Research Paper

Theoretical Aspects of Predicting the Results of Development of the Armed Forces' Capabilities, Considering the Assessments of Sufficiency of the State's Economic Capabilities Based on the Mathematical Apparatus of S-shaped Functions

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ABSTRACT

The purpose of the study is to formulate an improved algorithm for drawing up plans for the development and strengthening of the capacities of the Armed Forces of Ukraine, especially under conditions of limited resources and unforeseen circumstances. The mathematical method is a central for studying and predicting the dynamics of Armed Forces of Ukraine development, namely the calculations carried out using the apparatus of S-shaped functions. In addition, the following methods were also used: analysis, synthesis and abstraction. As a result of the study, it was proposed the models for development of the Armed Forces of Ukraine for the medium term (6 years) and long term (12 years) prospects, considering the previous experience and unforeseen circumstances. It was proposed a system of consistent planning for the Armed Forces development. The key problem in the development and planning of the Ukrainian army is the fact that the expected results do not correspond to the planned ones. It was found a direct correlation between the demands of military system and the capabilities of socio-economic system.

HIGHLIGHTS

◉ Ignoring the importance of a functional and high-performance army in the context of sovereignty preservation and the state's existence has always led to critical phenomena.

Keywords: Army, financing, sovereignty, long-term development, short-term development, planning

The Russian full-scale aggression against Ukraine proves the importance of investing in the development of the army, since this is the main guarantee of the country's security. This invasion in Ukraine is the most violent interstate conflict in the world after Iraq and Afghanistan (Nagy, 2022). In 2008-2012, the Armed Forces of Ukraine (AFU) were reformed and reduced, which led to the suspension or cancellation of some development programs.

Planning of military operations is impossible without a strong and steadily developing army. M.V. Muzychenko (2017; Semenenko *et al*. 2019) has determined that the accuracy and correctness of forecasting the expected results of the implementation of activities and the tasks of their development programs are one of the important problems in the development of the AFU. It is necessary to develop general principles and conditions for building a military-economic strategy for planning the development of the AFU, like, for example, the United States. S. Kem (2020) notes that the armed forces play a key role in preservation of the state' sovereignty. S. Wilkinson (2015) analyses the formation of the status of the Indian army after it has gained independence, when the military structure has remained almost unchanged. A particular difficulty in analysing the potential and development of the Ukrainian army lies in the fact that it is forced to develop in wartime conditions and cannot do it in a planned and gradual manner, since today the question of existence of the Ukrainian statehood depends on its condition.

The purpose of the article is to determine the theoretical foundations for the development of the AFU, the formation of forecasts and strategies using mathematical research methods.

MATERIALS AND METHODS

The use of mathematical models is basis of this scientific research, which describe the S-shaped functions of the development of complex systems. To describe the development of the AFU, it was chosen the sufficiency of the state's economic capabilities as a slowdown factor regarding the ensuring of the AFU in accordance with the needs for the medium-term (six years) and long-term (twelve years) forecasting periods. In the study, it was widely used the method of comparison to identify the positive experience of the American army, which is considered one of the best in the world. The method of abstraction made it possible to avoid considering the indicators that would make calculations impossible. The analytical method helps to systematically explore the facts of the type, structure, function, individual parts of the AFU development plan, and the synthesis method – the interaction of individual parts of this structure.

The theory of S-shaped curves in the task under consideration regarding the analysis of the efficiency of the development programs for AFU, considering the state's economic capabilities and the minimum deviation due to unforeseeable factors, made it possible to make implementation plans more reliable and more flexible if the unforeseeable events do occur. In further calculations, the fact of inadequate resource provision for AFU was considered. The general equation for evaluating the performance indicator of the AFU programs, considering the time interval *t*, can be depicted as follows:

$$dE_t / dt = w_t . E_t \qquad \qquad \dots(1)$$

where: t is the time interval of execution; E_t is the overall performance indicator of the AFU development programs; w_t is the average speed of program execution over the past period.

The solution of this equation is as follows:

$$E_t = E_{t=0} . s^{wt.t} \qquad \qquad \dots(2)$$

where: $E_{t=0}$ is the priority volume of the completed program as of a year.

In order to calculate the w_t indicator, it is necessary to divide the actual achievements of the AFU development program by the time of their implementation. In this case, the slowdown factor should be calculated using the improved formula:

$$w_t - q . E_t \qquad \qquad \dots(3)$$

where: q is taken as a slowdown coefficient.

Consideration of such a mathematical transformation leads to the transformation of differential equation (1) into the form:

$$dE_t / dt = w_t . E_t - q . E_t^2 . \qquad \qquad \dots(4)$$

Calculations and conclusions made as a result of using the above-mentioned formulas (Ladogubets, 2020; Hadecka and Dubnytskyi, 2021) were presented in the tables and figures in the "Results" section.

RESULTS

A military forecast is made on the basis of scientific

forecasts for the long-term prospect. This type of forecasting provides information about the state and trends in the development of science and technology, as well as the possibilities for the development of weapons and military equipment due to discoveries in science and technology (Boukhtouta *et al.* 2021). It should be understood that the program-targeted planning of the AFU development does not replace planning by the AFU types, and its main effort is to combine measures of the same purpose, consider the relationship between the creation and operation of the main forces and means, as well as make the choice of the most rational combination of events, which are planned to be carried out by various types of the AFU (Semenenko *et al.* 2021; Chugunova, 2009). The activities regarding the substantiation of prospects for the construction and development of the AFU can be conditionally divided into five stages:

1. Formation of the general forecasts and according to certain areas of the AFU.

2. Determination of goals, finding a balance between the costs of achieving the goal and its effectiveness, final approval of strategic goals and programs for the other types of prospects.

3. Development of a short-term, medium-term and long-term plan for the development of the AFU.

4. Formation of comprehensive programs for the development of the AFU, based on the available resources and means.

5. Finalization of the AFU development plans separately for each type (Methodological…, 2020; Army of 2030, 2023).

The war in Ukraine forced to increase the military budget of the leading countries of the world. Thus, the Swiss army has increased the budget for military expenditure. This is a specific example of how external factors can change the short-term and long-term plans regarding its development (Army investment…, 2022). At the beginning of 2022, the development plans of the AFU did not include the resistance to the many thousands' Russian army, and huge assistance from the West and the United States with weapons and funding (Clark and Patt, 2020). However, the mathematical model is not able to consider these changes, and accordingly, to

determine the relevant tasks. Therefore, to calculate this model, it is necessary to consider the maximum possible deviations in advance.

The value of this calculation lies in the fact that it allows calculating the real possibility of implementing new programs for the development of the AFU, considering the past experience. Table 1 includes the forecasts of changes in the level of implementation of the AFU development program for the medium-term prospect. The calculations were conducted considering the indicators of the AFU needs for the years of operation of the program of their development.

The above calculations are graphically reflected in Fig. 1.

Based on the same calculation model, the indicators for the AFU development programs in the long-term prospect will be determined. Table 2 and Fig. 2 include the forecasts of changes in the level of implementation of the AFU development program for the long-term prospects.

Projected changes in the level of implementation of the AFU development program for the long-term prospects are shown in the Figure 2; the calculations were carried out considering the results of predicting the dynamics of level of the AFU development and the indicators of needs formed in accordance with it by the years of the programs operation for two periods of 6 years, that is, the forecasting horizon was 12 years (Army investment…, 2022).

Forecasting the effectiveness of the implementation of development programs for the long-term period indicates that the AFU development programs will be underfulfilled by 1.3-1.5 times over 12 years, and the application of proposed approach to forecasting will reduce this underperformance by 50-65% (Clark and Patt, 2020).

DISCUSSION

Since the beginning of the 21st century and the development of humanism, an increasing number of countries began to publicly introduce a call to reduce investments in the army development, and invest these funds in social projects (Fazekas, 2021). T. Kai (2021) notes that the army of US is distinguished by a special way of waging war and the introduction of advanced technologies such as artificial intelligence, machine learning, etc.

Table 1: Forecast of the implementation of the strategy for the AFU development for 6 years

Indicators/ Years	1	2	3	4	5	6
Initial volume for the t-year of period T ($E_{t=0}$)	0.01	0.01	0.01	0.01	0.01	0.01
Average speed of the program execution over the last six years (t-6), w_t-6	0.78	0.78	0.78	0.78	0.78	0.78
Coefficient that determines the relevance of MEP resources, q_t	0.84	0.44	0.44	0.44	0.44	0.44
Degree	-0.78	-1.56	-2.34	-3.12	-3.9	-4.68
Exponent in degree ($-w_t$-6*t), e^($-w_t$-6*t)	0.45	0.21	0.09	0.04	0.02	0.009
General indicator of the effectiveness of implementation of development programs, considering the MEP sufficiency level for the long-term prospect T=12 years, E_t (q_t= 0.84)	0.022	0.047	0.099	0.202	0.388	0.673
General indicator of the effectiveness of implementation of development programs, considering the MEP sufficiency level for the long-term prospect T=12 years	0.028	0.035	0.087	0.169	0.301	0.512
Indicators/ Years	1	2	3	4	5	6
Initial volume for the t-year of period T ($E_{t=0}$)	0.01	0.01	0.01	0.01	0.01	0.01
Average speed of the program execution over the last six years (t-6), w_{t-6}	0.78	0.88	0.85	0.87	0.74	0.74
Coefficient that determines the relevance of MEP resources, q_t	0.64	0.62	0.71	0.53	0.43	0.53
Degree	-0.78	-1.76	-2.55	-3.48	-3.7	-4.44
Exponent in degree ($-w_t$-6*t), e^($-w_t$-6*t)	0.458406	0.17204486	0.07808167	0.03080741	0.02472353	0.01179594
General indicator of the effectiveness of implementation of development programs, considering the MEP level sufficiency with the annual changes in q_t without applying the methodology, E_t	0.02	0.06	0.12	0.27	0.33	0.53
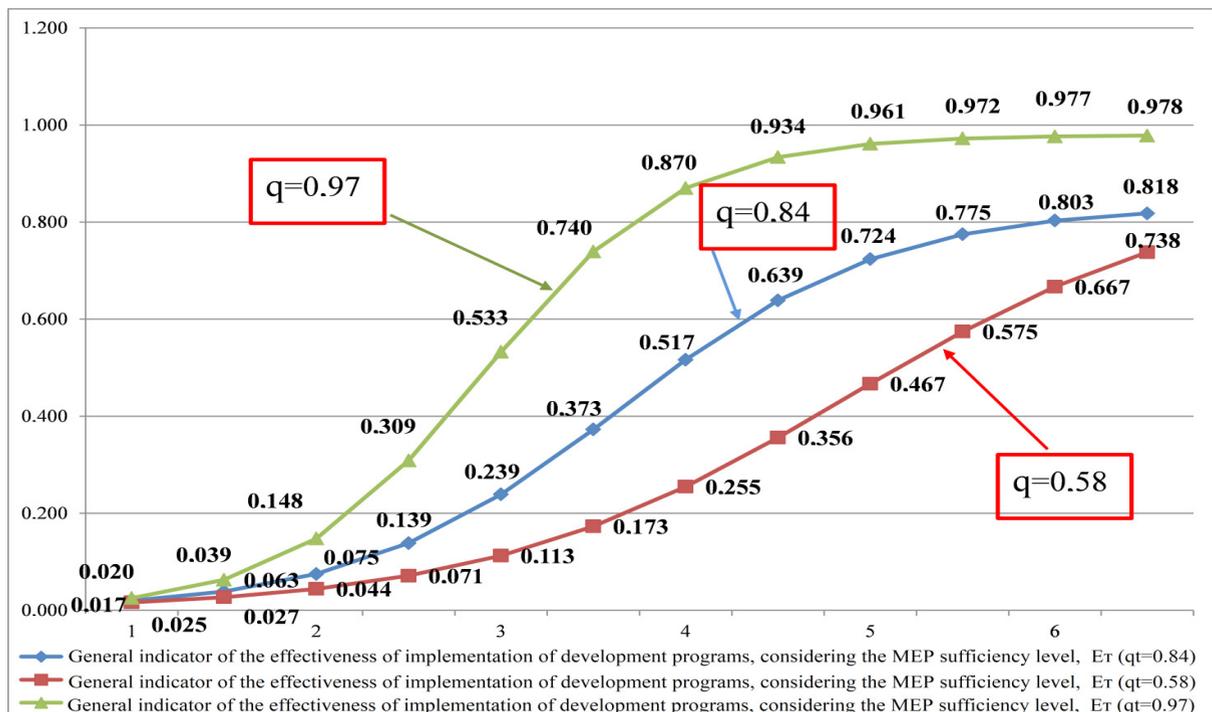
Fig. 1: Projected changes in the level of implementation of the AFU development program for the medium-term prospect

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Table 2: Forecast of the implementation of the AFU development strategy for 12 years

Indicators/ Years	7	8	9	10	11	12
Initial volume for the t-year of period T ($E_{t=0}$)	0.01	0.01	0.01	0.01	0.01	0.01
Average speed of the program execution over the last six years (t-6), w_t-6	0.78	0.78	0.78	0.78	0.78	0.78
Coefficient that determines the relevance of MEP resources, qt	0.44	0.44	0.44	0.44	0.44	0.44
Degree	-5.46	-6.24	-7.02	-7.8	-8.58	-9.36
Exponent in degree ($-w_t$-6*t), $e^{(-w_t-6*t)}$	0.004	0.001	0.0008	0.0004	0.0001	8.61
General indicator of the effectiveness of implementation of development programs, considering the MEP sufficiency level for the long-term prospect T=12 years, Eт (q_t=0.84)	1.013	1.319	1.531	1.653	1.716	1.746
General indicator of the effectiveness of implementation of development programs, considering the MEP sufficiency level for the long-term prospect T=12 years	0.789	0.994	1.207	1.329	1.438	1.543
Indicators/ Years	7	8	9	10	11	12
Initial volume for the t-year of period T ($E_{t=0}$)	0.01	0.01	0.01	0.01	0.01	0.01
Average speed of the program execution over the last six years (t-6), w_t-6	0.69	0.68	0.69	0.68	0.61	0.62
Coefficient that determines the relevance of MEP resources, qt	0.59	0.64	0.66	0.67	0.58	0.6
Degree	-4.83	-5.44	-6.21	-6.8	-6.71	-7.44
Exponent in degree ($-w_t$-6*t), $e^{(-w_t-6*t)}$	0.00798652	0.00433948	0.00200924	0.00111378	0.00121866	0.00058729
General indicator of the effectiveness of implementation of development programs, considering the MEP level sufficiency with the annual changes in qt without applying the methodology, Eт	0.61	0.73	0.87	0.91	0.93	0.97
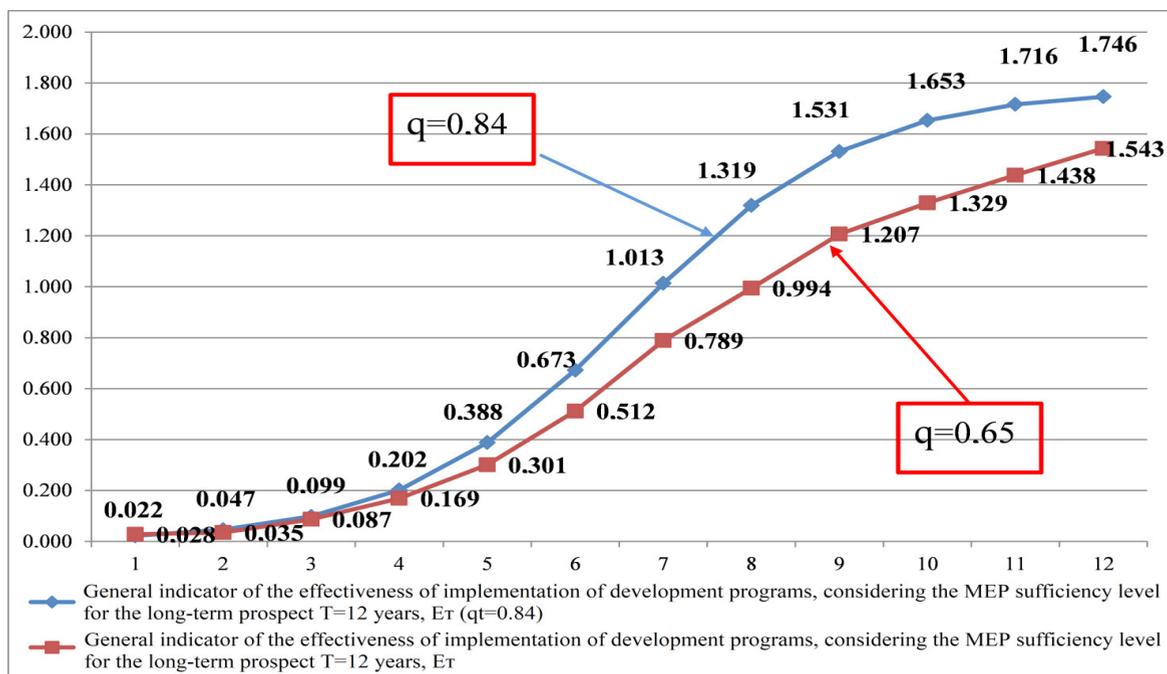
Fig. 2: Projected changes in the level of implementation of the AFU development program for the long-term prospect

To develop military measures and measures for modernization of the American army, such a unit as the dynamic Army Future Command was created. Its goal is to reduce bureaucracy in all levels of the army, introduce the latest technologies, train soldiers for the successful completion of all military tasks (Kania, 2019; Kem, 2020; Negyesi, 2021).

S. Hadecka and V. Dubnytskyi (2021) substantiated the use of S-shaped functions. They are used as a practical tool for the technological modeling. The researchers note that such models are quite effective and can even be used to organize anti-terrorist operations. T. Ladogubets (2020) has determined that the choice of the optimal solution to issues is one of the urgent problems in any activity. K. Sokol (2015) has developed formulas that determine whether a particular company is ready to enter the market. They are based on the average expert assessment of common parameters that can be tracked at each stage. O.M. Semenenko *et al*. (2020) have revealed in their work the essence of economic factors that directly affect the AFU state and the prospects for their development, as well as the level of military and economic security in the state. R.B. Khomchak *et al*. (2019) note that the change in the scenarios of using the army and its structure requires a new analysis of the resources and capabilities of the AFU.

It should be understood that the original plan ceases to operate with a very sharp change in goals and may require a large number of resources not included in the first plan (Jovanovic, 2022; Liwang, 2018). According to M.V. Muzychenko (2017), the process of planning and decision-making consists of two phases, namely the processing of facts and systematic actions. Initial modeling plays an important role in the successful management of situations that may arise in the future.

CONCLUSION

The army is a very important tool for preserving statehood. This has been empirically proven on the example of Ukraine. Despite limited resources and unpredictable external factors, the plans for development and improvement of the functioning of the Ukrainian army should be as close to real conditions as possible and should be highly effective. As a result of the study, it has been revealed that the analysis of the state's economic

capabilities on the basis of mathematical model for the formation of S-shaped functions has made it possible to assess the state and develop the ways to improve efficiency of implementing the programs and plans for the AFU development, as well as the efficiency of using financial resources in case they do not meet the needs or planned indicators.

The proposed approach regarding the determination of zones of effective resource spending for the development of individual capabilities of the AFUe and the development in general will improve the military-economic feasibility of plans and programs for the AFU development. The features of mathematical model based on the S-shaped function make it possible not only to determine the deterministic volumes of appropriate funding for the AFU development, but also the range of appropriate financing of one or another capability of the AFU. It is necessary at all levels of the defense planning system of Ukraine to additionally introduce the principles of methodology of the military-economic research, which will allow making more in-depth military-economic research and substantiate the most appropriate options for the AFU development.

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