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Mathematic Model of the Troop Management Cycle based on a Continuous Markov Chain for an Automated Control System

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Authors
Semenenko O.*[1] *MD,*
Kirsanov S.[2] *PhD,*
Mashkin O.[3] *MD,*
Pravdyvets O.[4] *PhD,*
Petrozhalko V.[5] *PhD*

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[1]Research Department of Economic Analysis of Development Activities of the Armed Forces of Ukraine, Central Research Institute of the Armed Forces of Ukraine, Kyiv, Ukraine
[2]Research Center for Investigation of Armed Forces Command and Control Problems, Central Research Institute of the Armed Forces of Ukraine, Kyiv, Ukraine
[3]Research Department for Modeling the Development of the Armed Forces, Central Research Institute of the Armed Forces of Ukraine, Kyiv, Ukraine
[4]Directorate of Digital Transformation and Information Security Policy in the Sphere of Defense, Ministry of Defense of Ukraine, Kyiv, Ukraine
[5]Research Center for Investigation of Armed Forces Command and Control Problems, Central Research Institute of the Armed Forces of Ukraine, Kyiv, Ukraine

****Correspondence***
Address: 03049, 28B Vozdukhoflotsky Ave., Kyiv, Ukraine
Phone: 044 520-19-44
Fax: -
semenenko8513@tanu.pro

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ABSTRACT

Aims The purpose of the article is to develop a mathematical model of the army management cycle based on a continuous Markov chain to justify the requirements for the efficiency of the control bodies (CB) of a promising automated control system.
Materials & Methods The basis of this methodological apparatus is the following methods: expert assessment, analogies, empirical methods used during testing of individual software and technical solutions of automated control systems, which are created in the Armed Forces of Ukraine.
Findings Authors developed a mathematical model of the troop management cycle based on a continuous Markov chain to justify the requirements for the efficiency of the operation of a promising automated control system. A special feature of this model, which determines its novelty, is the use of the theory of Markov Processes with discrete states and continuous time for mathematical modeling of the CB operation cycle in a control system of any level of subordination of troops. This made it possible, unlike other methods, to establish a relationship between the amount of information that circulates in the troop management cycle during the operation of the CB, and the time that is spent on this at each of its stages.
Conclusion The obtained scientific results made it possible to justify the time (to put forward a requirement for the efficiency of the CB) that is needed to perform certain measures of the CB of a promising automated control system to achieve the goal of the operation.

Keywords Mathematics; Military Personnel; Civil Defense

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Introduction

The experience of local wars and armed conflicts of the late XX – early XXI centuries shows that the forms and methods of conducting military operations have undergone significant changes. The first place is not the quantitative and qualitative composition of the opposing groups, but the information support of military operations to create the necessary conditions for more effective use of the armed forces, including in conditions of the numerical superiority of the opposing side. Superiority over the enemy can be achieved through a significant improvement in the quality of management: completeness and depth of knowledge, a unified understanding, and assessment of the operational situation, which is dynamically developing, by the command of all levels, prompt response to the changing situation, making timely and informed decisions, accelerated bringing them to subordinate troops (forces).

It is known that one of the priority tasks of the country's defense is to create an effective management system for the Armed Forces of Ukraine based on modern information technologies [1, 2]. This task is gradually being implemented by improving the management system of troops (forces). But, despite this, the current state of the system of management of troops (forces) does not meet the requirements that are put forward for it [3]. One of the reasons for this condition is the imperfection of the methodological apparatus used to study the process of managing troops and justify the requirements for it. First of all, this concerns the requirements for the efficiency of the op, which are the defining (main, most important) element of any management system, which determines the relevance of the topic of the article.

The purpose of the article was to develop a mathematical model of the army management cycle based on a continuous Markov chain to justify the requirements for the efficiency of the CB of a promising automated control system.

Materials and Methods

Analysis of recent research and publications on the existing methodological apparatus for justifying the requirements for the efficiency of the work of the CBATMS, considering its complexity, branching, and hierarchy, showed that insufficient attention was paid to its development.

The basis of this methodological apparatus is the following methods: expert assessment, analogies [4, 5], empirical methods used during testing of individual software, and technical solutions of automated control systems, which are created in the Armed Forces of Ukraine [6]. The use of these methods allows justifying with the help of partial indicators that characterize the functioning of the CB (namely: staffing, training of officials, their coherence, possible combat losses during the operation), approximate (predicted) values of the probability indicator for timely performance of tasks of the CB during a certain time for managing troops. But this does not consider the features and capabilities of the CB regarding working with information that circulates at the stages of the military management cycle. It is the amount of information with which it is necessary to perform certain actions of the CB (receive, process, summarize, send) that determines the duration of each stage and cycle of managing troops as a whole.

That is, the existing methods of justifying the requirements for the efficiency of CB of promising management systems do not have a single ideology, and the vast majority rely on probability theory [7, 8]. The mathematical expressions that form their basis contain a significant number of coefficients, the origin of which reflects the subjective vision of the authors who developed the methods. They do not allow justifying the requirements for the efficiency of the CB's work, considering changes in the amount of information that circulates in the management system, which is inherent in a promising automated control system. In contrast to the existing methods, the choice of a continuous Markov chain as the basis for mathematical modeling of the control cycle of troops will allow us to adequately describe the random process of information circulation that occurs in a prospective automated control system at the stages of the control cycle and calculate the relationships between the amount of information and the time spent on actions with it, considering its possible range of deviation.

The main goal of the office is to ensure the most effective use of the capabilities of the troops in any conditions of the situation that arise [9]. This can be achieved through sustainable, operational, covert management, etc. The goal of management is achieved by the simultaneous and consistent implementation of a number of tasks, which, first of all, must include: ensuring combat and mobilization readiness of troops; training CB, associations (formations, units, divisions) to perform tasks in the operation (battle) and organizing interaction between them and neighbors; continuous collection, generalization (processing), analysis of data on the operational (combat), technical and rear situation and forecasting its development, preparing the necessary reference data; planning the operation (battles) of troops [10]; timely decision-making on the use of troops and bringing tasks to subordinates; organizing and implementing measures for comprehensive support of the operation (battle) [11]; organization of stable operation of the control system (CS) of troops; ensuring cybersecurity; management of planned activities in the operation (battle), in particular, measures for covert management of troops, protection and defense of CS by the troops, increasing its survivability;

management of actions of subordinate CB, forces and means during the preparation and during the operation (battle); organization and implementation of control over the implementation of subordinates of planned activities, providing them with assistance, and other activities based on specific conditions of the situation [12]. By completing tasks, partial or final components of the management goal are achieved.

Findings

The management of troops is a purposeful and coordinated activity of commanders (chiefs), staff, and other management bodies (CB) to maintain the combat readiness and capability of troops, prepare operations (battle) and lead subordinate troops during the performance of their assigned tasks. In modern conditions, the implementation of CB management functions to solve certain tasks to achieve the management goal should be ensured by creating a promising automated control system and equipping it with modern control tools (communication and automated control systems (MAM)), coordinated work of officials of appropriate qualifications who manage troops, able to quickly and competently perform tasks. This system must function under the influence of external and internal factors. The main external factors affecting the functioning of the automated control system of a certain level of subordination include the nature of combat operations and the content and features of tasks performed by troops in an environment that has developed under the influence of the enemy.

The main internal factors affecting the functioning of this system include the level of staffing and readiness of the CB to perform tasks assigned to the control system of a certain level; the level of equipping the PU with modern means of communication and MAM by troops, their complexes and automated control systems, in general, using the modern mathematical and software installed on them to justify planned activities and control of troops.

The defining (main, most important) element of any system of command and control of troops is the CB. It is the timeliness and quality of its work, first of all, depends on the timely receipt, and analysis of incoming information from the operational-tactical situation, making, and considering, an effective decision, planning appropriate measures, timely setting tasks for subordinates and implementing effective control over the implementation of their planned measures, as well as other actions aimed at improving the effectiveness of the combat use of troops to achieve the goal of the operation. That is, achieving a given level of efficiency in the management of troops in a promising automated control system involves, first of all, getting ahead of the enemy in actions to plan, use troops and manage them in the operation.

Accordingly, it is the duration of actions of the CB to perform the assigned tasks for managing troops at the stages of the management cycle that primarily determines such an important property of a promising automated control system as its efficiency. At the same time, the cycle of managing troops should be understood as a period T_{CU}, during which a consistent solution of control tasks is carried out from the moment of receiving the combat task of the CB to its full implementation within the framework of this control system. The main tasks that conditionally determine the stages of the management cycle include task analysis; assessment of the situation; development of a plan; decision-making; setting tasks for troops; development of an operation plan, and monitoring the implementation of tasks.

The efficiency of managing troops is directly characterized by an indicator of the time of duration of the control cycle T_{CU}, which is carried out under strict time constraints. These restrictions determine that the time of execution of measures at each of its stages t_i it must not exceed the allowed time t_i^{add}, and the total time of the control cycle T_{CU} must not exceed the directive time set by the commander T_{dir}. That was:

$$t_i \leq t_i^{\text{add}},\ i = \overline{1,n}, \qquad (1)$$

where i – stage of the management cycle. And:

$$T_{\text{cu}} \leq T_{\text{dir}}, \qquad (2)$$

where:

$$T_{\text{cu}} = \sum_{i=1}^{n} t_i. \qquad (3)$$

Based on the above, it is advisable to understand the speed of their reaction (actions) to changes in the current situation to get ahead of the enemy in actions to achieve the goal of the operation. Because during the management of troops, CB carries out the procedures provided for in the stages of the management cycle directly with information, the time to complete each stage will determine its scope. The passage of this process in a promising automated control system should be considered as a continuous and consistent transformation in a time of the received information about the state of the control object (CO) and the situation that has developed into command information by preparing forecasts of the behavior of the CB depending on different options for the design of the CB, choosing one of these options, developing on its basis the action plan of the CO in the operation, managing it and monitoring the implementation of the plan. That is, this information is a set of certain information (data) necessary to perform the functions inherent in this control system by the purpose of its creation and the level of management, depending on the subordination of troops. It is the carrier of all changes taking place in the control system, and without it, the process of managing troops is impossible.

Following this, we will represent the troop management cycle as a process as a marked-up state graph *S*, in which certain actions are performed with information (Figure 1). According to this process, time can be in one of 7 states, which are determined by the stages of the army management cycle:

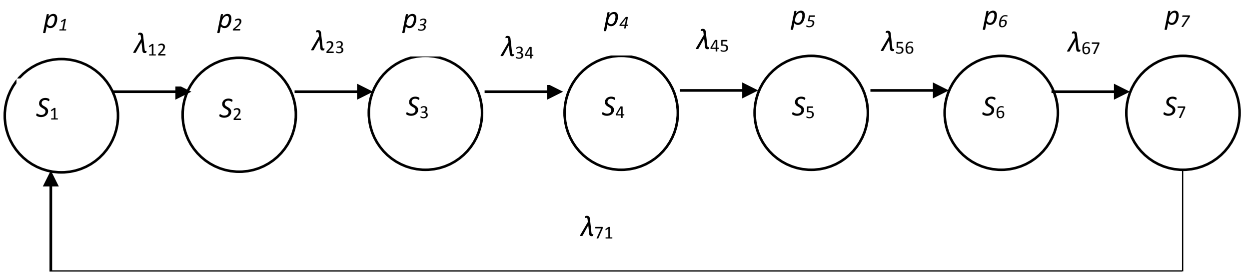

Figure 1) Marked-up graph of the states of the troop management cycle

Note: S_1 – Task analysis; S_2 – Assessment of the situation; S_3 – Development of the plan; S_4 – Making a decision; S_5 – Problem statement; S_6 – Development of an operation plan; S_7 – Monitoring the implementation of assigned tasks; p_1,p_2,…, p_7 – the probability of the process being in the S states$_{1,}$$S_{2,}$,.S_7; λ_{ij}, wherei, $j = \overline{1.7}$ – the amount of information received per unit of time and transfers the process S from the i-th state to the j-th state(the intensity of transitions of the process S).

The graph was constructed based on using the theory of Markov processes with discrete states and continuous time with the corresponding event flows. Under such conditions, the event streams circulating in the process *S* – protozoa, which, meet three basic requirements: stationarity, absence of aftereffect, and ordinariness, have an exponential (exponential) law of time distribution *t* between the occurrence of events with the parameter λ. According to this, from the state *i* in the state *j* process *S* translates the flow of received (processed, transmitted) information with the corresponding intensities λ_{ij}. At the same time, given the stochasticity of the process of managing troops, these transitions occur at random moments in time that cannot be predicted in advance. Considering that the process *S* (by definition) is a sequential cyclic process with one-way transitions, we describe the graph presented in Figure 1 as a system of Kolmogorov differential equations for state probabilities:

$$\left.\begin{aligned}
\frac{dp_1}{dt} &= -\lambda_{12}p_1 + \lambda_{71}p_7,\\
\frac{dp_2}{dt} &= -\lambda_{23}p_2 + \lambda_{12}p_1,\\
\frac{dp_3}{dt} &= -\lambda_{34}p_3 + \lambda_{23}p_2,\\
\frac{dp_4}{dt} &= -\lambda_{45}p_4 + \lambda_{34}p_3,\\
\frac{dp_5}{dt} &= -\lambda_{56}\mathrm{p}_5 + \lambda_{45}p_4,\\
\frac{dp_6}{dt} &= -\lambda_{67}p_6 + \lambda_{56}p_5,\\
\frac{dp_7}{dt} &= -\lambda_{71}p_7 + \lambda_{67}p_6,
\end{aligned}\right\} \qquad (4)$$

where R_1, R_2,…, R_7 – probabilities of the presence of the process of managing troops in the states S_1, S_2,…, S_7, accordingly, and $\sum_{i=1}^{n} p_i = 1$, n = 7, since the events are incompatible and make up a complete group; λ_{ij} – the intensity of the transition of the process of managing troops from *i*- go to *j*– and the state where $i, j = \overline{1,7}$.

Please note that when justifying the requirements for promising types of weapons and military equipment, their complexes and systems, which, among other things, include a promising automated control system, their systematic and repeated use over a long period is assumed ($t \to \infty$): both during the preparation and in the process of using groups of troops (forces) to fully achieve the goal. Under such conditions, it is advisable to accept the hypothesis of establishment in the process *S* in $t \to \infty$ stationary mode, which consists in the fact that this process randomly changes its state, but the marginal probabilities R_1, R_2,…, R_7 of each of the states are no longer time-dependent: the transition to each state is carried out with a certain constant probability. These probabilities represent the average relative residence time of the process *S* in states S_1, S_2,…, *S*7 accordingly. The present time is determined by the amount of information with which actions are performed at the stages of the process *S*.

Since all probabilities of states are constant, their derivatives are zero. Based on this, we equate all the left parts of 4 to 0 and write for the process *S*in stationary mode, the corresponding system of linear algebraic equations for determining the limit probabilities of states:

$$\left.\begin{aligned}
\lambda_{23}p_2 &= \lambda_{12}p_1,\\
\lambda_{34}p_3 &= \lambda_{23}p_2,\\
\lambda_{45}p_4 &= \lambda_{34}p_3,\\
\lambda_{56}\mathrm{p}_5 &= \lambda_{45}p_4,\\
\lambda_{67}p_6 &= \lambda_{56}p_5,\\
\lambda_{71}p_7 &= \lambda_{67}p_6\\
\lambda_{12}p_1 &= \lambda_{71}p_7.
\end{aligned}\right\} \qquad (5)$$

We express the probability from the system of equations 5 $R_2,\ldots,R_7$ via R_1.

$$\left.\begin{aligned} p_2 &= \frac{\lambda_{12}}{\lambda_{23}} p_1, \\ p_3 = \frac{\lambda_{23}}{\lambda_{34}} p_2 &= \frac{\lambda_{12}\cdot\lambda_{23}}{\lambda_{23}\cdot\lambda_{34}} p_1 = \frac{\lambda_{12}}{\lambda_{34}} p_1, \\ p_4 &= \frac{\lambda_{12}}{\lambda_{45}} p_1, \\ p_5 &= \frac{\lambda_{12}}{\lambda_{56}} p_1, \\ p_6 &= \frac{\lambda_{12}}{\lambda_{675}} p_1, \\ p_7 &= \frac{\lambda_{12}}{\lambda_{71}} p_1 \end{aligned}\right\} \quad (6)$$

that is, in general, an expression for calculating the marginal probability *i*-th state of the process *S* will look like this:

$$p_i = \frac{\lambda_{12}}{\lambda_{ij}} p_1. \quad (7)$$

Considering the normalising condition $\sum_{i=1}^{n} p_i = 1$, $n = 7$, defined in 4, and substituting expressions 6 in it, we obtain: $p_1 + \lambda_{12} p_1 (\frac{1}{\lambda_{23}} + \frac{1}{\lambda_{34}} + \frac{1}{\lambda_{45}} + \frac{1}{\lambda_{56}} + \frac{1}{\lambda_{67}} + \frac{1}{\lambda_{71}}) = 1$. Where do we get the following system of equations:

$$\left.\begin{aligned} p_1 &= \frac{1}{1+\lambda_{12}\left(\frac{1}{\lambda_{23}}+\frac{1}{\lambda_{34}}+\frac{1}{\lambda_{45}}+\frac{1}{\lambda_{56}}+\frac{1}{\lambda_{67}}+\frac{1}{\lambda_{71}}\right)}, \\ p_2 &= \frac{\lambda_{12}}{\lambda_{23}} \cdot \frac{1}{1+\lambda_{12}\left(\frac{1}{\lambda_{23}}+\frac{1}{\lambda_{34}}+\frac{1}{\lambda_{45}}+\frac{1}{\lambda_{56}}+\frac{1}{\lambda_{67}}+\frac{1}{\lambda_{71}}\right)}, \\ p_3 &= \frac{\lambda_{12}}{\lambda_{34}} \cdot \frac{1}{1+\lambda_{12}\left(\frac{1}{\lambda_{23}}+\frac{1}{\lambda_{34}}+\frac{1}{\lambda_{45}}+\frac{1}{\lambda_{56}}+\frac{1}{\lambda_{67}}+\frac{1}{\lambda_{71}}\right)}, \\ p_4 &= \frac{\lambda_{12}}{\lambda_{45}} \cdot \frac{1}{1+\lambda_{12}\left(\frac{1}{\lambda_{23}}+\frac{1}{\lambda_{34}}+\frac{1}{\lambda_{45}}+\frac{1}{\lambda_{56}}+\frac{1}{\lambda_{67}}+\frac{1}{\lambda_{71}}\right)}, \\ p_5 &= \frac{\lambda_{12}}{\lambda_{56}} \cdot \frac{1}{1+\lambda_{12}\left(\frac{1}{\lambda_{23}}+\frac{1}{\lambda_{34}}+\frac{1}{\lambda_{45}}+\frac{1}{\lambda_{56}}+\frac{1}{\lambda_{67}}+\frac{1}{\lambda_{71}}\right)}, \\ p_6 &= \frac{\lambda_{12}}{\lambda_{675}} \cdot \frac{1}{1+\lambda_{12}\left(\frac{1}{\lambda_{23}}+\frac{1}{\lambda_{34}}+\frac{1}{\lambda_{45}}+\frac{1}{\lambda_{56}}+\frac{1}{\lambda_{67}}+\frac{1}{\lambda_{71}}\right)}, \\ p_7 &= \frac{\lambda_{12}}{\lambda_{71}} \cdot \frac{1}{1+\lambda_{12}(\frac{1}{\lambda_{23}}+\frac{1}{\lambda_{34}}+\frac{1}{\lambda_{45}}+\frac{1}{\lambda_{56}}+\frac{1}{\lambda_{67}}+\frac{1}{\lambda_{71}})} \end{aligned}\right\} \quad (8)$$

That is in the general case:

$$p_i = \frac{\lambda_{12}}{\lambda_{ij}} \cdot \frac{1}{1+\lambda_{12}(\frac{1}{\lambda_{23}}+\frac{1}{\lambda_{34}}+\ldots+\frac{1}{\lambda_{ij}})}. \quad (9)$$

The average time of stay of the control process in the state of S_i is equal to $\bar{t}_i = \frac{1}{\lambda_{ij}}$, that is:

$\bar{t}_1 = \frac{1}{\lambda_{12}}$, $\bar{t}_2 = \frac{1}{\lambda_{23}}$, $\bar{t}_3 = \frac{1}{\lambda_{34}}$, $\bar{t}_4 = \frac{1}{\lambda_{45}}$, $\bar{t}_5 = \frac{1}{\lambda_{56}}$, $\bar{t}_6 = \frac{1}{\lambda_{67}}$, $\bar{t}_7 = \frac{1}{\lambda_{71}}$.

Considering the above, we substitute these expressions in 8 and after simple transformations we obtain:

$$\left.\begin{aligned} p_1 &= \frac{\bar{t}_1}{\bar{t}_1+\bar{t}_2+\bar{t}_3+\bar{t}_4+\bar{t}_5+\bar{t}_6+\bar{t}_7}, \\ p_1 &= \frac{\bar{t}_2}{\bar{t}_1+\bar{t}_2+\bar{t}_3+\bar{t}_4+\bar{t}_5+\bar{t}_6+\bar{t}_7}, \\ p_3 &= \frac{\bar{t}_3}{\bar{t}_1+\bar{t}_2+\bar{t}_3+\bar{t}_4+\bar{t}_5+\bar{t}_6+\bar{t}_7}, \\ p_4 &= \frac{\bar{t}_4}{\bar{t}_1+\bar{t}_2+\bar{t}_3+\bar{t}_4+\bar{t}_5+\bar{t}_6+\bar{t}_7}, \\ p_5 &= \frac{\bar{t}_5}{\bar{t}_1+\bar{t}_2+\bar{t}_3+\bar{t}_4+\bar{t}_5+\bar{t}_6+\bar{t}_7}, \\ p_6 &= \frac{\bar{t}_6}{\bar{t}_1+\bar{t}_2+\bar{t}_3+\bar{t}_4+\bar{t}_5+\bar{t}_6+\bar{t}_7}, \\ p_7 &= \frac{\bar{t}_7}{\bar{t}_1+\bar{t}_2+\bar{t}_3+\bar{t}_4+\bar{t}_5+\bar{t}_6+\bar{t}_7}. \end{aligned}\right\} \quad (10)$$

That is, in general, considering equation 2:

$$p_i = \frac{\bar{t}_i}{\sum_{i=1}^{n} \bar{t}_i} = \frac{\bar{t}_i}{T_{\text{cu}}}, \quad (11)$$

where $n = 7$,

what confirms the validity of the interpretation of the limit probabilities of process states *S* as the average relative residence time of the process in certain states.

$$m_i = \overline{N} p_i, \quad (12)$$

where m_i – the average value (mathematical expectation) of the amount of information with which certain actions occur (receiving, processing, transmitting, generalizing, etc.) in the S_i state of the troop management process; $\overline{N}$ – the average amount of information that circulates in a promising automated control system during the management of troops; $\overline{N} = \sum_{i=1}^{n} m_i$; m_i and $\overline{N}$ are determined by the experience of numerous exercises with the use of troops using elements, means, complexes, and ATM systems during their management; p_i – the probability of the process being located *S* in the state of S_i.

From where:

$$p_i = \frac{m_i}{\overline{N}}. \quad (13)$$

Based on the above and considering equations 2 & 11, we obtain the expression for calculating $\bar{t}_i$:

$$\bar{t}_i = p_i \cdot \sum_{i=1}^{n} \bar{t}_i = \frac{m_i}{\overline{N}} \cdot \sum_{i=1}^{n} \bar{t}_i = \frac{m_i}{\overline{N}} \cdot \text{Т}_{\text{цу}} \quad (14)$$

After the expression 14 is obtained during the design of a promising automated control system, the question arises about the possible range of changes as $\bar{t}_i$ at one stage or another of the army management cycle, and for the entire cycle T_{CU}. From expression 14, it can be seen that this depends on the range within which the oscillation occurs m_i. Therefore, it is necessary, as emphasised by the statements of mathematical statistics, to determine its variance and mean square deviation.

As noted above, the information that circulates in the prospective automated control system during its long-term operation to ensure the management of troops ($t \to \infty$), will have significant volumes with the same exponential random variable distribution law and finite mathematical expectations m_i, the appearance of which in time is independent and has a continuous character. These volumes have approximately the same effect on the total amount $\overline{N}$. Based on this, according to the Central Limit Theorem, we obtain the distribution law $\overline{N}$, which is infinitely close to normal. With this in mind, we can calculate the variance of information volumes m_i in S_i process states S. Let:

$$D_k = (0 - p_i)^2(1 - p_i) + (1 - p_i)^2 p_i = p_i(1 - p_i) \quad (15)$$

where: D_k – variance m_i in the state of S_i process S.

Considering the total amount of information $\overline{N}$, which circulates in the process S, we get:

$$D_i = \sum_{k=1}^{N} D_k = Np_i(1 - p_i) = m_i \cdot \left(1 - \frac{m_i}{N}\right) \quad (16)$$

and their average square deviations, respectively, by the expression:

$$\sigma_i = \sqrt{D_i}. \quad (17)$$

That is:

$$-3\sigma_i \leq m_i \leq +3\sigma_i. \quad (18)$$

In this case, the probability that m_i in each state of the process S does not exceed the specified limits is equal to:

$$P(V_i \in (\alpha, \beta)) = \Phi\left(\frac{\beta - m_i}{\sigma_i}\right) - \Phi\left(\frac{\alpha - m_i}{\sigma_i}\right) \quad (19)$$

Where α, β – limits of the amount of information in the S_i process status S, which are given; F is the Laplace function.

Expressions 16-19 provide a possibility for any state S_i of process S to determine the approximate range of practically possible amounts of information m_i, $\overline{N}$ with which certain actions of the CB in ATMS occur in a promising automated control system and, accordingly, form requirements for the speed of their receipt, processing, transfer of array volumes to databases for their storage, etc.

Thus, to ensure the implementation of 1-2, the efficiency of the CB's work in a promising automated control system must meet the requirement 14-19:

$$T_{\text{cu}} = \overline{N}\frac{\overline{t_i}}{m_i} \leq \text{T}_{\text{dir}}, \quad (20)$$

where $\overline{t_i}$, m_i – parameters i-state of the process S, if the permissible values of quantitative indicators are observed, the definition of which is provided for by expressions 16-19, which determines the content of the developed method.

Discussion

Thus, the article develops a mathematical model of the troop management cycle based on a continuous Markov chain to substantiate the requirements for the efficiency of the CB of a promising automated control system. A special feature of this model, which determines its novelty, is the use of the theory of Markov processes with discrete states and continuous time for mathematical modeling of the CB operation cycle in a control system of any level of subordination of troops. This made it possible, unlike other methods, to establish a relationship between the amount of information that circulates in the troop management cycle during the operation of the CB, and the time that is spent on this at each of its stages.

The dynamics of conducting modern operations (combat operations) are such that the information content of troops should correspond to the situation that has developed on the battlefield, and in some cases, it is proactive, that is, the time factor is crucial for the successful performance of tasks of managing troops [13, 14]. The fundamental feature of this theory, which distinguishes it from the current combat charters and guidelines [3], is the ability to ensure the continuity and flexibility of combat management of military operations, the ability of the system to quickly adapt to the situation that is dynamically changing, and transfer control functions to any level, both in terms of subordination of troops and interaction in accordance with the needs that arise during the conduct of military operations [15].

Practical implementation of these theoretical provisions in the United States and NATO member countries is carried out based on advanced information technologies since the 90s of the last century in accordance with the “concept of conducting military operations in a single information space using unified information and control networks” [16]. The implementation of the concept takes place within the framework of the program “Control systems, communications, analytical support, intelligence and surveillance” [17], which provides for the combination of distributed in-space heterogeneous forces and means of global and local information and control systems (automated control systems) and automation of troop management processes in the following areas: daily activities, bringing to the highest degrees of combat readiness, mobilization, regrouping, combat use, intelligence and other types of support [18-21].

In a modern dynamic high-tech war, the winner is the one who finds the enemy faster, plans and strikes first” [22]. This means that the advantage in efficiency and quality of execution of stages of the military management cycle directly affects the effectiveness of their use. Having such an advantage, a group of troops can ensure victory over the enemy, which is superior in number and firepower. First of all, this should be done by optimizing the decisions made and improving the efficiency and quality of planning operations (battles) of troops based on automating the process of managing them [23]. According to this, one of the priority tasks of the defense reform of Ukraine at the present stage is the creation of an effective system for managing troops (forces) [24, 25]. This task is gradually being implemented by improving the management system of troops (forces).

The direction of further research is the development of a mathematical model to justify the survivability requirements of a promising automated control system, which is a logical continuation of the obtained scientific results. By its construction, such a mathematical model should reflect the adverse impact on a promising automated control system in two main areas that directly determine its achievement of the required level of survivability, namely: enemy fire damage to control points and the functioning of electronic warfare equipment. When achieving this goal, you can use probability theory for modelling the failure of control point elements for the first direction, and graph theory for modeling the vulnerability of radio communication channels for the second direction.

Conclusion

As a result, the obtained scientific results made it possible to justify the time (to put forward a requirement for the efficiency of the CB) that is needed to perform certain CB measures to achieve the goal of the operation, considering its possible range of deviation.

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