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Improvement of the informatively computational task of determining the ratio of forces and means of the parties in terms of predicting the loss of combat potential of forces in an operation

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Abstract. The article highlights the views on improving the informatively computational task of determining the ratio of forces and means of the parties from the complex of mathematical models and informatively computational task in terms of predicting the loss of combat potential of troops in an operation. It should be noted that during the planning of an operation, as a rule, the effectiveness of the use of forces and means of the opposing parties is assessed, and the main indicators are the projected losses of forces and means of both parties in the operation. That is, the timeliness, reliability and efficiency of obtaining the results of forecasting the losses of forces and means of the parties depend on the development of the plan and, as a result, on the success of the operation. Therefore, the question of the need to automate the process of determining the projected losses of the combat potential of the parties arises, and this is the reason for the relevance of the article.

In this regard, it is proposed to improve the informatively computational task "Ratio" by using analytical expressions characterizing the dependence of losses of combat potential of forces on the initial ratio of the parties. These expressions are based on the processing of statistical data obtained as a result of a numerical experiment on simulation of a military operations. The dependence of the values of the final ratio, the losses of the combat potential of the parties on the initial ratio for different levels of Task Forces was presented in the form of histograms. Based on the analysis of the histograms, hypotheses about the type of functions of dependence of the values of the final ratio, the loss of combat potential of the parties on the initial ratio with the relevant parameters were made. Based on the results of the regression analysis in MathCAD's environment, the corresponding parameters of the functions were obtained. The parameters of the functions are determined for different levels of Task Forces and conditions of readiness of the position of the defending party. Then the determination coefficients was carried out by comparing statistical data (obtained from the results of simulation of combat operations using the informatively computational task "UA") and theoretical data (obtained using the defined dependencies). The values of the coefficients of determination are within acceptable limits, which allows us to conclude that the defined dependencies (formulas) should be used to predict the loss of combat potential of forces during an operation. An example of the application of the proposed analytical dependencies for certain conditions of the level of Task Forces and the degree of readiness of defensive positions is considered. The values of the

final ratio, losses of combat potential of the parties calculated by the proposed formulas differ by 2-3% from the same values obtained as a result of simulation, which allows to use them in the informatively computational task "Ratio" during operational calculations. Thus, the proposed approach makes it possible to automate the calculation process, which significantly increases the efficiency of obtaining results, and allows eliminating subjective errors of the operational staff and, accordingly, increasing the validity of decisions made by the commander. The materials are of practical value for the work of C2 in planning and conducting operations.
Promising areas for further research are the improvement of this informatively computational task in terms of automating the formulation of a conclusion on the possibility of achieving the purpose of the operation.

Keywords: combat potential, simulation of combat operations, projected losses, ratio of forces and means of the parties, regression analysis.

Introduction

The operation under study (combat actions) can be quantitatively characterised by a number of performance indicators, each of which reflects its specific characteristics. Among these indicators, the most important in the theory of the formation and use of armed forces was and is the category of the ratio of forces to means. The ratio of forces and means is an objective indicator of the combat power of the parties, which makes it possible to determine the degree of superiority of one side over the other. Correct calculation of the ratio of forces and means and their assessment contribute to making an informed decision on timely creation and maintenance of the necessary advantage in the selected areas. In this field of research, methods of assessing the ratio of forces belonging to the traditional forms of armed struggle (operations and combat actions) have been and are being used (Romanchenko, 2008). The ratio is determined by comparing the quantitative and qualitative characteristics of units, brigades, task forces, weapon systems of one's own troops and those of the enemy (Military Encyclopedic Dictionary, 1984). It is calculated on a strategic, operational and tactical scale over the entire battlefield, in the main and secondary directions. This assessment is used both to determine the forces and means necessary for an operation (battle) during planning, and to assess the situation at any stage of the operation in order to predict further operations and respond in time to changes in the situation (General Tactics. Division (Regiment) in Offensive, 1986).

The purpose of the article is to describe an approach to improving the informatively computational task "Ratio" in terms of predicting the loss of combat potential of forces in an operation depending on the initial ratio of forces and means of the parties, the degree of engineering equipment of the positions of the defending party, and the level of the grouping.

It should be noted that the existing methods of calculating the ratio of forces are based on an assessment of the combat capabilities of the opposing parties (Katsalap, 2013), which are summed up by the combat capabilities of their weapon systems and military equipment, and the losses of the combat capabilities of the attacking and defending parties are determined from tables that show the dependence of the amount of losses on the initial ratio of the parties (Straychnyi, 2012). However, these tables can be used to predict losses within a limited range of the ratio of forces and means of the parties. Another drawback of these tables is the assumption made during the numerical experiment (simulation of military operations) using the informatively computational task "UA" that in case of critical losses of combat potential (30% for the attacking and 40% for the defending side), the troops of the parties stop fighting, which does not correspond to the experience of military conflicts in the world during XX-XXI centuries. In addition, predicting losses in such a "manual" way by selecting values from tables significantly reduces the efficiency of obtaining the results. Subjective errors on the part of the operational staff of military command and control bodies in determining the projected losses of the combat potential of the parties and analyzing the data obtained

cannot be ruled out, especially when the values of the initial ratio go beyond the range given in the tables. Therefore, automating the process of determining the projected losses of the combat potential of the parties is an important and urgent issue.

Materials and Methods

The research materials are the values of losses of combat capabilities of the attacking and defending sides, which are determined by the following initial data (Methodology for determining the combat capabilities of mechanized (tank) units, 2000, 2004):

the initial ratio of parties;

the degree of the defending party's fortifications (hasty defense, deliberate defense);

level of Task Forces (Joint TF (operational level), TF (tactical), brigade (regiment)).

The method of regression analysis is used in the research. This is a statistical method of research the relationship between two variables, the purpose of which is to determine how changes in one or more independent variables are related to changes in the dependent variable (Frost, 2020). Regression analysis is used to solve a number of problems, including predicting future values of the dependent variable (Draper, 2007). Therefore, this method was chosen to determine the predicted amount of losses of their own and enemy troops in the operation, based on the initial ratio of forces and means of the opposing parties.

The tool chosen for the necessary calculations was the universal mathematical package MathCAD, which is designed to perform engineering and scientific calculations (Herhager, 2000).

Results and Discussions

It should be emphasized that in a number of works, in particular (Combat capabilities of troops in defense, 1977) (Combat capabilities of troops in offensive, 1977), (General tactics. Defense of the Division (Regiment), 1985), (General Tactics. Offensive of a Division (Regiment), 1986) generally abandoned the determination of the projected losses of the parties depending on the value of the ratio. The approach implemented in these sources provides only for the values of the ratio necessary to achieve the objective of the operation, depending on the type of battle (operation), the degree of engineering equipment of the defending side. That is, the question of the cost of achieving the goal of the operation is excluded.

Pavlovsky in 2014 and in 2015 analyzed the analytical dependence of troop losses on the initial ratio of forces and means of the parties. However, they focused not on the loss of combat potential, but on the calculation of losses of certain types of weapon systems and military equipment.

Zahorka (2020) presents a methodology that allows determining the projected losses of forces of one of the parties in an operation (battle) given the losses of forces of the other party, taking into account the initial ratio of forces of the parties. The methodology provides a reasonable mathematical apparatus, but a detailed analysis reveals some inconsistencies. There is no consideration of such an important factor as the degree of the defending party's fortification. According to the benchmark example given in the source, with a ratio of 1 : 1 and critical losses of the attacking party of 40 percent, the losses of the defending party are also 40 percent. With a ratio of 1 : 1.14 (in favor of the attackers) and critical losses of the attacking party of 40 %, the losses of the defending party are 53 %, which contradicts tactical (operational) standards, analyzes of real operations, and simulation results.

Today, the task of calculating the ratio of forces and means of the parties can be partially solved by using such the informatively computational systems as SLAVUTYCH, DZVIN, and TMSS. However, none of them allows for automatic calculations of the projected amount of losses of their troops and the enemy in the operation, based on the initial ratio of forces and means, although these calculations are necessary when planning an operation at the stage of assessing the situation and during the operation to assess the situation at any stage of the operation.

Using the informatively computational systems "UA" (simulation of the actions of our troops and the enemy's troops), we calculated the losses of combat potential of our troops and the enemy during the offensive and defense, as well as at different initial ratios of the parties and the degree of preparedness of the defense. The actions of different types of military forces, such as Joint Task Forces, Task Forces, and brigade were simulated. Based on the results obtained, the relevant tables of dependencies of combat potential losses on the initial ratio of forces and means of the parties, the degree of the positions' fortification of the defending party, and the level of the TF were compiled.

It should be noted that when simulating the actions of the parties in an operation using the informatively computational systems UA, certain restrictions were adopted, such as: calculations were stopped when the losses of the defending party reached 40% or the offensive party reached 30%. This restriction was justified as follows. When the party conducting the offensive suffers losses of 30% or more, it becomes limitedly combat-ready and will be forced to abandon its further conduct. In turn, when the defending side suffers losses of 40% or more, it becomes incapacitated and will be forced to abandon its positions. Although these assumptions are reasonable, they significantly limit the range of loss forecasting. In some cases, it is necessary to forecast the losses of the parties to the transaction beyond these limitations.

In our opinion, the least costly, analyzing the above software products, will be the improvement of the informatively computational systems "Ratio" (from the complex of mathematical models and the informatively computational systems "TMSS") in terms of predicting the loss of combat potential of troops in an operation.

To automate this process, it is proposed to apply the following analytical expressions that characterize the dependence of losses of combat potential of troops on the initial ratio of the parties. These expressions are based on the processing of statistical data obtained as a result of a numerical experiment (simulation of combat operations) using the informatively computational systems "UA" from the complex of mathematical models. This the informatively computational systems was used to determine the value of the projected losses of combat potential at different ratios of the parties for different types of military formations (JTF, TF, brigade) at different degrees of defense readiness. At the same time, the indicators of critical losses were not included in the informatively computational systems "UA".

Table 1 shows the results of the combat simulation for the JTF (deliberate defense).

Table 1. Results of the JTF simulation (deliberate defense)

Parties ratio (defense: offense)	at the beginning of engagement, $\alpha_{поч.}$	1 : 1,5 1,5	1 : 1,6 1,6	1 : 1,7 1,7	1 : 1,8 1,8	1 : 1,9 1,9	1 : 2,0 2,0	1 : 2,1 2,1	1 : 2,2 2,2	1 : 2,3 2,3
	at the end of of hostilities, $\alpha_{кін}$	1 : 0,94 0,94	1 : 1,06 1,06	1 : 1,23 1,23	1 : 1,42 1,42	1 : 1,69 1,69	1 : 1,87 1,87	1 : 2,08 2,08	1 : 2,77 2,77	1 : 3,03 3,03
Loss of combat potential	Defense, β_O	15,13	17,61	21,14	25,11	28,5	32,31	34,31	41,16	43,5
	Offensive, β_H	46,63	45,48	43,32	39,2	38,3	36,37	35,06	26,23	24,01

Notes: Indicators $\alpha_{поч}$ and $\alpha_{кін}$ characterize how many times the attacking party outnumbers the defending party at the beginning and end of engagement, respectively.

Graphically, in the form of histograms, the dependencies $\alpha_{кін}$ $(\alpha_{поч})$, β_O $(\alpha_{поч})$ and β_H $(\alpha_{поч})$ for the TF (deliberate defense) are shown in Figure 1.

Similar tables and histograms were compiled for the JTF, TF, and brigade for different types of operations (defense, offense) under hasty and deliberate defense conditions. After analyzing them, we hypothesized that the dependencies $\alpha_{кін}$ $(\alpha_{поч})$ and β_O $(\alpha_{поч})$ can be represented as a function of the type $f(x) = b \cdot x^c$, and the dependency β_H $(\alpha_{поч})$ can be represented as a function of the type $f(x) = d - b \cdot x^c$, where *b*, *c* and *d* are certain constants (parameters of functions).

Then the following dependencies were obtained for regression analysis in MathCad:

$$\alpha_{кін} = A \cdot \alpha_{поч}, \quad (1)$$

$$\beta_O = C \cdot \alpha_{поч}^{\ D}, \quad (2)$$

$$\beta_H = 100 - C \cdot \alpha_{поч}^{\ D}, \quad (3)$$

where *A*, *B*, C, and *D* are the parameters of the functions.

The values of the function parameters for different military formations and the types of operations they conduct are given in Tables 2 and 3.

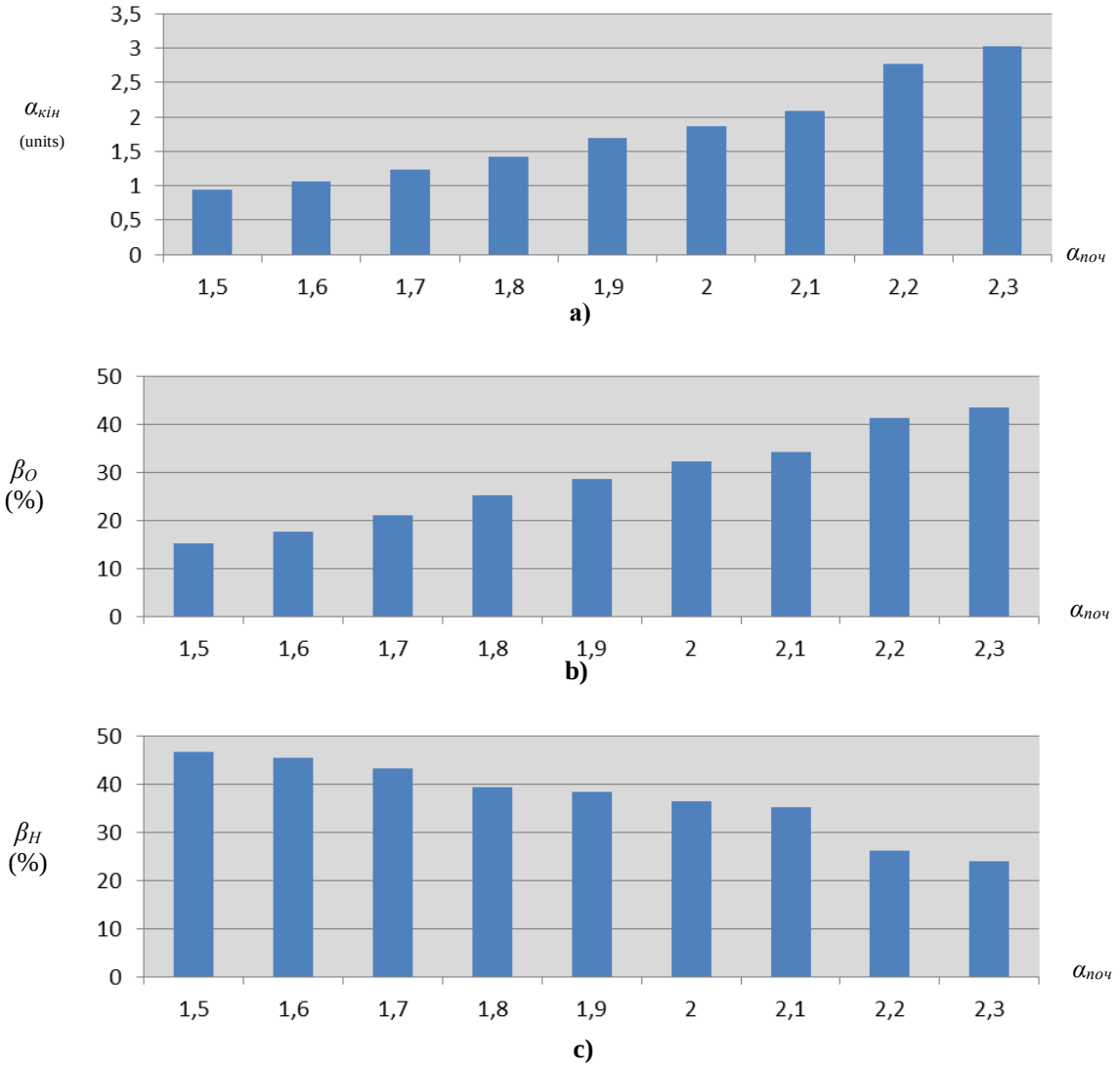


Figure 1. Histograms of dependencies: a) $\alpha_{кін}$ $(\alpha_{поч})$; b) β_O $(\alpha_{поч})$; c) β_H $(\alpha)_{поч}$

Table 2. Parameter values of the function $\alpha_{кін} = f(\alpha)_{поч}$

Military formation	Defense readiness (for the defending party)	Function parameters		The coefficient of determination R^2
		A	*B*	
Brigade	deliberate	0,149	3,398	0,994
	hasty	0,397	2,757	0,997
TF	deliberate	0,251	2,974	0,988
	hasty	0,496	2,549	0,994
JTF	deliberate	0,345	2,744	0,992
	hasty	0,534	2,637	0,998

Table 3. Parameter values of the functions $\beta_O = f(\alpha_{поч})$ and $\beta_H = f(\alpha)_{поч}$

Military formation	Type of operations	Defense readiness (for the defending party)	Function parameters		The coefficient of determination R^2
			C	*D*	
Brigade	defense	deliberate	4,4	2,547	0,986
		hasty	16,5	1,378	0,984
	offensive	on a deliberate defense	27,2	1,061	0,989
		on hasty defense	51,0	0,549	0,997
TF	defense	deliberate	5,8	2,439	0,996
		hasty	14,8	1,639	0,994
	offensive	on a deliberate defense	36,5	0,85	0,992
		on hasty defense	54,7	0,458	0,999
JTF	defense	deliberate	9,7	1,879	0,969
		hasty	20,8	1,33	0,999
	offensive	on a deliberate defense	49,2	0,523	0,998
		on hasty defense	54,7	0,51	0,999

Let's consider an example of applying the proposed analytical dependencies.

Suppose, you need to determine the final ratio $\alpha_{кін}$, the losses of the defending side β_O, and the losses of the attacking side β_H, under the following conditions: the level of the unit is TF, the defense is deliberate, the initial ratio $\alpha_{поч}$ is 1 : 1.7.

Solution. According to the given conditions, we determine the parameters of the functions: A=0.251; B=2.974; C_O =5.8; D_O =2.439; C_H =36.5; D_H =0.85.

According to the formula (1), $\alpha_{кін} = 0.251\text{-}1.7^{2,974} = 1.22$ (1.23 according to the simulation results).

According to the formula (2), $\beta_O = 5.8\text{-}1.7^{2,439} = 21.16$ (21.14 according to the simulation results).

According to the formula (3), $\beta_H = 100\text{-}36.5\text{-}1.7^{0,85} = 42.7$ (43.3 according to the simulation results).

The example shows that the values of $\alpha_{кін}$, β_O, β_H, calculated by formulas (1-3), differ from the same values obtained in the simulation by 2-3 %. To verify this, the use of task forces was simulated using the informatively computational systems "UA" with ratios outside the range indicated in the tables (Sluchayniy, 2012). The values of $\alpha_{кін}$, β_O, β_H, calculated using formulas (1-3), differ from the modeling results by no more than 3 %.

Conclusion

Thus, an element of improvement in the proposed approach to determining the projected losses of the parties is the transition from tabulated values to analytical expressions, where independent variables are calculated by regression analysis based on the results of simulation. This makes it

possible to automate the calculation process, which significantly increases the efficiency of the overall assessment, which is especially important in conditions of limited time for operational planning and decision refinement in the forces mission command in the course of military operations. The result of solving the information and calculation problem - the overall balance of forces of the parties is indicative, but in general it allows to increase the validity of predicting possible outcomes of military operations.

Promising areas for further research are the improvement of the said informatively computational systems "Ratio" (from the complex of mathematical models and informatively computational systems "TMSS") in terms of automating the formulation of a conclusion on the possibility of achieving the goal of the operation as a whole.

Recommendations

The materials of the article are recommended for use by the staff elements of military HQ at the tactical, operational, and tactical levels and for developers of mathematical models and informatively computational tasks for operational planning.

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