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Method for Assessing the Guaranteed Fuel Reserves in Fuel Supply System of Ground Forces Group

Gorodnov Viacheslav Petrovich
National Academy of National Guard of Ukraine, Ukraine

Abstract: *The article presents analytical calculation expressions that are the implementation of method for assessing the reserves level in bodies and in the fuel supply system of the ground forces grouping, and which allow assessing the probability of performing tasks by each body and by entire system, as well as calculating the amount of fuel reserves in the bodies and in the system for performing tasks of supplying fuel to the grouping subunits with a given probability. For practical application of method, a table of probability values of completing tasks on supplying fuel to the group's subunits is provided, based on the existing fuel volume in supply body (or in a system).*

Keywords: *Fuel, Consumption, Random expense, Probability.*

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I. INTRODUCTION

To carry out combat missions, each subunit and military unit of the ground forces group has necessary weapons and military equipment (WME). In good condition, weapons and military equipment can be used for their intended purpose only if there is the required amount of fuel. Without fuel, every subunit becomes incapable of combat. Therefore, the performance of combat missions by subunits and units of the ground forces group largely depends on the timely replenishment of fuel supplies.

The process of carrying out combat missions by subunits and units of ground forces grouping is accompanied by expenditure of material resources, which necessitates the organization of their timely delivery and transfer to subunits operating at different distances from the material support bodies and in different combat conditions.

At present, the experience of military operations demonstrates a noticeable change in the tactics of combat operations of subunits and units of the ground forces, which is due to the use of more advanced means of reconnaissance and fire damage. As a result, during the course of military operations, rapid and abrupt changes in the situation became possible, and the intensity of unpredictable, maneuverable actions by the parties increased [1, pp. 41, 43].

In these conditions, due to the more intensive use of weapons and military equipment in various combat situations, unforeseen fuel consumption occurs with the possibility of an unpredictable decrease in fuel reserves below acceptable levels and a loss of combat capability of subunits. As a result, the moments of exhaustion of fuel reserves in subunits and the formation of requirements for fuel supply may not be known in advance (are random).

Accounting, planning and forecasting of fuel consumption in battles and operations, organization of the reception, storage and distribution of fuel and lubricants (F&L) to subunits and military units is one of functions of fuel management bodies created in the structure of logistics bodies. In this case, the required F&L volumes are calculated in accordance with known consumption rates for each type of weapon and military equipment in each subunit, taking into account the type of combat operations and other conditions [1].

The implementation of fuel supply functions in the system of providing troops with fuel for the ground group is carried out by the material support (MS) subunits in various levels of fuel supply system (FSS) control, which we will further define as MS bodies. Each such body has the forces, technical means of delivery and the corresponding fuel reserves necessary to perform its tasks. Each MS body forms requests for replenishment of fuel reserves and transmits them to the higher MS body as its own reserves are exhausted. The execution of these requests for replenishment of fuel reserves forms the input flow of fuel volumes into the MS body. The output flow of fuel volumes in each MS body (and in the FS system) is formed by demands for fuel supply, which may have a volume that is not known in advance and may occur at previously unpredictable moments in time. The possibility of taking into account random components of fuel consumption and supply in existing FSS bodies is absent due to the lack of an appropriate mathematical apparatus that would allow establishing and using in practice the method of assessing the degree of sufficiency of the current volume of fuel in the MS bodies and in the fuel supply system of the ground forces grouping, which makes the topic of this study relevant.

The theoretical part of assessment the adequacy of fuel reserves in the MS bodies can be based on solving the problems of forecasting fuel consumption by special vehicles of subunits and units.

A large number of publications are devoted to the development of appropriate models for predicting fuel consumption by vehicles.

Thus, in [2] a detailed comparative review of existing types of models for predicting vehicles fuel consumption is presented, based on a physical model of the vehicle (the first group of models) and based on data (the second group of models). The models of the first group use data on the physical characteristics of the vehicle, driver behavior and driving conditions. The second group of models includes statistical models of machine learning using support vector machines, decision tree methods and others. Models in the form of an artificial neural network are singled out separately, which provide greater forecast accuracy, but do not have memory functions in the forecasting process.

Each of noted models has a statistical link to a specific type of vehicle and to specific conditions of its operation, which does not correspond to the conditions of weapons and military equipment of ground forces subunits use during combat operations.

Another group of publications [3] contains recommendations for assessing fuel consumption and the necessary calculation formulas based on deterministic fuel consumption standards by WME.

However, in practice, actual fuel consumption differs from the average values used for calculation and is an unpredictable (random) value.

The increase in fuel consumption (and reserves) to take into account the randomness of conditions in WME use by subunits and units, proposed in the noted methods [3], partially compensates the indicated lack in calculations. However, questions remain open about how the increased volume of fuel reserves in MS bodies is related to the probability that the need for fuel will not be greater than its available volume, whether the increase in the volume of fuel reserves is sufficient to guarantee the provision of subunits with fuel in combat, and what the fuel reserve should be to guarantee its sufficiency for the performance of tasks by subunits and units of troops with a given probability.

There are no answers to such questions in the literature. Therefore, the problem of developing a method for assessing the sufficiency degree of current fuel volume in fuel supply system of ground forces grouping becomes relevant, which can make it possible to assess and predict the sufficiency degree of fuel volumes in fuel supply system at different levels of hierarchy, which determines the relevance of this study topic.

The purpose of article is to develop a method for estimating the size of fuel reserves in bodies of fuel supply system to ensure the fulfillment of fuel supplying tasks to subunits, taking into account unforeseen (random) fuel consumption in subunits of ground forces group in battle and in operations.

II. EXPERIMENTAL PROCEDURE

To form a method for assessing the degree of reliability and sufficiency of the current fuel volume in the bodies and in the system of providing fuel to a group of ground forces in battle and in operations, we will take into account the random volumes and times of fuel consumption and supply in the material support (MS) bodies. Let's build a simplified model of control the body (and system) for the providing troops with fuel.

In this consideration, we take into account only two possible states of fuel supply system (FSS), which are essential from the fulfilling, their tasks point of view: $S_{not.c}$ – tasks are not completed and S_{compl} – tasks are completed.

We note that the duration of FSS analyzed period of work in such consideration can be chosen in accordance with current conditions and tasks of troops (day, week, month, period of operation, etc.). For certainty, let's build a model in terms of the FSS daily mode of operation. Let's also assume that the fuel supply system's MS body has a certain existing daily volume (q) of fuel at its disposal.

In this case, the main parameter of the MS body work process is the daily amount of fuel required for supplying the troops. Requests of various volumes for such fuel supply are submitted to the MS body of the military fuel supply system simultaneously from many units. Therefore, according to the central limit theorem of O.Ya. Khinchin [4, pp. 64-68], the total volume of daily fuel supplies in the FSS body will be unpredictable (random) with a distribution close to exponential and will have its average value (q_{avr}). Therefore, it is possible to consider the needed model in the class of Markov processes with discrete states and with a continuous argument (argument is an existing fuel volume (q) in the MS body or in FSS generally).

It should be noted that under the conditions of the FSS body work, the more the average daily volume of fuel (q_{avr}) is needed for supply to the troops, the less chance the FSS body has to fulfill its tasks.

Therefore, the intensity (η) of transition from state $S_{not.c}$ to the state S_{compl} will be inversely proportional to the average daily amount of fuel q_{avr} required by troops:

$$\eta = \frac{1}{q_{avr}}. \qquad (1)$$

In this case, the controlled and main parameter of the MS body work process is the volume of fuel available in it. Therefore, for the probability ($P_{not.c}$) of the state $S_{not.c}$ (tasks are not completed), it is possible to formulate and solve the Kolmogorov differential equation:

$$\frac{dP_{not.c}}{dq} = -\eta \cdot P_{not.c}; \qquad \frac{dP_{not.c}}{P_{not.c}} = -\eta \cdot dq. \tag{2}$$

After integrating the left and right parts of equation (2), we get:

$$\ln|P_{not.c}| = -\eta \cdot q + C. \tag{3}$$

Applying the potentiation operation, we will obtain an intermediate expression for the probability of failure to fulfill its tasks by body (and/or by system) of fuel supply to the troops:

$$P_{not.c} = e^{-\eta \cdot q + C}. \tag{4}$$

To solve the Cauchy problem, we will find the value of arbitrary constant "C" in (4). For this purpose, we'll consider the initial conditions under which, in the case of absence a fuel supply in MS body or in FSS ($q = 0$), the probability of MS body (or of FSS system) performing its tasks will be strictly equal to zero ($P_{compl} = 0$), and the probability of not performing the tasks ($P_{not.c}$) will be equal to one. We will get it step by step:

$$P_{not.c}(q = 0) = e^{-\eta \cdot 0 + C} = e^{0+C} = e^{C} = 1. \tag{5}$$

Where do we find the value of an arbitrary constant:

$$C = 0. \tag{6}$$

Therefore, the expression for the probability ($P_{not.c}$) of non-fulfillment of its tasks by the body (or by the system) of providing troops with fuel will take the form:

$$P_{not.c} = e^{-\eta \cdot q}. \tag{7}$$

Probabilities $P_{not.c}$ and P_{compl} states $S_{not.c}$ and S_{compl} satisfy the condition of probabilities for complete events group. In this case, it is possible to find the probability P_{compl} of the state S_{compl} that corresponds to the event of sufficient volume of fuel in the MS body (and/or in the FSS as a whole) to perform all its tasks. We find step by step:

$$P_{not.c} + P_{compl} = 1, \quad P_{compl} = 1 - P_{not.c} = 1 - e^{-\eta \cdot q},$$
$$P_{compl} = 1 - e^{-\eta \cdot q}. \tag{8}$$

Next, we take into account expression (1) and obtain the calculated expression of the probability indicator for the MS body (and/or for the FSS system) fulfilling its task to provide the troops with fuel depending on the available fuel amountq:

$$P_{compl} = 1 - e^{-\frac{q}{q_{avr}}}. \tag{9}$$

Expression (9) illustrates the method of assessing the degree of fuel volume sufficiency in the fuel supply system (and/or in the MS body) for a group of ground forces. Expression (9) allows us to find the value of daily fuel amount in the fuel supply body or in fuel supply system for the troops to perform their tasks with a specific value of its execution probability (reliability). We find step by step:

$$e^{-\frac{q}{q_{avr}}} = 1 - P_{compl}; \qquad -\frac{q}{q_{avr}} = \ln(1 - P_{compl}) . \tag{10}$$

We'll finally get:

$$q = -q_{avr} \cdot \ln(1 - P_{compl}) . \tag{11}$$

For practical application of obtained method (9), (11), Table 1 provides typical interrelated values for probability P_{compl} of completing tasks by the MS body (and/or by FSS system) depending on the existing fuel daily volume q, measured in units of average daily fuel consumption q_{avr} in the MS body (and/or in FSS system).

In mathematical statistics, the level of practical confidence in the occurrence of a random event is taken to be the value of this event occurrence probability, which is equal to$P_{compl} = 0{,}95$, and which corresponds to three-fold excess of the available fuel volume in the MS body (or in the system of providing fuel to the troops) over the required average value (q_{avr}) of its consumption ($q \geq 3q_{avr}$).

Table 1Dependence of probability $\boldsymbol{P_{compl}}$ on the existing volume of fuel $\boldsymbol{q}$ in the body of FSS

$\boldsymbol{q}$	$\boldsymbol{P_{compl}}$
$0{,}5 \cdot q_{avr}$	0,39
$1 \cdot q_{avr}$	0,63
$2 \cdot q_{avr}$	0,86
$3 \cdot q_{avr}$	**0,95**
$4 \cdot q_{avr}$	0,98
$5 \cdot q_{avr}$	**0,99**

(Author's development)

In the fuel supply system of ground troops or in any of its material supply bodies, for any current value of the available fuel volume (q), the degree of its sufficiency can be estimated by the probability of fulfilling the current tasks of supplying the fuel volume to subunits, by the probability (P_{compl}) according to the expression (9). At the same time, when organizing the work of the FS body in the ground forces fuel supply system, the required amount of fuel reserves (q) at the disposal of these bodies can be calculated according to formula (11) in accordance with the tasks set regarding the required level of reliability (probabilityP_{compl}) of fuel supply of subunits and units of the ground forces group.

III. RESULTS AND DISCUSSIONS

The obtained calculation expressions (9) and (11) are the realization for method of assessing the degree of fuel volume sufficiency in bodies of FSS and allow to find quantitative estimates of answers to practical questions about determining the necessary fuel reserves, from determining the probability of completing tasks by each body of the FSS and by entire system of providing the grouping of ground troops with fuel.

Thus, the purpose of the article, which was to develop a method for assessing the degree of reliability and sufficiency of fuel volume in the bodies and in the fuel supply system of the ground forces group in combat and in the operation, taking into account random volumes and time moments of fuel consumption and supply in the MS bodies, is achieved.

IV. CONCLUSION

Calculation expressions (9) and (11) can be used in the fuel service management bodies to obtain estimates of tasks completing probabilities by fuel supply system of the ground troops grouping, both for a separate material support body of the lowest level and for the entire fuel supply system for the troops grouping as a whole. Based on the evaluations obtained with the help of obtained expressions (9) and (11), in the dynamics of the work of the headquarters of the corresponding level, the head of the fuel service has the opportunity to make management decisions to prevent disruption of the execution of individual tasks by units due to a lack of fuel.

Conflict of interest

There is no conflict to disclose.

REFERENCES

[1]. Kombat statute of mechanized and tank troops of ground forces of armed forces of Ukraine. Part II (Battalion, Company). (in Russian) 2018. K.: Command Land Forces Armed Forces of Ukraine, https://duikt.edu.ua. URL: https://duikt.edu.ua/ru/lib/1/category/736/view/1614 (date of access: 21.08.2024).

[2]. Dengfen Zhao, Haiyang Li, Junjian Hou, Pengliang Gong, Yudong Zhong, Wenbin He and Zhijun Fu. 2023. A Review of Data-Driven Prediction Method of Vehicle Fuel Consumption. Energies. No. 16(14). 5258. URL: https://doi.org/10.3390/en16145258 (date of access: 21.08.2024).

[3]. Kubal, R.V. 2018. Methodology for calculating the consumption of Armed Forces of Ukraine in burning materials for carrying out operations (combat actions) (in Ukrainian). Kyiv: TsUZ PMM ZSU, 8 p.

[4]. Kinchin, A.Ya. 1963. Works on the mathematical theory of mass service (in Russian). / ed. by B. V. Hnedenko. Moscow: Fizmatgiz, 236 p.