results correspond to the optimal distribution of weapons, the procedure for which is set forth in this chapter.

Table 3

Input data to verify the adequacy of the proposed methodology and reliability of the obtained results

Weapon type	Number of weapons	Target type: Anti-aircraft installation	Interference station	Intelligence complex	Launcher	CSM
		Coefficient of importance of some type of target				
		4	7	6	10	5
Howitzer D20	4	0.56	0.32	0.40	0.60	0.87

Our analysis of the results in Table 5 indicates the appointment of one howitzer to target No. 4 (Launcher), one to target No. 3 (Reconnaissance system), one howitzer to target No. 2 (Interference station), and one to target No. 1 (CSM). The above results correspond in general to the results obtained from the proposed methodology. However, there are certain differences, in particular, in the proposed procedure, target No. 2 is not accepted for hitting while 2 howitzers are assigned to target No. 4. This is explained by the fact that the proposed methodology takes into consideration the share of the importance of the target in the whole set of targets. Once the method of weapon target assignment includes the defined fractions, the results are the same. Thus, it can be argued that the proposed procedure is adequate, and the results obtained with it would be reliable.

However, it should be noted that in the case of the use of heterogeneous weapons samples, the results of calculations would differ slightly in these approaches. This is explained by that the weapon target assignment method does not take into consideration the lost ability to assign a certain weapon sample to other targets.

In general, the proposed procedure makes it possible to execute optimal overall distribution. Moreover, it takes into consideration both the possible gain from the appointment of a certain means to defeat a certain target and the possible loss from not assigning this tool to defeat other targets.

Table 4

Results of determining the need for weapons samples and targeting when applying the methodology proposed in this study

Step number	Weapon type	Number of weapons	Target type: Anti-aircraft installation	Interference station	Intelligence complex	Launcher	CSM	Select the maximum value of the function	Assigning weapon to task		The maximum value of the objective function at a given step
			Target importance factor								
			4	7	6	10	5				
			Normalized fractions								
			0.13	0.22	0.19	0.31	0.16				
1	Howitzer D20	4	0.05	0.05	0.06	0.17	0.13	0.17	1	4	0.17
2	Howitzer D20	3	Normalized fractions					$\max_{k,l} \Delta_{k,l}^{(2)}$	$\vartheta_{kl}^{(2)}$		$\max \Delta_{kl}^{(2)}$
			0.13	0.22	0.19	0.14	0.16				
			0.06	0.06	0.06	0.07	0.13	0.13	1	5	0.30
3	Howitzer D20	2	Normalized fractions					$\max_{k,l} \Delta_{k,l}^{(3)}$	$\vartheta_{kl}^{(3)}$		$\max \Delta_{kl}^{(3)}$
			0.13	0.22	0.19	0.14	0.03				
			0.06	0.06	0.06	0.07	0.02	0.07	1	4	0.37
4	Howitzer D20	1	Normalized fractions					$\max_{k,l} \Delta_{k,l}^{(4)}$	$\vartheta_{kl}^{(4)}$		$\max \Delta_{kl}^{(4)}$
			0.13	0.22	0.19	0.07	0.03				
			0.06	0.06	0.06	0.03	0.02	0.06	1	3	0.44

Table 5

Results of determining the need for weapons samples and targeting when using a weapon target assignment method

Weapon type	Number	Target type				
		Anti-aircraft installation	Interference station	Intelligence complex	Launcher	CSM
		Target importance factor				
		4	7	6	10	5
Howitzer D20	4	0.56	0.32	0.40	0.60	0.87
Assignment		0	0	0	1	0
Saved value		0	0	0	6	0
Howitzer D20	3	Target importance factor				
		4	7	6	4	5
		0.56	0.32	0.40	0.60	0.87
Assignment		0	1	0	0	0
Saved value		0	2.24	0	0	0
Howitzer D20	2	Target importance factor				
		4	5	6	4	5
		0.56	0.32	0.40	0.60	0.87
Assignment		0	0	1	0	0
Saved value		0	0	2.4	0	0
Howitzer D20	1	Target importance factor				
		4	5	4	4	5
		0.56	0.32	0.40	0.60	0.87
Assignment		0	0	0	0	1
Saved value		0	0	0	0	4.35

6. Discussion of results of devising a methodology for justifying the need for samples of weapons and targeting

We have proposed an algorithm to substantiate the need for samples of weapons and targeting when using RFS (Fig. 3). This algorithm is based on the use of the method of nonlinear programming, in particular, the method of two functions (Fig. 1, 2). The application of this method in the algorithm makes it possible to take into consideration the nonlinearity of functions that describe both targets and different types of weapons (3). Moreover, it should be noted that this algorithm makes it possible to take into consideration both the possible gain from the appointment of certain weapons to a certain target and the loss due to the non-appointment of these weapons to defeat other targets.

Additionally, a feature of this algorithm is the use, as weight coefficients, of the normalized fractions of the "weight" of a target (2). This makes it possible to take into consideration the decrease in the combat potential of the enemy group in general.

The advantages of this algorithm include its relative simplicity in practical use. Additionally, the ability to take into consideration the established level of value for the objective function $\left(F^{(t)}_{set\ level}\right)$, that is, the level of reduction of the combat potential of the enemy group (unit 10, Fig. 3).

Overall, the algorithm makes it possible to determine the need for weapons and perform targeting, which would make it possible to take into consideration a change in the combat potential due to the peculiarities of different types of weapons. Additionally, this algorithm makes it possible to optimize costs to achieve the desired effect and determine the number and purpose of weapons, taking into consideration the degree of achievement of the level of functional tasks.

Limitations in applying this algorithm include the need to determine the probabilities of hitting a particular target with a certain type of weapon separately for certain conditions of the situation. Another limitation is the need to include in the list of targets the maximum number of enemy objects to adequately take into consideration the combat potential of this group.

Another caveat is the possibility of applying this algorithm only at the stage of planning a combat operation. That is, determining the need for weapons and targeting is applied only for the first attack (strike). However, two directions of further advancement of this study are possible. First, it is possible to apply approaches from dynamic programming. The essence of that approach is to break the operation into several stages and perform calculations for each stage. Moreover, it is possible to use the algorithm proposed in this study for each stage but with the input data, which would be formed according to the results of the previous stage.

The disadvantages of this algorithm include the difficulty of taking into consideration the possibility of maneuvering with weapons samples. Indirectly, this is taken into consideration through the probability of hitting a particular target with a certain sample of weapons. However, for a more adequate consideration of the possibility of maneuverability, we think it necessary to introduce separate coefficients of maneuverability.

Additionally, the task has been fulfilled of devising a procedure for determining the need for samples of weapons and targeting when using RFS (Table 2). The essence of the procedure is to establish the procedure for actions to justify the need for weapons samples and to execute targeting when using RFS.

It was established that in order to achieve a predefined level of reduction of the combat potential of the enemy group, not all samples of weapons should be used (Table 3). That saves the resource of weapons, as well as indirectly increases the survivability of the group in general. This is due to the fact that, as a rule, an enemy strikes those objects that have begun to function, thereby demasking themselves. That is, reducing the number of weapons involved in the fire damage increases the likelihood of their non-hitting.

In general, this procedure makes it possible to optimize targeting and determine the minimum required number of weapons by type to perform tasks under such conditions.

The peculiarities of this procedure are taking into consideration the characteristics of not only the target but also the samples of weapons. That is the number of variations of targeting increases significantly.

The limited application of this procedure may include the fact that it can be applied in the so-called "dual conflict". That is, the situation is considered when fire impact, radio-electronic suppression are carried out alternately. In fact, quite often, this situation occurs due to the fact that one of the parties begins a firing attack (strike) while the other one carries out a fire attack (strike) in response. This is due to the fact that one side would analyze the location of enemy objects that have started their active functioning and carry out a fire attack (strike) in response. Then the roles change. This is clearly demonstrated in recent military conflicts.

The further advancement of this procedure may be to execute several targeting activities for different stages of a combat operation since the number of weapons samples and the probability of hitting targets could vary depending on the enemy's counteraction.

The advantages of this procedure are the ability to modify it depending on the needs, to supplement it with the necessary units without losing the adequacy of the specified procedure. Additionally, the advantage is the ease of use of this procedure. Another advantage of this procedure is the ability to use it at different levels (tactical, operational, strategic).

The disadvantage of this procedure is the difficulty in applying it for hitting group targets and inflicting a group blow with heterogeneous forces. Although this possibility can be indirectly taken into consideration by breaking the group object into several single ones and, accordingly, involving different types of weapons in its defeat.

In general, the totality of our results indicates the development of a methodology for justifying the need for weapons samples and targeting when using RFS. This procedure includes an algorithm (Fig. 3), a method of nonlinear programming, the so-called "two functions method", and a procedure for determining the need for weapons samples and targeting when using RFS (Table 2). This procedure has been tested for performance and adequacy by considering an example of determining the need for samples of weapons and targeting (Tables 1, 2) and obtaining an adequate result (Table 3), confirmed by experience in the use of RFS.

In general, the devised procedure makes it possible to overcome existing problems both in practice and in theory. In particular, in practice, this procedure makes it possible to determine the optimal number of weapons samples to achieve the predefined effect. In theory, our procedure makes it possible to take into consideration the nonlinearity of changes in combat potential due to the nonlinearity of functions describing different types of weapons.

7. Conclusions

1. An algorithm to substantiate the need for samples of weapons and targeting when using RFSs has been proposed, taking into consideration the peculiarities of the functioning of such systems. The essence of this algorithm is to streamline the stages for determining the increase in the objective function (reducing the combat potential of the enemy) and, on its basis, to form the need for the number of weapons by type. The features of this algorithm are taking into consideration the nonlinearity of the functions that describe both different types of weapons and targets. A distinctive feature of this algorithm is the use of a modified method of two functions. The modification involves the use, as weight coefficients, of the normalized fractions of the weight of each target. This could make it possible to execute targeting taking into consideration the established level of value of the objective function (the combat potential of the enemy). The application scope of this algorithm is the stage of planning a combat operation (battle), in particular, when determining the need for weapons samples and executing targeting.

2. A procedure for determining the need for samples of weapons and targeting when using RFS has been proposed. It was determined that 66 % of weapons samples are not needed to achieve the enemy's goal of fire damage $\left(F^{(t)}_{set\ level}=0.6\right)$ (11 out of 15). Moreover, the types of weapons that are needed to achieve the goal of fire damage have been determined, in particular, the Smerch MLRS – 1 unit, and BM-21 Grad – 2 units, 1 unit of the 203 mm Pion 2S7 self-propelled gun. A distinctive feature of this procedure is the ability to take into consideration the peculiarities of weapons samples and their suitability to strike a certain target. Due to this feature, it was possible to prevent problems related to overspending the resources, failures in the detection-defeat cycle, non-fulfillment (not fully performing) tasks when hitting an enemy with fire. The application scope of this procedure and the results obtained from the consideration of an example is the planning of combat use of RFS at tactical level headquarters.

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