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## THE DYNAMIC ANALYSIS OF THE STATE DEFENSE FORCES GROUP LOGISTICS SUPPORT SYSTEM USING OF THE QUEUING MODEL

**Abstract.** The subject matter of the article is the logistics support for the state defense forces. The goal of the study is the finding out a logistics support model that allows to obtain quantitative estimates of the required number of weapons ensured a given level of combat readiness and support the serviceability of troops, as well as optimal management of procurement, repair and modernization of weapons over time. The tasks to be solved are: to present the process of logistics support of the state defense forces group using the queuing model; to compile a state graph of a sample of weapons and military equipment; to compose a equations system describing the average number of weapons and military equipment samples in different states during their operation in the troops; by solving the differential equations system to obtain the dependences of the main logistics support system's parameters in time. General scientific and special methods of scientific knowledge are used. The following results were obtained: The logistics support of the state defense forces group is presented as a queuing model, the parameters of which are determined by statistical data from the troops. Based on the obtained solution of the corresponding of differential equations system, an analysis of the logistics support system of the state defense forces group for a certain period of time can be made. The dynamic analysis of the logistics support system will form the basis of the recommendation for the implementation of promising guidelines of equipping state defense forces weapons and military equipment and optimizing the management of the system according to the certain criteria. **Conclusions.** A model of queuing is proposed to describe the logistics support process for the state defense forces group. In the model, the transitions of the sample of weapons from one state to another are carried out with intensities,  $\mu$  or  $\lambda$  dependis on the influence of the external environment and management. Within the framework of the proposed model, a differential equations system is obtained describes the average numbers of weapons samples in different states during their operation in the army. The obtained differential system solution corresponding the model is a quantitative estimate of the required number of weapons needed to ensure a given level of combat readiness and serviceability of state defense forces troops, as well as optimal management of procurement, repair and modernization of weapons over certain time.

**Keywords:** logistics; queuing model; state graph of armaments and military equipment; quantitative estimates of logistics support system.

### Introduction

#### Formulation of the problem and research tasks.

Today, given Ukraine's path to European and Euro-Atlantic integration, NATO standards and procedures are being intensively implemented in all spheres of activity. The defense reform defining the ways of its implementation based on and principles guided by NATO member states. It was introduced the concept of "logistics" replaced the maintenance, deliveries and materials. The development of logistics forces and the entry of capabilities to ensure the actions of troops (forces) in conducting interspecies, interdepartmental joint operations is one of the priorities for the development of the state defense forces.

Thus, the system of logistical support of SOD at all levels (strategic, operational and tactical) is being developed with the development of regulatory documents, change of organizational and staffing structures and redistribution of powers and functions. In these conditions, such measures of logistics support of actions of troops (forces) in the performance of assigned tasks, such as supply of troops with the necessary nomenclature of weapons and military equipment (WME), maintenance of armaments in certain combat readiness and technical condition, ensuring the implementation of maintenance and repair (maintenance and repair), modernization, write-off and disposal of weapons. Depending on the completeness and quality of

these measures, their level of combat readiness, combat capability and combat potential depends.

Therefore, an important scientific and applied task is to develop information and mathematical models for military-economic analysis and management of technical in particular, and logistics of troops in general.

In this regard, the authors consider it important to search for new methods for both analysis and optimization of the process of drug management, equipping armored weapons and acquisition of armored property of the SFD group [1-3].

**Analysis of recent research and publications** of recent research and publications on the above issues shows that a lot of effort is being put into the creation and development of logistics for both the SFD and the Armed Forces of Ukraine, in particular, including the experience of NATO member countries.

The authors worked out the ideology of logistics management of SFD supply, proposed logistics SFD models of different structure. Studies of the flow nature of the process of WME acceptance, storage, repair, maintenance and write-off (disposal) give an abstract idea of WME during the preparation and conduct of SFD operations. However, the mechanism of obtaining quantitative assessments of the compliance of SFD armored weapons with modern requirements in the interests of forming prospects for the development and equipping of troops (forces) with them has been fully studied [4-7].

The **goal** of the study is the development a model of equipping SFD armored weapons and armored equipment of a group of troops allows to obtain quantitative estimates of the required number of weapons to ensure a given level of combat readiness and combat potential, as well as costs necessary for optimal procurement management, repair and repair. for a certain period of time.

This **goal** defined the following research tasks:

- to present the process of logistics support (LS) of the SFD group using the queuing model;
- make a graph of states of the sample of weapons;
- to make a system of equations that describes the average number of weapons samples are in different states during their operation in the army;
- by solving a system of differential equations to obtain the dependences of the basic parameters of the vehicle system over time.

General scientific and special **methods** of scientific knowledge are used.

**Main material**

**1. A queuing model and graph of states of WME samples of SFD group**

Let's consider a group of SFD troops includes weapons of various kinds, in number, each. A certain number is needed to solve a certain amount of tasks for the purpose. Let's assume each WME sample can be in one of the incompatible states.

For the TS system under consideration, we accept:

$S_0$  - serviceable (operational) a sample is in storage mode (ready for use);

$S_1$  - faulty (inoperable), a sample needs repair of a certain type;

$S_2$  - serviceable (operational), a sample is in combat readiness;

$S_3$  - defective, a sample requires write-off and further disposal;

$S_4$  - serviceable (operational) condition, a sample requires modernization.

Accordingly, in each  $j$ -th state can be found  $n_{ij}$ ,  $j = \overline{0, m}$  samples of  $i$ -th type weapons (armored vehicles automobile equipment). With what

$$\sum_{i=1}^n n_{ij} = N_j, i = \overline{0, n}, j = \overline{0, m}, \quad (1)$$

We assume that a serviceable condition is a condition of a sample of weapons and ammunition characterized by the presence of a stock of technical resources and the finding of all technical parameters within the established limits.

The working condition differs from the working condition in that some parameters of the sample of weapons that do not affect its operation may not meet the established limits.

The most important factor determining the serviceability (serviceability) of a WME sample is the technical resource reserve. In case of a technical resource expenditure, a WME sample is considered defective and its operation should be terminated.

After that, the sample is subject to technical inspection and further, or overhaul (O) to restore the technical resource, or write-off and disposal.

Repair of weapons and military equipment, has a reserve of technical resources, is carried out in military repair units. Major repairs associated with the restoration of technical resources are carried out at industrial enterprises.

WME disposal of weapons and military equipment is usually carried out in special units (bases) or at industrial enterprises.

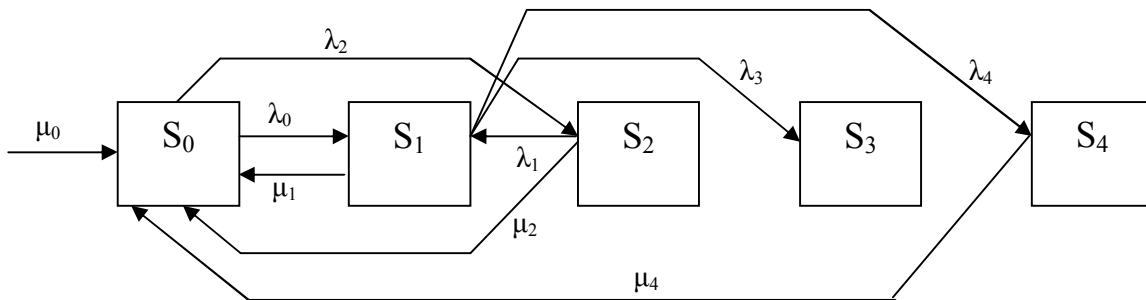
Modifications of WME samples for the purpose of their modernization aimed at increasing their combat capabilities (reliability, operational adaptability, combat effectiveness) are carried out both in the troops and at repair enterprises of the defense industry. At the same time WME samples are excluded from the list of military units.

To re-equip the troops with new equipment, new WME types are being supplied to industry. The transfer of weapons and military equipment from one state to another is carried out under the action of certain management.

A queuing model is proposed to describe the TS process of the SOD group [8].

According to the theory of queuing transitions of the sample of weapons from one state to another are carried out with intensities,  $\mu$  or  $\lambda$ , depends on the influence of the external environment and control influences from the control system.

Fig. 1 shows a graph of possible states of the WME sample.



**Fig. 1.** Graph of possible states of the WME sample

As it is seen from Fig. 1, an WME sample can be in one of five states. We define the corresponding intensities

of the transition from state to state of change as follows:  $\mu_0$  □ the intensity of the arrival of new WME samples;  $\lambda_0$

□ the WME samples failure rate in storage;  $\lambda_1$  □ the WME samples failure rate in a state of combat readiness;  $\mu_1$  □ the WME samples restoration intensity by means of repair;  $\lambda_2$  □ the intensity of WME samples transferring to a combat readiness state;  $\mu_2$  □ the intensity of WME samples transferring to a state of constant readiness;  $\lambda_3$  □ the intensity of WME samples leaving for disposal;  $\lambda_4$  □ the WME samples departure rate for modernization;  $\mu_4$  □ the WME samples receipt of modernized rate. These model parameters can be determined from statistical data from the combat operations.

**2. The logistics support process dynamic analysis of the state defense forces group for a certain time.** According to the state graph (Fig. 1) for a certain  $i$ -th type, the average number of weapons in each  $j$ -th state can be determined by a system of differential equations

$$\frac{dn_0^i(t)}{dt} = -(\lambda_1^i + \lambda_2^i + \lambda_4^i)n_0^i(t) + \mu_1^i n_1^i(t) + \mu_2^i n_2^i(t) + \mu_4^i n_4^i(t) + \mu_0^i(t); \quad n_0^i(0) = N_0^i; \quad (2)$$

$$\frac{dn_1^i(t)}{dt} = -(\mu_1^i + \lambda_3^i)n_1^i(t) + \lambda_1^i n_0^i(t) + \mu_1^i n_2^i(t); \quad n_1^i(0) = N_1^i; \quad (3)$$

$$\frac{dn_2^i(t)}{dt} = -(\mu_1^i + \lambda_3^i)n_2^i(t) + \lambda_1^i n_0^i(t) + \mu_1^i n_2^i(t); \quad n_2^i(0) = N_2^i; \quad (4)$$

$$\frac{dn_3^i(t)}{dt} = \lambda_3^i n_1^i; \quad n_3^i(0) = N_3^i; \quad (5)$$

$$\frac{dn_4^i(t)}{dt} = -\mu_4^i n_4^i(t) + \lambda_4^i n_1^i(t); \quad n_4^i(0) = N_4^i; \quad (6)$$

$$n_0^i(t) + n_1^i(t) + n_2^i(t) + n_3^i(t) + n_4^i(t) = N^i(t); \quad (7)$$

here  $i = \overline{1, n}$ ,  $t \in [0, T]$ ,  $T$  □ certain time.

The solution of the differential equations system (2) □ (7) will be the time dependences of the  $i$ -th type WME samples average numbers in each state  $n_j^i(t)$ ,  $i = \overline{1, n}$ ,  $j = \overline{0, m}$ . Based on this solution, a dynamic analysis of the logistics support system of the SFD group can be made for a certain period of time  $T$  by types (for example, for automotive equipment, armored vehicles, etc.) weapons:

$$N^i(t) = n_0^i(t) + n_1^i(t) + n_2^i(t) + n_3^i(t) + n_4^i(t) = \sum_{j=0}^m n_j^i, \quad (8)$$

here  $N^i(t)$   $i = \overline{1, n}$  □ current number of the  $i$ -th type WME samples in the group SFD;  $T$  - a certain time.

Similarly, the average number of the  $j$ -th state ( $j = \overline{0, m}$ ) WME samples can be calculated.

$$N_j(t) = n_1^j(t) + \dots + n_j^i(t) + \dots + n_m^m(t) = \sum_{i=1}^n n_j^i. \quad (9)$$

For example,  $N_j(t)$  determines the current number of serviceable (able-bodied) WME samples are in combat readiness mode.

The ratios between the different  $N_j(t)$ ,  $j = \overline{0, m}$  will allow to assess the indicators of combat readiness and combat potential of the SFD group. Thus, the coefficient of serviceability of weapons can be calculated by expression

$$K_c = (N_0(t) + N_2(t)) / N(t), \quad (10)$$

where  $N(t)$  □ the total current number of the WME samples in the SFD group.

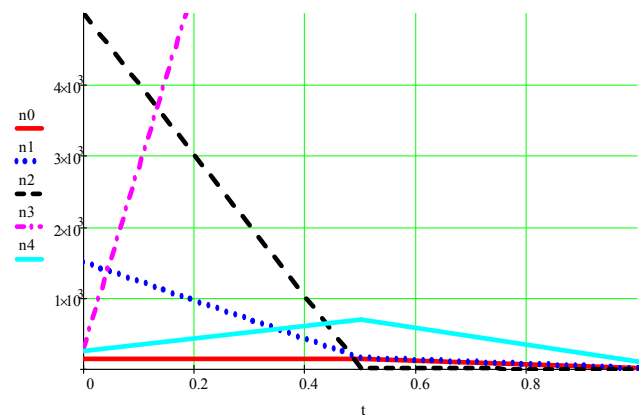
$$N(t) = \sum_{i=1}^n \sum_{j=0}^m n_j^i. \quad (11)$$

By analogy, the coefficient of the SFD group combat readiness can be determined:

$$K_{CR} = \frac{N_2(t)}{N_0(t) + N_2(t)}. \quad (12)$$

**3. Study of the process of maintenance by types of weapons and military equipment to ensure compliance with the requirements of the combat readiness and combat potential of the SFD group.**

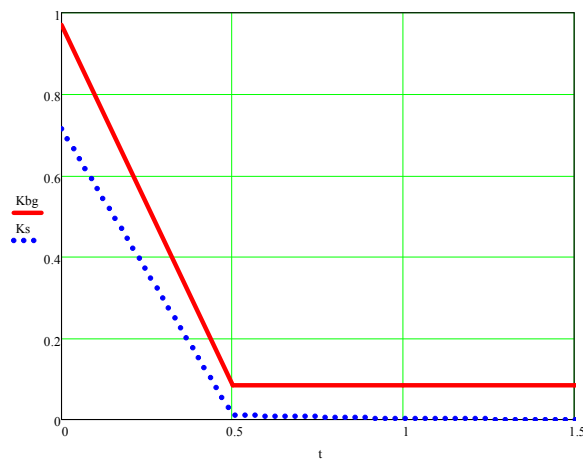
The specifics of performing of assigned tasks for the SFD group purpose allows us to consider it expedient to study the process of maintenance by WME types (for example, armored weapons and military equipment) with a fixed  $i$ . An example of solving the system of differential equations (2) - (7) in the environment of computer algebra Mathcad [9] is shown in Fig. 2.



**Fig. 2.** Dynamics of weapons average numbers of a certain type by state during a certain time

The obtained calculated data of the average number of weapons and military equipment weapons in each  $j$ -th state, allow a dynamic analysis of the vehicle system in the period of 1.5 years. Similarly, data were obtained on the change of the serviceability coefficient  $K_s$  and the combat readiness coefficient  $K_{cr}$  of a certain type of weapons over time (Fig. 3).

The obtained data should be used to ensure compliance with the requirements of combat readiness and combat capability of the SFD group. Based on the analysis of changes in quantitative estimates of the number of weapons in each of the possible states, it is possible to form appropriate management decisions on the LS for the procurement, repair and modernization of AMWE staff samples during a certain period.



**Fig. 3.** Changes in the coefficient of serviceability  $K_s$  and the coefficient of combat readiness  $K_{cr}$  weapons of a certain type over time

Thus, with a constant intensity of the conversion of weapons into combat readiness and the combat readiness factor of the SFD group will decrease.

To maintain a constant level of combat readiness, the intensity of  $\lambda_2$  must vary according to a certain law.

Adjustments of the intensity of  $\lambda_2$  as well as other parameters of the drug system will form the basis of the recommendation on the implementation of promising areas of SFD equipping SOD with AWME and optimizing the management of the drug system by a certain criterion as a whole.

### Conclusions

A model of queuing is proposed to describe the logistics support process for the state defense forces group. In the model, the transitions of the sample of weapons from one state to another are carried out with intensities,  $\mu$  or  $\lambda$  depends on the influence of the external environment and management. Within the framework of the proposed model, a differential equations system is obtained describes the average numbers of weapons samples in different states during their operation in the army. The obtained differential system solution corresponding the model is a quantitative estimate of the required number of weapons needed to ensure a given level of combat readiness and serviceability of state defense forces troops, as well as for optimal management of procurement, repair and modernization of weapons over certain time.

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### Динамічний аналіз системи логістичного забезпечення угруповання сил оборони держави з використанням моделі масового обслуговування

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**Анотація.** Предметом вивчення в статті є логістичне забезпечення сил оборони держави. Метою дослідження є розробка моделі логістичного забезпечення, що дозволяє отримувати кількісні оцінки потрібної чисельності ОБТ для забезпечення заданого рівня боєготовності і підтримки справності військ, а також для здійснення оптимального управління закупівлями, ремонтом і модернізацією ОБТ протягом визначеного періоду часу. **Завдання дослідження:** представити процес логістичного забезпечення угруповання сил оборони держави з використанням моделі масового обслуговування; скласти граф станів зразка ОБТ; скласти систему рівнянь, що описує середні чисельності зразків ОБТ; шляхом вирішення системи диференціальних рівнянь отримати залежності основних параметрів системи логістичного забезпечення у часі. Методологічною основою дослідження стали загальнонаукові та спеціальні методи наукового пізнання. **Отримані такі результати.** Процес логістичного забезпечення угруповання сил оборони держави представлений як модель масового обслуговування, параметри якої визначаються за статистичними даними з військ. На підставі отриманого розв'язання відповідної системи диференціальних рівнянь може бути зроблений аналіз системи логістичного забезпечення угруповання сил оборони держави за визначений період часу. Динамічний аналіз системи логістичного забезпечення складатиме основу рекомендації щодо реалізації перспективних напрямків оснащення сил оборони держави озброєння та військовою технікою. **Висновки.** Для опису процесу логістичного забезпечення угруповання сил оборони держави пропонується модель масового обслуговування. В моделі переходи зразка ОБТ з одного стану в інший здійснюються з інтенсивностями,  $\mu$  або  $\lambda$ , які залежать від впливу зовнішнього середовища і керуючих впливів з боку системи управління. Розв'язання відповідної моделі і системи диференціальних рівнянь являє собою кількісні оцінок потрібної чисельності ОБТ, необхідної для забезпечення заданого рівня боєготовності і справності ОБТ угруповання сил оборони держави, а також для здійснення оптимального управління закупівлями, ремонтом і модернізацією ОБТ протягом визначеного періоду часу.

**Ключові слова:** логістичне забезпечення; модель масового обслуговування; граф станів зразка озброєння та військової техніки; кількісні оцінки системи логістичного забезпечення.

### Динамический анализ системы логистического обеспечения группировки сил обороны государства с использованием модели массового обслуживания

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**Аннотация.** Предметом изучения в статье является логистическое обеспечение сил обороны государства. Целью исследования является разработка модели логистического обеспечения, позволяющей получать количественные оценки нужной численности ВВТ для обеспечения заданного уровня боеспособности и поддержания исправности войск, а также необходимые для осуществления оптимального управления закупками, ремонтом и модернизацией ВВТ в течение определенного периода времени. **Задачи исследования:** представить процесс логистического обеспечения группировки сил обороны государства с использованием модели массового обслуживания; составить граф состояний образца ВВТ; составить систему уравнений, описывающую средние численности образцов ВВТ; путем решения системы дифференциальных уравнений получить зависимости основных параметров системы логистического обеспечения во времени. Методологической основой исследования стали общенаучные и специальные методы научного познания. **Получены следующие результаты.** Процесс логистического обеспечения группировки сил обороны государства представлен как модель массового обслуживания, параметры которой определяются по статистическим данным из войск. На основании полученного решения соответствующей системы дифференциальных уравнений может быть сделан анализ системы логистического обеспечения группировки сил обороны государства за определенный период времени. Динамический анализ системы логистического обеспечения будет составлять основу рекомендации по реализации перспективных направлений оснащения сил обороны государства вооружения и военной техникой и оптимизации управления системой по определенному критерию. **Выводы.** Для описания процесса логистического обеспечения группировки сил обороны государства предлагается модель массового обслуживания. В модели переходы образца ВВТ из одного состояния в другое осуществляется с интенсивностями,  $\mu$  или  $\lambda$ , которые зависят от влияния внешней среды и управляющих воздействий со стороны системы управления. Решение соответствующей модели и системы дифференциальных уравнений представляет собой количественные оценки нужной численности ВВТ, необходимой для обеспечения заданного уровня боеспособности и исправности ВВТ группировки сил обороны государства, а также для осуществления оптимального управления закупками, ремонтом и модернизацией ВВТ в течение определенного периода времени.

**Ключевые слова:** логистическое обеспечение; модель массового обслуживания; граф состояний образца вооружения и военной техники; количественные оценки системы логистического обеспечения.