Informatics and Control Problems 44 Issue 1 (2024)
journal homepage: www.icp.az

Optimization of the tactical group composition with minimum manpower losses

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A R T I C L E I N F O

Article history:
Received 14.09.2023
Received in revised form 20.09.2023
Accepted 25.09.2023
Available online 03.07.2024

Keywords:
Tactical group
Attack
Losses
Mathematical model
Optimization
Integer linear programming

A B S T R A C T

The article deals with the problem of determining tactical group composition for attack subject to the minimum possible weapons and manpower losses. The construction of mathematical model of losses optimization is considered. This mathematical model is an integer linear programming problem. To evaluate military personnel losses, the Peterson model is as the basis. In accordance with this model, military personnel losses of each side are proportional to number of men of each side participating in the battle.

1. Introduction

Determining the number of weapons and equipment, as well as manpower in the tactical group before the start of an offensive, is one of the important tasks in the planning of military operations. Many scientific publications are devoted to the principles of determining the composition of a tactical group depending on the form and type of offensive, as well as on the state of the terrain and the environment [1, 2]. It is known that according to these principles, various options for choosing weapons and equipment are provided. This creates the possibility of making the optimal choice depending on the additional requirements. Mathematical formalization of these principles is presented in [1, 2] in various forms; as an optimization criterion, minimization of the price or value of weapons necessary to supply a tactical group was adopted. However, in most cases, before the start of offensive operations, when forming a tactical group, it is required to minimize possible manpower losses, taking into account the crew and maintenance personnel of weapons and military equipment, as well as the troops landed.

There are many studies [2-4] on the planning of military operations, taking into account losses in terms of organizational, sanitary and medical, etc. reasons. Of these models listed, only two will be briefly covered. The Peterson model [3] is based on the hypothesis that manpower losses of each side is proportional to the number of people of each side participating in the battle [3]. Below, the Peterson model is used for calculations. Colonel Babayev's model proposes a mathematical model for minimizing the number of weapons needed to defeat the enemy both in offensive and defensive actions [2].

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www.icp.az/2024/1-02.pdf https://doi.org/10.54381/icp.2024.1.02

When conducting military operations, performing the assigned combat mission before the offensive, each commander tries to minimize losses, primarily in manpower. Therefore, the task is to develop such a method for determining the composition of a tactical group during an offensive, so that, depending on the form and type of offensive, depending on the degree of protection of fortifications, to minimize probable losses in weapons, equipment and manpower. The approach presented in this article is an extension of Colonel Babaev's model [1].

Solving the problem of forming the composition of the tactical group before the offensive, taking into account the minimization of possible manpower losses, building a mathematical model for optimizing losses is the aim of this article.

2. Methodology

Talking of losses in battle, first of all, manpower losses are implied. In principle, the repair and restoration of weapons and equipment can be carried out during battle, but manpower losses can only be restored by new replenishment in manpower. As is known, the military uniforms of infantrymen with bulletproof vests have different resistance to fire from enemy weapons. In addition, their role and conditions of participation on the battlefield, the balance of forces, the nature of battle activities, duration, and the probable possibility of losses are different.

During the calculation, the possible losses of weapons and equipment can be calculated using well-known algorithms [5, 6]. For example, in [5, p.50-52] the coefficients of possible losses are given depending on the balance of forces, the type of battle and the duration of the battle. These data were obtained for the organization of sanitary and medical services.

As the data [5, p.53] indicate, in order to calculate the percentage of losses of weapons and equipment of various categories, the loss coefficient depending on the type of battle is multiplied by the loss coefficient depending on the category of weapons. In other words, the percentage of losses of weapons I_f and equipment is $I_f = I_d \times I_K$. Here, I_d is the percentage of losses depending on the type of battle, I_K is the percentage of losses depending on the category. By multiplying the resulting value of the percentage of losses by the number of weapons, it is possible to calculate the number n of expected losses.

Strikes on military equipment causes its partial or temporary incapacitation. For example, the main systems of a tank can retain their functions after being hit by a hollow-charge shell. However, the high pressure inside the tank that occurs at this time causes the death of all or some of the tank crew. Therefore, when it comes to manpower losses, regardless of the extent to which weapons or equipment retain their combat capability, the number of possible losses of the crew (maintenance personnel) is calculated using the "calculation of personnel losses" algorithm [5, 6]. In accordance with this algorithm, possible crew losses N can be calculated by multiplying the number of losses of weapons and equipment n by the corresponding crew loss coefficient for each weapon category I_s [5, 6]:

$$N = n \times I_s.$$

It should be noted that when planning military operations, it is assumed that losses during night combat operations are two times less than losses during daytime operations.

When constructing a mathematical model for determining the optimal composition of a tactical group, two hypotheses can be assumed to be true:

– During military operations, the probable losses for each category of weapons and equipment are proportional to their total number; as a proportionality coefficient, we can take the loss coefficient for a given category of weapons and equipment.

– It is believed that during the destruction of weapons and equipment, the loss indicator obtained for each weapon is proportional to the total number of crew members for this category of weapons;

the indicators of crew losses for different categories of weapons can be taken as a proportionality coefficient.

3. Optimization model of the tactical group composition

Sometimes, taking into account the arms of the enemy and its dynamic power, in order to fulfill a combat mission, it becomes necessary to strengthen the tactical group with weapons and equipment. This problem was considered in the model of Colonel Babayev [2]. To determine the composition of the tactical group, the following requirements are put forward:

– During the reinforcement of the tactical group, the number of weapons and equipment does not decrease;

– The number of weapons and equipment to reinforce the tactical group is limited;

– The number of tanks and infantry fighting vehicles in a tactical group should be sufficient to destroy enemy tanks;

– The number of tanks and infantry fighting vehicles in the tactical group should be sufficient to destroy the enemy infantry fighting vehicles;

– The dynamic power of a reinforced tactical group should be 3 times greater than the dynamic power of the enemy;

– The number of personnel (crew, landing and infantry) of a reinforced tactical group should be 3 times greater than the corresponding number of the enemy.

The reinforcement of the tactical group that satisfies these conditions can be carried out in various ways. In this case, the choice of the most optimal variant of the composition of the tactical group is an urgent task. In this work, the most optimal option is considered when the possible manpower losses would be minimal. The following principles will be taken as a basis:

– Depending on the type and form of tactical activity, the number of probable losses of weapons and equipment can be calculated as the product of the category loss coefficient by type of battle by the number of weapons in the tactical group;

– Regardless of the degree of loss of combat capability, damage to weapons and military equipment can be assessed as the product of the coefficient of loss of personnel by the number of personnel (crew) members.

We proceed to a mathematical formalization of the task in accordance with these conditions and principles, based on [2]. Assume that the number of tanks, infantry fighting vehicles and infantry of the enemy is b_1, b_2 and b_3, respectively.

We denote by natural numbers various samples of weapons and equipment $i = 1, 2, \dots$. Denote x_i by the number of the i-th type of weapons in the composition of the tactical group, intended against enemy tanks, and through y_i - against infantry fighting vehicles. Denote by z_i the number of the i-th type of weapons, which are mainly directed against the enemy's manpower, this also includes the landing of infantrymen, which can be given to the crew of tanks, etc.

Introduce the following notation:

– K_i is the category of type of i-th weapon;

– T_i is the impact index;

– α_i is the coefficient characterizing the possibility of destroying a tank;

– β_i is the coefficient characterizing the possibility of destroying IFV (infantry fighting vehicle);

– h_i is the number of men in the crew;

– k_i is the initial number of the i-th type of weapons in the tactical group, aimed to destroy tanks and IFVs;

– m_i is the number of weapons in the tactical group after reinforcement, aimed to destroy tanks and IFVs;

– m_{zi} is the number of the i-th type of weapons aimed to destroy enemy manpower.

Based on the above main principles, the condition for the minimum manpower loss for all weapons can be written in the following form:

$$\sum_i I_{Ki} I_{si} h_i (x_i + y_i) + \sum_i I_{Ki} I_{si} h_i z_i \to \min. \tag{1}$$

Here, I_{Ki} is the loss rate of the i-th type of weapon, I_{si} is the coefficient of the corresponding losses of personnel (crew) [5, 6]. Given the meaning of the task, it should be noted that x_i, y_i, and z_i are non-negative integers.

In light of the above, the following inequalities can be written:

$$x_i \geq 0, y_i \geq 0, z_i \geq 0, \qquad \text{and integer numbers}, \tag{2}$$

$$x_i + y_i \geq k_i, \tag{3}$$

$$x_i + y_i \leq m_i, \tag{4}$$

$$z_i \leq m_{zi}, \tag{5}$$

$$\sum_i \alpha_i x_i \geq b_1. \tag{6}$$

$$\sum_i \beta_i y_i \geq b_2, \tag{7}$$

$$\sum_i h_i (x_i + y_i) + \sum_i h_i z_i \geq 3 b_3, \tag{8}$$

$$\sum_i K_i T_i (x_i + y_i) + \sum_i K_i T_i z_i \geq 3 \frac{D}{\mathfrak{J} \cdot U}. \tag{9}$$

Here, D is the dynamic power of enemy, U is the coefficient of superiority of own troops relative to the enemy, $\mathfrak{J}$ are quantities that determine the form and type of offensive [1]. These inequalities must be satisfied simultaneously.

Thus, the problem of minimizing manpower losses when determining the composition of a tactical group can be formulated as follows:

– It is necessary to find non-negative integers x_i, y_i, and z_i such that satisfy inequalities (2)-(9), and at the same time afford a minimum to functional (1).

Mathematically, the constructed model is an integer linear programming problem and can be solved using appropriate methods (for example, [7, p.154-175]).

4. Application of the model

Suppose that an enemy motorized rifle squadron, reinforced by three motorized rifle and one tank platoon, occupies a protected position and its dynamic power is $D = 3328$. Fortification obstacles and geographical features of the area are average. It is planned to occupy these enemy positions from the side and with a surprise assault. The structure of the enemy forces, its weapons and static power are known (see Table 1).

Table 1

The structure of the enemy forces

The name of weapons and equipment	Number of arms	Number of personnel
T-72	5	15
BMP-2	10	30
AKM	50	50
RPK-74	9	9
PKM	6	6
SVD	6	6
RPG-7	9	

Taking into account the above conditions, for a confident victory over the enemy with the requirement of minimal losses, we will consider the problem of forming the optimal composition of a tactical group. It is accepted that when choosing weapons there are certain restrictions on their number, i.e., the maximum number of weapons and equipment that can be assigned to reinforce a tactical group: tank-72 - 10 units; BMP-2 – 0 (i.e., this equipment is not in stock); anti-tank weapons – 10 units; guns and mortars - 24 units; small arms - 210 units.

The values of the weapon impact categories and indices are taken from [8, 9]. According to the terms of the assignment received by the commanders, they can also accept $U = 1.0$ and $\Im = 3$ [8]. Introduce the following designations of weapons and equipment necessary for the formation of a tactical group:

x_1, x_2 and x_3 are the number of tanks, infantry fighting vehicles and anti-tank weapons designed to destroy enemy tanks;

y_1, y_2 and y_3 are the number of tanks, infantry fighting vehicles and anti-tank weapons intended to destroy enemy infantry fighting vehicles;

z_1 is the number of guns and mortars;

z_2 is the number of small arms.

In accordance with formulas (1) - (9), it is possible to build a system of inequalities:

$$x_i \geq 0, y_i \geq 0, z_i \geq 0, \qquad i = 1.2.3,$$

$$x_2 + y_2 \geq 30, z_1 \geq 6, z_2 \geq 240,$$

$$x_1 + y_1 \leq 10, x_2 + y_2 \leq 30, x_3 + y_3 \leq 10,$$

$$z_1 \leq 30, z_2 \leq 450,$$

$$0.4x_1 + 0.286x_2 + 0.4x_3 \geq 5,$$

$$0.667y_1 + 0.4y_2 + 0.4y_3 \geq 10.$$

$$3(x_1 + y_1) + 3(x_2 + y_2) + 3(x_3 + y_3) + 5z_1 + z_2 \geq 402,$$

$$113(x_1 + y_1) + 71.07(x_2 + y_2) + 36.3(x_3 + y_3) + 33.6z_1 + 3.63z_2 \geq 3328,$$

$$15.6(x_1 + y_1) + 7.8(x_2 + y_2) + 10.2(x_3 + y_3) + 12.7z_1 + 1.8z_2 \to \min.$$

If we solve this linear programming problem, we obtain $x_1 = 0$, $y_1 = 0$, $x_2 = 5$, $y_2 = 25$, $x_3 = 9$, $y_3 = 0$, $z_1 = 6$, $z_2 = 255$, that is, to reinforce the tactical group, an additional minimum of 30 units of BMP-2, 9 units of anti-tank weapons, 6 units of mortars, 255 units of small arms are needed (Table 2, column 5), while manpower losses will be minimal.

Table 2

The initial armament of the tactical group and the possibility of reinforcement

The name of weapons and equipment	Arms and weapons			
	Initial composition of the tactical group	The maximum amount that can be added	The number of weapons calculated using the standard method based on intuition and experience	Calculation results using the integer method
1	**2**	**3**	**4**	**5**
Tank T-72	0	10	15	0
BMP-2	30	30	30	30
Anti-tank weapons	0	10	10	9
Guns and mortars	6	30	30	6
Small arms	240	450	480	255

This problem was proposed for solution to a group of experienced officers. Given similar initial conditions, these officers, using known methods, intuition and experience, calculated the amount of heavy equipment and weapons needed to destroy the enemy and achieve victory (Table 2, column 4). Thus, the calculation results given in Table 2 show that the probable losses of a tactical group in manpower in a battle with a condition of assured victory, according to the proposed model, can be reduced by half: $480/255 \approx \mathbf{1.9}$.

5. Conclusion

The article presents the results of constructing a mathematical model for determining the optimal composition of the tactical group before the offensive, subject to a minimum of manpower losses. This mathematical model, being an integer linear programming problem, is solved using well-known methods. Using the proposed model, calculations were carried out for the specific case of strengthening a tactical group during an offensive. The calculations presented in the article show that when planning a battle, commanders can use this model before the offensive to solve the assigned combat mission and minimize in advance the likely losses in weapons, equipment, and, very importantly, in manpower.

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