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Dynamic model of optimized supply for organizational units of armed forces (at decentralized procurement)

Abstract: Efficient activity of organizational units in armed forces is impossible without comprehensive and continuous logistics. The key role in the arrangement of logistics is played by supply processes: ordering, purchase, delivery, and storage of material and technical resources (goods). The Complexity and multiplicity of implementing the logistics process assume the use of economic-mathematical modeling, as an efficient tool for supporting decisions, which ensures the selection of the most favorable supply options. This paper provides a dynamic model of optimized supply (at decentralized procurement of material and technical resources), which describes the possible options of arranging the logistics of organizational units of the armed forces. The criterion of global optimization is represented by a normalized performance indicator characterizing the level of provision of organizational units with material and technical resources. The proposed economic-mathematical model is an efficient tool for supporting decisions taken by logistics-management divisions of organizational units of armed forces – at multiple options of implementing the logistic processes and limited financial resources, which allows optimizing the level of provision of organizational units with required material and technical resources (for the entire planning period of supply, regarding change of needs, scope of funds allocated for logistics and logistic costs accompanying the supply process).

Keywords: supply, logistic processes, dynamic model, optimization, decentralized procurement, organizational unit of armed forces.

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Introduction

One of the most important factors defining the success of the armed forces is their comprehensive and continuous logistics, which is not just the material basis of their activity, but also a connecting link between the armed forces and state economy. The

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complexity of managing logistics processes for the armed forces is, on the one hand, due to their heterogeneity: wide nomenclature of consumed material and technical resources (MTR), various sources and options of meeting needs at sale markets, and, on the other hand, due to their dynamics: change of needs (based on specific activities of organizational units of the armed forces), scope of financial resources allocated from the budget for their support, and logistics costs for orders, purchase, delivery, and storage of MTR (determined by various market factors).

In the context of developing (regional and local) sale markets, which offer an ever widening range of goods/services, decentralized purchase management (ensuring more flexible response to change in market environment, efficiency and saving of funds in the course of supply – due to smaller distances) is becoming actual for the hierarchical logistics systems of the armed forces (regarding the location of their organizational units across the country). In this case, management divisions of bottom hierarchical levels of the system (authorized for independent purchase of certain MTR – at relevant sale markets, for served organizational units of the armed forces) operate autonomously and, therefore, will have the efficient tools for supporting decisions – to choose the most advantageous supply options regarding the features of the logistics process.

The solution of this logistics problem (characterized by multiple solutions) will involve economic-mathematical modeling ensuring the optimized provision of organizational units of the armed forces in terms of time-changing logistics parameters and limited funding of needs.

1. Literature review

The following studies are concerned with the supply management of companies on the principles of logistics: Dobler, Lee and Burt [1995], Fearon et al. [2010], Sergeyev and Elyashevich [2011].

The theoretical and methodological basis, as well as practical tools of modeling the individual logistics processes (supply of companies), are found in papers by Barkalov et al. [2000], Volodina [2003], Semenenko and Sergeev [2003], Lukinskiy (ed.) [2007], Fertsch, Grzybowska and Stachowiak [2009].

In recent years, an important place in studying logistics (supply) processes is occupied by the modeling of supply chain management (aimed at optimizing material flows between all parties of product distribution – from producers to end users): Tayur, Ganeshan and Magazine [1999], Shapiro [2006], Ivanov [2009], Monczka et al. [2011], Schonberger [2011].

The range of mathematical methods applied in logistics (regarding the streaming nature of supply processes and optimization procedures) is reviewed in papers

by Simchi-Levi, Chen and Bramel [2004], Prosvetov [2008], Brodetskiy [2011], Brodetskiy and Guser [2012].

However, the potential of applying the models of logistic processes (supply of companies) for research/management of logistics in the armed forces is limited, as it does not account for such features of supply, as that:

- organizational units of armed forces are non-profit entities, the results of which are not evaluated by economic parameters,
- determinacy of logistics for organizational units of armed forces , especially in peacetime (rationed consumption of MTR, program-oriented and goal-oriented planning of activities with definition of required MTR, covering the unplanned consumption of resources by reserve stocks),
- in the course of purchasing MTR, logistics departments at organizational units of armed forces interact only with those suppliers, who directly sell the products to end users, i.e., they are not interested in logistics chains of supply created by various parties of product markets for sale of goods,
- dependence on budget funding (provided at certain periods by state bodies, limited, unbalanced, and excluding any pre-payment of goods),
- diverse nomenclature and various priorities of consumed material and technical resources,
- mandatory setting of minimum provision levels for each type of MTR – to ensure the life support of staff and implementation of service and combat activities at a minimum-allowed level,
- variation of need for different MTR – depending on nature of tasks performed by organizational units.

Thus, such models can not be applied for the simulation of logistics processes (supply of armed forces).

Computational models of certain logistics tasks (supply of armed forces) were reviewed in papers by Grigoriev [1999], Moskovchenko [2001], Mihaylov [2002]. Optimization models (management of certain logistics processes for supply of armed forces) provided in papers by Pluzhnikov [1999], Pytlak and Stecz [2006], Chistov [2006], Gallasch et al. [2008], Hester [2009], Lisovski [2012] do not account for the dynamic nature of supply, and the objective function is represented by logistic costs only, which limits the use of models for control of the actual logistics process and does not reflect its main goal – providing the organizational units of armed forces with required MTR (according to their rationed needs).

Given that the supply of organizational units in the armed forces is a permanent task of logistics management, which depends on numerous (time-varying) features of orders, purchase, delivery, and storage of MTR, establishment of efficient logistics-management tools (subject to dynamics and comprehensive review of all inter-related logistics processes) is actual.

The Purpose of present paper is to develop an economic-mathematical model, which ensures the optimized provision of organizational units in armed forces – at decentralized procurement, regarding the dynamics of their needs, allocated funds and logistics costs accompanying the process of supply.

2. Formulation of the model

Despite the fact that, under market conditions, logistics-management divisions at organizational units of armed forces act as market entities, their activity (unlike businesses) is realized under strict limitations for the scope of allocated funds, which is due to limited budget funding and consequent restrictions on the needs of organizational units – set as a range of values for each type of MTR and reflecting the minimum and rationed need for them – to ensure the activities of organizational units at a minimum and maximum possible level respectively.

The dynamics of the supply process will be presented as a time chart reflecting the split of the planned period (operation of logistics systems in the armed forces) into T equal periods of time, where logistics-management divisions gain a certain scope of funds (within each period) and purchase the MTR required for this period (Figure 1).

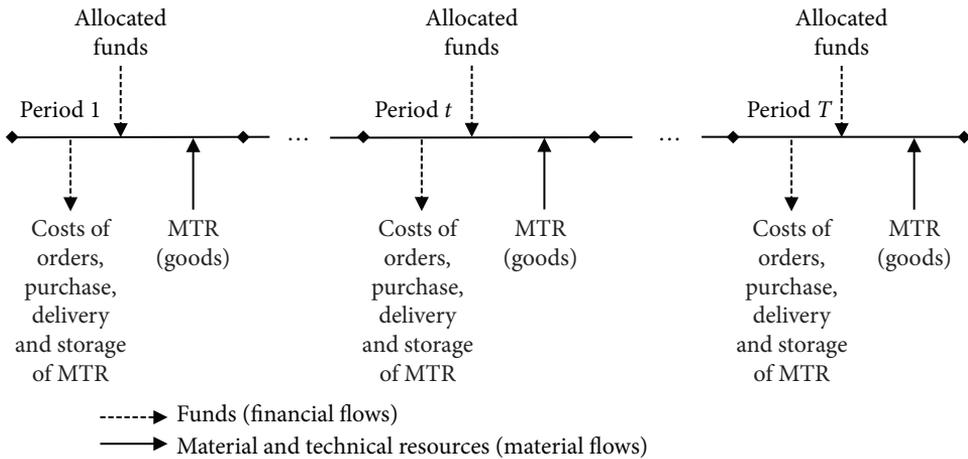


Figure 1. Time chart of planned supply for organizational units in the armed forces

Limited budget funding is manifested in two aspects.

First, the total amount of funds allocated for the whole planning period is less than the required funds for this period (to meet the rationed demand of organizational units at armed forces).

Second, there is an unevenness (variation) in the flow of funds within different periods of time, which (in case of their shortage to meet the minimum needs for MTR) causes the use of stocks reserve, replenishment which takes into account the value of the order formed for the next period.

The logistics of organizational units in the armed forces is characterized by a set of logistics indicators, which include the costs for ordering the required MTR from suppliers and their value (regarding the possible discounts and costs of transportation and storage of MTR at warehouses of organizational units). For this reason, costs of material and technical resources (goods), transportation, and storage are calculated per unit of MTR, and ordering costs – per each order (based on type of MTR).

To simplify the modeling of the supply process (for organizational units of the armed forces), let us introduce the following heuristic assumptions:

- parameters of the logistics process (allocated funds, needs of organizational units, price of MTR, cost of ordering, transporting, storage) are constant within each time period and only vary on transition from one period to another;
- regardless of the amount of MTR (same type), purchased within the same period, only one order is issued and only one shipment from one supplier is performed;
- material and technical resources are purchased at the beginning of each time period – so, storage costs of the purchased lot are calculated for the entire period and are similar for the same type of MTR (regardless of supplier);
- within the entire (planned) period of supply, warehouses of organizational units maintain a set level of stock reserve (for MTR of each type).

Given the diverse nature of consumer goods and multiple vendors supplying them to market, there are three options of arranging the logistics process for organizational units of the armed forces (at decentralized procurement):

- option 1 – one consumer, one type of MTR, one supplier;
- option 2 – one consumer, one type of MTR, many suppliers;
- option 3 – one consumer, many types of MTR, and many suppliers.

The first two options are isolated situations of the third one; so, let us build a dynamic model of optimized supply for organizational unit of the armed forces – the most common case characterized by various types of material resources, which can be purchased from multiple vendors, thus allowing the selection of vendors ensuring the most favorable terms for purchase of goods within each period of time (Figure 2).

Let us define the basic parameters of the model:

- v_{sit} – amount of MTR of type s , $s = 1, \dots, S$, available by supplier i , $i \in I$, during the period t , $t = 1, \dots, T$;
- a_{st}^{\min} – minimum demand of MTR of type s , $s = 1, \dots, S$, during the period t , $t = 1, \dots, T$;
- a_{st}^{rat} – rationed demand of MTR of type s , $s = 1, \dots, S$, during the period t , $t = 1, \dots, T$;

- z_s – level of stock reserve of MTR of type s , $s = 1, \dots, S$, which must always be available at warehouses of organizational unit;
- c_{sit}^{or} – cost of one order for the purchase of MTR of type s , $s = 1, \dots, S$, from the supplier i , $i \in I_s$, during the period t , $t = 1, \dots, T$;
- c_{sit}^{del} – unit transportation cost of MTR of type s , $s = 1, \dots, S$, from the supplier i , $i \in I_s$, during the period t , $t = 1, \dots, T$;
- c_{sit}^{stor} – unit storage cost of MTR of type s , $s = 1, \dots, S$, during the period t , $t = 1, \dots, T$;
- I_s – set of indices of the suppliers offering the MTR of type s , $s = 1, \dots, S$, at the market;
- v_{sit}^{thr} – the threshold value amount of MTR of type s , $s = 1, \dots, S$, in the case of purchase of which from the supplier i , $i \in I_s$, is given a discount on the price unit of production during the period t , $t = 1, \dots, T$;
- c_{sit}^{pwtd} – unit price of MTR of type s , $s = 1, \dots, S$, purchased from the supplier i , $i \in I_s$, during the period t , $t = 1, \dots, T$, without discount;
- c_{sit}^{pwd} – unit price of MTR of type s , $s = 1, \dots, S$, purchased from the supplier i , $i \in I_s$, during the period t , $t = 1, \dots, T$, with discount;
- C_{sit}^{alloc} – funds allocated for purchase of material and technical resources during the period t , $t = 1, \dots, T$.

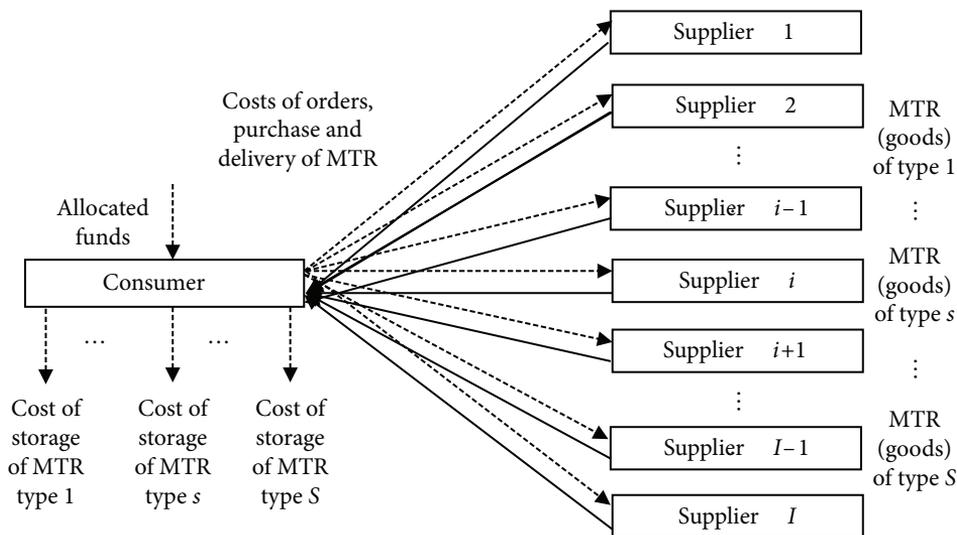


Figure 2. Scheme of supply process at decentralized procurement (option 3)

Within a certain period of time, each type of MTR makes its contribution to the activities of the organizational unit (determined by weighting factors):

$$w_{st} \geq 0; s = 1, \dots, S; t = 1, \dots, T \quad (1)$$

$$\sum_{s=1}^S w_{st} = 1; t = 1, \dots, T \quad (2)$$

where w_{st} – the weight of MTR of type $s, s = 1, \dots, S$, during the period $t, t = 1, \dots, T$.
Variables of the model are as follows:

- x_{sit} – required amount of MTR of type $s, s = 1, \dots, S$, purchased by the consumer from the supplier $i, i \in I_s$, during the period $t, t = 1, \dots, T$;
- C_t^{av} – funds available at the consumer after period $t, t = 1, \dots, T$. For the sake of completeness, we assume that $C_t^{\text{av}} = 0$;
- θ_{sit} – binary variable equal to 0 or 1 depending on the presence of the order for MTR of type $s, s = 1, \dots, S$, purchased by the consumer from the supplier $i, i \in I_s$, during the period $t, t = 1, \dots, T$.

As is known, during the purchase of goods, vendors provide discounts, the value of which depends on a lot of goods. So, a unit price is a function of a number of purchased goods and can be represented via a system of equations or as a continuous dependence. Let us set the unit price as the following system of ratios:

$$c_{sit}^{\text{pr}} = \begin{cases} c_{sit}^{\text{pwd}}, & x_{sit} < v_{sit}^{\text{thr}}; \\ c_{sit}^{\text{pwd}}, & x_{sit} \geq v_{sit}^{\text{thr}}; \end{cases} \quad s = 1, \dots, S; i \in I_s; t = 1, \dots, T \quad (3)$$

where c_{sit}^{pr} – unit price of MTR of type $s, s = 1, \dots, S$, purchased from the supplier $i, i \in I_s$, during the period $t, t = 1, \dots, T$, at that

$$c_{sit}^{\text{pwd}} = c_{sit}^{\text{pwd}} \left(1 - \frac{\delta_{sit}^{\text{pwd}}}{100} \right); \quad s = 1, \dots, S; i \in I_s; t = 1, \dots, T \quad (4)$$

where $\delta_{sit}^{\text{pwd}}$ – percent discount per unit price in the case of bulk purchase.

The efficiency of supply management is represented by an indicator characterizing the provision of organizational units by MTR (with the best reflection of achieved ability to implement the set service and combat tasks):

$$u_{st} = \frac{\sum_{i \in I_s} x_{sit} - a_{st}^{\text{min}}}{a_{st}^{\text{u}} - a_{st}^{\text{min}}}; \quad s = 1, \dots, S; t = 1, \dots, T. \quad (5)$$

In this task, values $\sum_{i \in I_s} x_{sit} - a_{st}^{\text{min}}$ can be considered as “criteria-forming” – i.e., this is the objective function that is aimed at increasing the difference between the supply of MTR (each type) and a minimum need for them, which corresponds to an increased level of providing the organizational unit of armed forces with material and technical resources. Given that the minimum demand of organizational unit ensures its activities under fixed norms of logistics and the ability to perform the

service and combat tasks in accordance with an assignment (at minimum acceptable level), the scope of delivery value $\sum_{i \in I_s} x_{sit}$ can't be less than the minimal needs value a_{st}^{\min} in fact.

As the various types of MTR with different dimensions may have a significant difference in ranges of supply values $\sum_{i \in I_s} x_{sit}$, simultaneous maximizing of their difference $\sum_{i \in I_s} x_{sit} - a_{st}^{\min}$ shall be normalized; because of that

$$0 \leq u_{st} \leq 1; s = 1, \dots, S; t = 1, \dots, T. \quad (6)$$

Thus, the formula for objective function

$$\frac{1}{T} \sum_{t=1}^T \sum_{s=1}^S w_{st} \frac{\sum_{i \in I_s} x_{sit} - a_{st}^{\min}}{a_{st}^{\text{rat}} - a_{st}^{\min}} \quad (7)$$

to optimize the supply for organizational units can be considered as an expression of a scalar convolution for maximized (private) efficiency indicators $u_{st}; s = 1, \dots, S; t = 1, \dots, T$, while corresponding to a weighted average of provision levels (from minimum need for each type of MTR).

The mathematical model of supply optimization (in case of many types of MTR and multiple suppliers) is the following.

$$\frac{1}{T} \sum_{t=1}^T \sum_{s=1}^S w_{st} \frac{\sum_{i \in I_s} x_{sit} - a_{st}^{\min}}{a_{st}^{\text{rat}} - a_{st}^{\min}} \rightarrow \max \quad (8)$$

$$C_{t+1}^{\text{av}} = C_{t+1}^{\text{alloc}} + C_t^{\text{av}} - \sum_{s=1}^S \sum_{i \in I_s} \left(c_{sit}^{\text{or}} \theta_{sit} + (c_{sit}^{\text{pr}} + c_{sit}^{\text{del}}) x_{sit} + \frac{c_{st}^{\text{stor}} x_{sit}}{2} \right) - \sum_{s=1}^S c_{st}^{\text{stor}} z_s \geq 0; \quad t = \overline{0, T-1} \quad (9)$$

$$C_0^{\text{av}} = 0 \quad (10)$$

$$\theta_{sit} = \begin{cases} 1, & x_{sit} > 0; \\ 0, & x_{sit} = 0; \end{cases} \quad s = 1, \dots, S; i \in I_s; t = 1, \dots, T \quad (11)$$

$$a_{st}^{\min} + z_s \leq \sum_{i \in I_s} x_{sit} \geq \min \left(a_{st}^{\text{rat}}; \sum_{i \in I_s} v_{sit} \right); t = 1, \dots, T \quad (12)$$

$$x_{sit} = [x_{sit}] \geq 0; s = 1, \dots, S; i \in I_s; t = 1, \dots, T. \quad (13)$$

For the first two options of arranging the logistics process (at decentralized purchase), optimized supply models are similar to the reviewed model and differ from it by the number of dimensions (option 1 considers the time period only, option 2 – time period and variety of vendors).

At decentralized purchase, presented problem of optimizing the supply for organizational units of the armed forces is a hard Mixed Integer Nonlinear Programming problem. The integer part of the problem follows from the fact that some of the constraints are defined by logical terms “or – or”.

3. Example of application of the model

Let us imagine the implementation of the developed model with the example of a logistic system consisting of a single consumer – organizational unit of armed forces and five suppliers (A, B, C, D, and E), while suppliers A and B supply the MTR of type X, suppliers C and D – MTR type Y, and supplier E – MTR of type Z. Cost indicators are shown in conventional monetary units (CMU). Initial data for modeling the logistics process of organizational units are presented in Table 1.

Modeling was implemented via Microsoft Excel 2010 Solver tool.

As a result, the optimal level of the provision of organizational unit of armed forces is equal to 0.2988, and the value of total logistic costs equal 9,449,853.3 CMU, and distributions in time purchase volumes of MTR, total logistic costs, funds remaining at consumers after each period time, and a variable showing the presence of orders at suppliers were obtained.

The procurement optimal values of each MTR type (x_{sit}) are presented in Table 2. Their distribution is depicted on the background of dynamics changes of minimal and regulatory organizational formations’ needs levels for these MTR types (Figure 3).

The distribution of total logistic costs is shown at the background of the distribution of funds planned for logistics of organizational units in armed forces (Figure 4), which allows us to see their remainders arising at the end of each time period (Figure 5), and to make certain adjustments in budgeting process. The optimal values of funds remaining in the customer after each period (C_t^{av}) are presented in Table 3.

Distribution of variables reflecting the presence of the orders at certain supplier (θ_{sit}) is only shown for types of resources purchased at multiple suppliers (Figure 6).

In the general case the obtained solution is a local optimum, because the problem is not a problem of convex programming under all imposed assumptions.

Table 1. Initial data for modeling the logistics process (example)

| Parameters | Units | Planned period of time (1 year) | | | | | | | | | | | |
|--------------|------------|---------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| t | month | 690,0 | 700,0 | 700,0 | 740,0 | 770,0 | 810,0 | 840,0 | 850,0 | 850,0 | 840,0 | 840,0 | 820,0 |
| C^{allobc} | Th. CMU | | | | | | | | | | | | |
| v_{X-A} | pcs | 800 | 800 | 800 | 900 | 900 | 900 | 900 | 1000 | 1000 | 1000 | 1000 | 1000 |
| v_{X-B} | pcs | 1500 | 1500 | 1500 | 1500 | 1500 | 1500 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 |
| v_{Y-C} | pcs | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 |
| v_{Y-D} | pcs | 3500 | 3500 | 3500 | 3500 | 3500 | 3500 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| v_{Z-E} | pcs | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5300 | 5300 | 5300 | 5300 | 5300 | 5300 |
| a_X^{min} | pcs | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1300 | 1300 | 1000 | 1000 | 1000 |
| a_X^{rat} | pcs | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2400 | 2400 | 2000 | 2000 | 2000 |
| a_Y^{min} | pcs | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4200 | 4200 | 4200 | 4000 | 4000 | 4000 |
| a_Y^{rat} | pcs | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5500 | 5500 | 5500 | 5000 | 5000 | 5000 |
| a_Z^{min} | pcs | 3000 | 3000 | 3000 | 3000 | 3000 | 3200 | 3200 | 3200 | 3200 | 3000 | 3000 | 3000 |
| a_Z^{rat} | pcs | 4500 | 4500 | 4500 | 4500 | 4500 | 5200 | 5200 | 5200 | 5200 | 4500 | 4500 | 4500 |
| z_X | pcs | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| z_Y | pcs | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| z_Z | pcs | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 |
| w_X | | 0,5 | 0,5 | 0,5 | 0,4 | 0,5 | 0,5 | 0,6 | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 |
| w_Y | | 0,2 | 0,2 | 0,2 | 0,3 | 0,2 | 0,1 | 0,1 | 0,2 | 0,2 | 0,2 | 0,3 | 0,2 |
| w_Z | | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 0,4 | 0,3 | 0,3 | 0,3 | 0,3 | 0,2 | 0,3 |
| c_A^{or} | CMU | 350 | 350 | 350 | 350 | 380 | 380 | 380 | 380 | 380 | 380 | 380 | 380 |
| c_B^{or} | CMU | 340 | 340 | 340 | 340 | 340 | 340 | 360 | 360 | 360 | 360 | 360 | 360 |
| c_C^{or} | CMU | 400 | 400 | 400 | 400 | 400 | 400 | 450 | 450 | 450 | 450 | 450 | 450 |

| | | | | | | | | | | | | | | | | | | | | |
|----------------------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| c_D^{or} | CMU | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 350 | 350 | 350 |
| c_E^{or} | CMU | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 280 | 280 | 280 |
| c_{X-A}^{pwd} | CMU | 120 | 120 | 120 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 145 | 145 | 145 |
| c_{X-B}^{pwd} | CMU | 110 | 115 | 120 | 125 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 140 | 145 | 150 |
| c_{Y-C}^{pwd} | CMU | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 70 | 70 | 70 |
| c_{Y-D}^{pwd} | CMU | 65 | 65 | 65 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 65 | 65 | 65 |
| c_{X-E}^{pwd} | CMU | 40 | 45 | 50 | 55 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 55 | 55 | 55 |
| c_{X-A}^{del} | CMU | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 24 | 24 | 24 |
| c_{X-B}^{del} | CMU | 20 | 20 | 20 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| c_{Y-C}^{del} | CMU | 10 | 12 | 14 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| c_{Y-D}^{del} | CMU | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 15 | 15 | 15 |
| c_{X-E}^{del} | CMU | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| c_X^{stor} | CMU | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 8 | 8 | 8 |
| c_Y^{stor} | CMU | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 |
| c_Z^{stor} | CMU | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| v_{X-A}^{thr} | pcs | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 |
| v_{X-B}^{thr} | pcs | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| v_{Y-C}^{thr} | pcs | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 |
| v_{Y-D}^{thr} | pcs | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 |
| v_{Z-E}^{thr} | pcs | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| δ_{X-A}^{pwd} | % | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| δ_{X-B}^{pwd} | % | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| δ_{Y-C}^{pwd} | % | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| δ_{Y-D}^{pwd} | % | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| δ_{Z-E}^{pwd} | % | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |

Table 2. The optimal values of purchases MTR

| Variables | Units | Planned period of time (1 year) | | | | | | | | | | | | |
|-----------|-------|---------------------------------|-------|------|------|------|------|------|------|------|------|------|------|------|
| | | t | month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| x_x | pcs | | 1645 | 1208 | 1100 | 1100 | 1100 | 1100 | 2000 | 1400 | 1400 | 1628 | 1251 | 1469 |
| x_y | pcs | | 4300 | 4300 | 4300 | 5000 | 4300 | 4300 | 4500 | 4500 | 4500 | 4300 | 5000 | 4300 |
| x_z | pcs | | 3201 | 3200 | 3200 | 3200 | 3200 | 3400 | 3400 | 3400 | 3597 | 3200 | 3200 | 3200 |

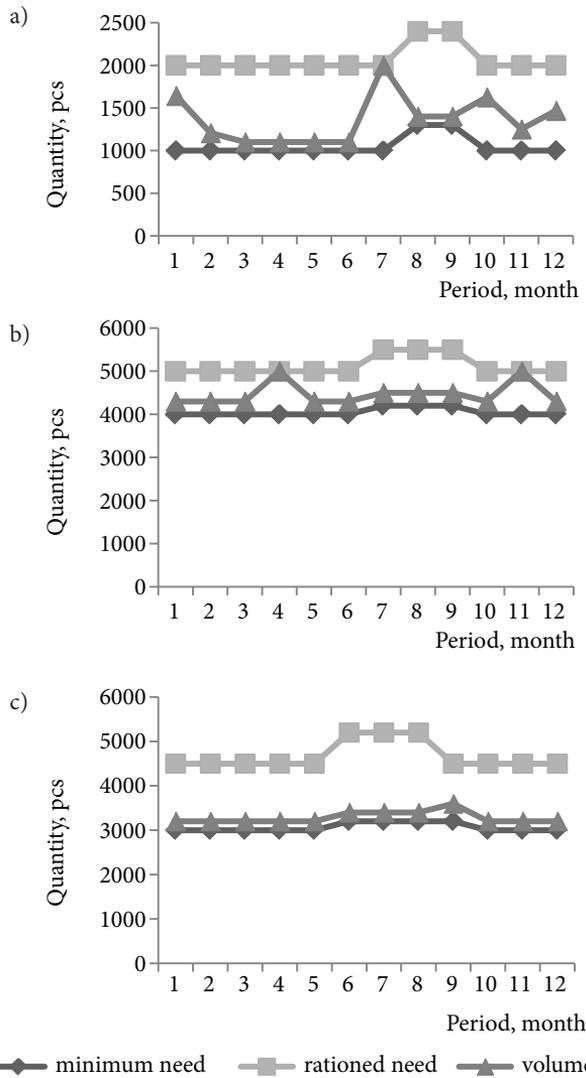


Figure 3. Distributions purchase volumes of MTR (a – X, b – Y, c – Z)

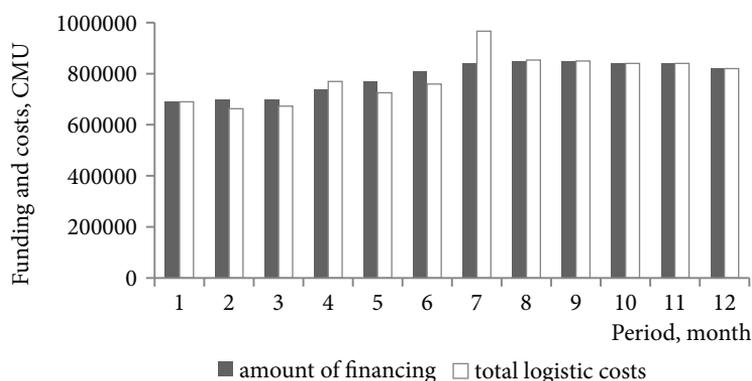


Figure 4. Distribution of total logistic costs and funds

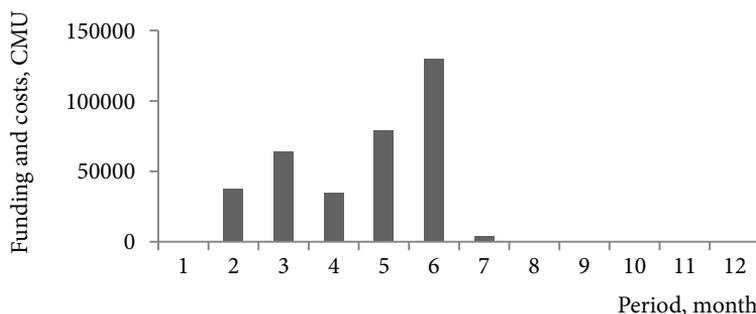


Figure 5. Distribution of funds remaining in the customer after each period

Table 3. The optimal values of funds remaining in the customer after each period

| Variables | Units | Planned period of time (1 year) | | | | | | | | | | | |
|------------|-------|---------------------------------|---------|---------|---------|---------|----------|--------|-------|-------|-------|-------|-------|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| t | month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| C_t^{av} | CMU | 30,5 | 37208,1 | 64028,1 | 34563,1 | 79013,1 | 129863,1 | 3673,1 | 113,1 | 157,1 | 251,7 | 128,5 | 146,7 |

The proposed model shows a good response to changes of any model parameter through time which allows identification of cause-and-effect relationships between main components of supply process and to select the most beneficial options in arranging of logistics process at any time period.

Model adequacy and accuracy are confirmed by objective function values (7) that differ less than 0.001 using with various initial plans.

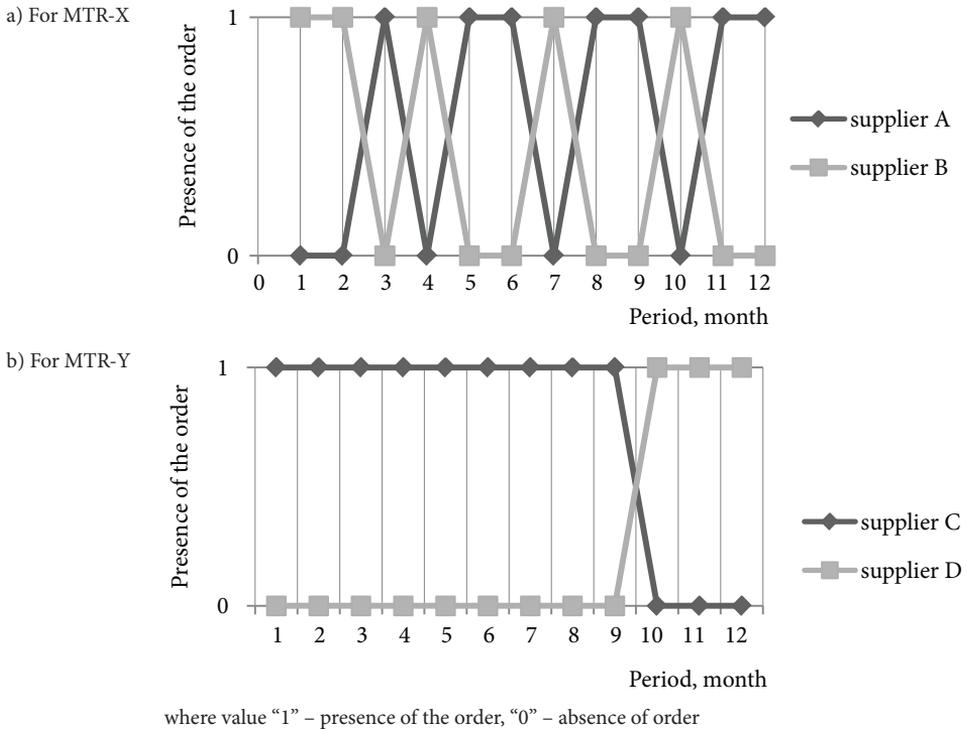


Figure 6. Distribution of variable reflecting the presence of the orders for MTR (a – X, b – Y) at multiple suppliers

Conclusions

In terms of the limited funding and dynamics of logistics process, efficient supply management of organizational units in the armed forces is achieved by solving a global optimization problem, which covers the full range of logistics processes (implemented throughout the planned supply period and within mutual relations). The modeling of the logistics process in time allows the use of predictive estimates, which characterize the trends of change in parameters (used in models to describe the process components under study). In the course of simulation, it is possible to consider the different scenarios of potential variation in certain parameters (at certain periods), which reflect both the activities (demands) of organizational units and changes in market conditions.

The model enables more detailed description of logistics processes, which ensures the consideration of multiple parameters affecting the formation of logistics costs (e.g., delivery and storage). Through modeling, they choose the most efficient (in terms of the lowest logistics costs) options of supply – within each individual

time period, subject to decisions made during the previous period, and aimed at achieving the maximum provision of organizational units in the armed forces (over the entire planned period). In addition, the obtained values of total logistic costs for each time period may be indicative data for the budgeting of logistic process of the organizational units of armed forces on considered planned period of time.

The developed dynamic model reflects the features of arranging the logistics for organizational units in the armed forces (at decentralized procurement in terms of market economy), and considers the nature, the set of parameters and the logical sequence of the components of its logistic processes.

The model is an efficient tool for supporting the decisions taken by logistics-management divisions of organizational units in the armed forces – at multiple options of implementing the logistic processes and limited financial resources, which allows optimizing the level of provision of organizational units with the required MTR (for the entire planning period of supply, regarding change of needs, scope of funds allocated for logistics and logistic costs accompanying the supply process).

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