DYNAMIC MODEL OF OPTIMIZED SUPPLY FOR ORGANIZATIONAL UNITS OF ARMED FORCES (AT DECENTRALIZED PROCUREMENT)

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Abstract: Efficient activity of organizational units at armed forces is impossible without comprehensive and continuous logistics. Key role in arrangement of logistics is played by supply processes: ordering, purchase, delivery, and storage of material and technical resources (goods). Complexity and multiplicity of implementing the logistics process assume the use of economic-mathematical modeling, as efficient tool for supporting the decisions, which ensures the selection of the most favorable supply options. The paper provides 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. Criterion of global optimization is represented by normalized performance indicator characterizing the level of provision of organizational units with material and technical resources. Proposed economic-mathematical model is efficient tool for supporting the 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 to optimize the level of provision of organizational units with required MTR (for the entire planning period of supply, regarding the change of need, 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.
JEL Classification: C61, H56, H57

ДИНАМІЧНА МОДЕЛЬ ОПТИМІЗАЦІЇ ПОСТАЧАННЯ ОРГАНІЗАЦІЙНИХ ФОРМУВАНЬ ЗБРОЙНИХ СИЛ ПРИ ДЕЦЕНТРАЛІЗОВАНИХ ЗАКУПІВЛЯХ

Сисоєв В.В.

Анотація: Ефективна діяльність організаційних формувань збройних сил не можлива без їх всебічного і безперервного матеріально-технічного забезпечення. Ключову роль в організації процесу матеріально-технічного забезпечення грають логістичні процеси постачання: замовлення, закупівля, транспортування і зберігання матеріально-технічних ресурсів (товарів). Складність і багатоваріантність реалізації процесу матеріально-технічного забезпечення обумовлюють використання методу економіко-математичного моделювання як ефективного інструменту обґрунтування рішень, що дозволяє вибрати найбільш вигідні варіанти постачання. У статті представлена динамічна модель оптимізації постачання при децентралізованих закупівлях матеріально-технічних ресурсів, яка описує можливі варіанти організації матеріально-технічного забезпечення організаційних формувань збройних сил. Як критерій оптимізації запропонований нормалізований показник ефективності, що характеризує рівень забезпеченості матеріально-технічними ресурсами організаційного формування збройних сил. Запропонована економіко-математична модель дозволяють оптимізувати забезпеченість організаційного формування необхідними матеріально-технічними ресурсами за весь плановий період постачання в цілому з урахуванням зміни потреб, обсягів фінансових коштів, що виділяються на матеріально-технічне забезпечення, і логістичних витрат, що супроводжують даний процес, а також є ефективним інструментом обґрунтування рішень, що приймаються органами управління матеріально-технічним забезпеченням організаційних формувань збройних сил в умовах багатоваріантності реалізації логістичних процесів та обмеженості фінансових ресурсів.

Ключові слова: постачання, логістичні процеси, динамічна модель, оптимізація, децентралізовані закупівлі, організаційне формування збройних сил.

ДИНАМИЧЕСКАЯ МОДЕЛЬ ОПТИМИЗАЦИИ СНАБЖЕНИЯ ОРГАНИЗАЦИОННЫХ ФОРМИРОВАНИЙ ВООРУЖЕННЫХ СИЛ ПРИ ДЕЦЕНТРАЛИЗОВАННЫХ ЗАКУПКАХ

Сысоев В.В.

Аннотация: Эффективная деятельность организационных формирований вооруженных сил не возможна без их всестороннего и непрерывного материально-технического обеспечения. Ключевую роль в организации процесса материально-технического обеспечения играют логистические процессы снабжения: заказ, закупка, транспортировка и хранение материально-технических ресурсов (товаров). Сложность и многовариантность реализации процесса материально-технического обеспечения обуславливают использование метода экономико-математического моделирования как эффективного инструмента обоснования решений, позволяющего выбрать наиболее выгодные варианты снабжения. В статье представлена динамическая модель оптимизации снабжения при децентрализованных закупках материально-технических ресурсов, которая описывает возможные варианты организации материально-технического обеспечения организационных формирований вооруженных сил. В качестве критерия оптимизации предложен нормализованный показатель эффективности, характеризующий уровень обеспеченности материально-техническими ресурсами организационного формирования силовой структуры. Предложенная экономико-математическая модель позволяют оптимизировать обеспеченность организационного формирования необходимыми материально-техническими ресурсами за весь плановый период снабжения в целом с учетом изменения потребностей, объемов финансовых средств, выделяемых на материально-техническое обеспечение, и логистических затрат, сопровождающих данный процесс, а также является эффективным инструментом обоснования решений, принимаемых органами управления материально-техническим обеспечением организационных формирований силовых структур в условиях многовариантности реализации логистических процессов и ограниченности финансовых ресурсов.

Ключевые слова: снабжение, логистические процессы, динамическая модель, оптимизация, децентрализованные закупки, организационное формирование вооруженных сил.

Introduction

One of the most important factors defining the success of armed forces is their comprehensive and continuous logistics, which is not just a material basis of their activity, but also a connecting link between the armed forces and state economy. Complexity of managing the logistics processes for armed forces is, on one hand, due to their heterogeneity: wide nomenclature of consumed material and technical resources (MTR), various sources and options of meeting the needs at sale markets, and, on the other hand, due to their dynamics: change of needs (based on specific activities of organizational units of 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 the 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 less distance) is becoming actual for hierarchical logistics systems of 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 armed forces) operate autonomously and, therefore, shall have the efficient tools for supporting decisions – to choose the most advantageous supply options regarding the features of logistics process.

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

1. Literature review

The following studies are dedicated to supply management of companies on the principles of logistics: Dobler D. et al. (1995), Johnson F. et al. (2010), Sergeyev V. and Elyashevich I. (2011).

Theoretical and methodological basis, as well as practical tools of modeling the individual logistics processes (supply of companies), are stated in papers Barkalov S. et al. (2000), Volodina E. (2003), Semenenko A. and Sergeyev V. (2003), Lukinskiy V. ed. (2007), Fertsch M. et al. (2009).

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

Range of mathematical methods applied in logistics (regarding the streaming nature of supply processes and optimization procedures) is reviewed in papers Simchi-Levi D. et al. (2004), Prosvetov G. (2008), Brodetskiy G. (2011, 2012).

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

- organizational units of armed forces are non-profit entities, 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 the 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 minimum-allowed level;
- variation of need for different MTR – depending on nature of tasks performed by organizational unit.

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

Computational models of certain logistics tasks (supply of armed forces) were reviewed in papers Grigoriev Y. (1999), Moskovchenko V. (2001), Mihaylov Y. (2002). Optimization models (management of certain logistics processes for supply of armed forces) provided in papers Pluzhnikov B. (1999), Pytlak, R. and Stecz, W. (2006), Chistov I. (2006), Gallasch G. et al. (2008), Hester J. (2009), Lisovskiy V. (2012) do not account for dynamic nature of supply, and objective function is represented by logistic costs only, which limits the use of models for control of 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 supply of organizational units at 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 interrelated logistics processes) is quite actual.

Purpose of present paper is to develop the economic-mathematical model, which ensure 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 problem and a description 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 scope of allocated funds, which is due to limited budget funding and consequent restrictions on needs of organizational units – set as 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 minimum and maximum possible level respectively.

Dynamics of supply process shall be presented as time chart reflecting the split of planned period (operation of logistics systems at armed forces) into T equal periods of time, where logistics-management divisions get certain scope of funds (within each period) and purchase the MTR required for this period (Fig. 1).

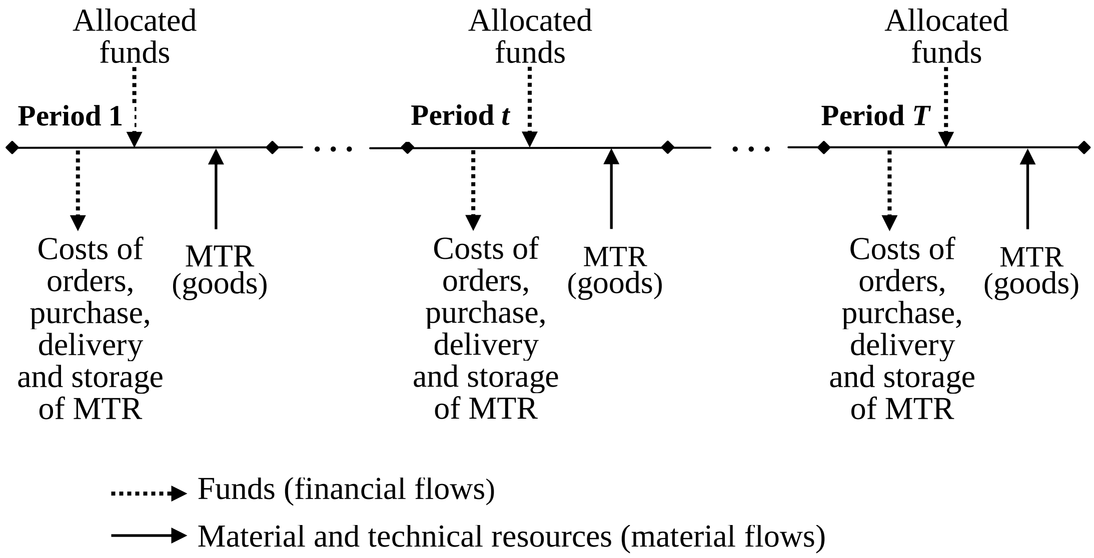


Figure 1. Time chart of planned supply for organizational units at armed forces

Limited budget funding is manifested in two aspects.

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

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

The logistics of organizational units at 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 that 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 supply process (for organizational units of armed forces), let's introduce the following heuristic assumptions:

- parameters of 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 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 material and technical resources 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 armed forces (at decentralized procurement):

option 1 – one consumer, one type of material and technical resources, one supplier;

option 2 – one consumer, one type of material and technical resources, many suppliers;

option 3 – one consumer, many types of material and technical resources, 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 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 (Fig. 2).

Let us define the basic parameters of the model:

v_{sit} – amount of MTR of type s, $s = 1,\ldots, S$, available by supplier i, $i \in I_s$, during the period t, $t = 1,\ldots, T$;

$a_{st}^{\min}$ – minimum demand of MTR of type s, $s = 1,\ldots, S$, during the period t, $t = 1,\ldots, T$;

a_{st}^{rat} – rationed demand of MTR of type s, $s = 1,\ldots, S$, during the period t, $t = 1,\ldots, T$;

z_s – level of stock reserve of MTR of type s, $s = 1,\ldots, S$, which must be always available at warehouses of organizational unit;

c_{sit}^{or} – cost of one order for the purchase of MTR of type s, $s = 1,\ldots, S$, from the supplier i, $i \in I_s$, during the period t, $t = 1,\ldots, T$;

c_{sit}^{del} – unit transportation cost of MTR of type s, $s = 1,\ldots, S$, from the supplier i, $i \in I_s$, during the period t, $t = 1,\ldots, T$;

c_{st}^{stor} – unit storage cost of MTR of type s, $s = 1,\ldots, S$, during the period t, $t = 1,\ldots, T$;

I_s – set of indices of the suppliers offering the MTR of type s, $s = 1,\ldots, S$, at the market;

v_{sit}^{thr} – the threshold value amount of MTR of type s, $s = 1,\ldots, S$, 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, $t = 1,\ldots, T$;

c_{sit}^{pwtd} – unit price of MTR of type s, $s = 1,\ldots, S$, purchased from the supplier i, $i \in I_s$, during the period t, $t = 1,\ldots, T$, without discount;

c_{sit}^{pwd} – unit price of MTR of type s, $s = 1,\ldots, S$, purchased from the supplier i, $i \in I_s$, during the period t, $t = 1,\ldots, T$, with discount;

C_t^{alloc} – funds allocated for purchase of material and technical resources during the period t, $t = 1,\ldots, T$.

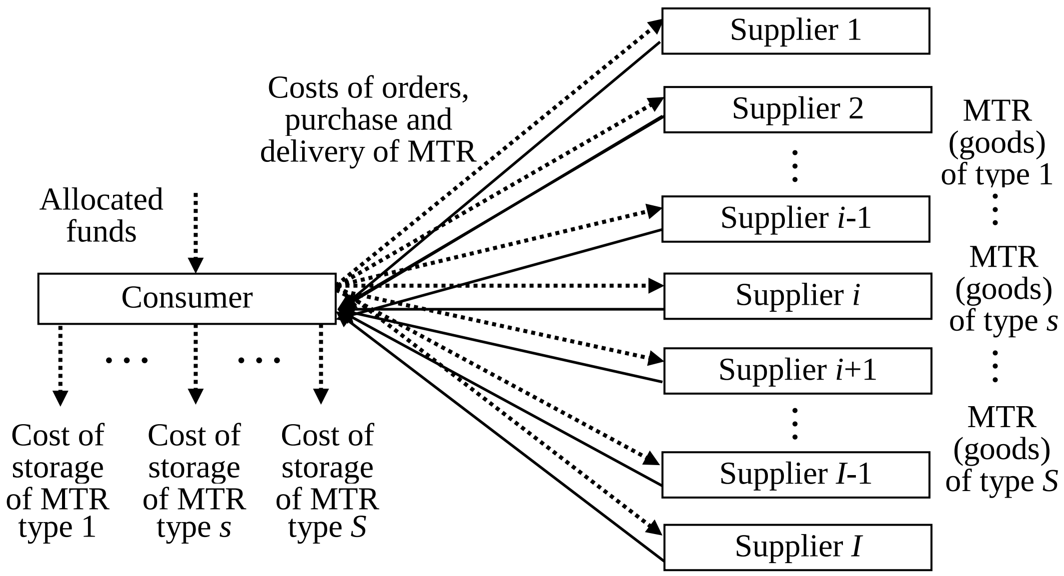


Figure 2. Scheme of supply process at decentralized procurement (option 3)

Within certain period of time, each type of MTR makes its contribution to activities of 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,…, *S*, during the period *t*, *t* = 1,…, *T*.

Variables of the model are as follows:

x_{sit} – required amount of MTR of type *s*, *s* = 1,…, *S*, purchased by the consumer from the supplier *i*, $i \in I_s$, during the period *t*, *t* = 1,…, *T*;

C_t^{av} – funds available at consumer after period *t*, *t* = 1,…, *T*. For sake of completeness, we assume that $C_0^{\text{av}} = 0$;

θ_{sit} – binary variable equal to 0 or 1 depending on the presence of the order for MTR of type *s*, *s* = 1,…, *S*, purchased by the consumer from the supplier *i*, $i \in I_s$, during the period *t*, *t* = 1,…, *T*.

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

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

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

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

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

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

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

In this task, values $\sum_{i \in I_s} x_{sit} - a_{st}^{\min}$ can be considered as "criteria-forming" – i.e., target function is aimed at increasing the difference between supply of MTR (each type) and minimum need for them, which corresponds to increased level of providing the organizational unit of armed forces with material and technical resources. Given that minimum demand of organizational unit ensures its activities under set norms of logistics and ability to perform the service and combat tasks in accordance with assignment (at minimum acceptable level), value of supply $\sum_{i \in I_s} x_{sit}$ less than value of minimum demand $a_{st}^{\min}$ is actually impossible.

As the various types of MTR with different dimensions may have 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; at that

$$0 \le u_{st} \le 1; s = 1, \ldots, S; t = 1, \ldots, T \; . \qquad (6)$$

Thus, the formula for target function

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

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

Mathematical model of optimized supply (in case of many types of MTR and multiple suppliers) looks like the following.

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

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

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

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

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

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

where $[x_{sit}]$ – integer part of x_{sit}.

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

At decentralized purchase, reviewed task of optimized supply (for organizational units of armed forces) is non-linear, and proposed economic-mathematical model refers to mixed integer programming models, as area of feasible solutions shows limitations set by logical terms “or – or”.

3. An example of application of the model

Let us imagine the implementation of developed model on the example of 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 of 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.

The modeling was made via Solver module of MS Excel 2010.

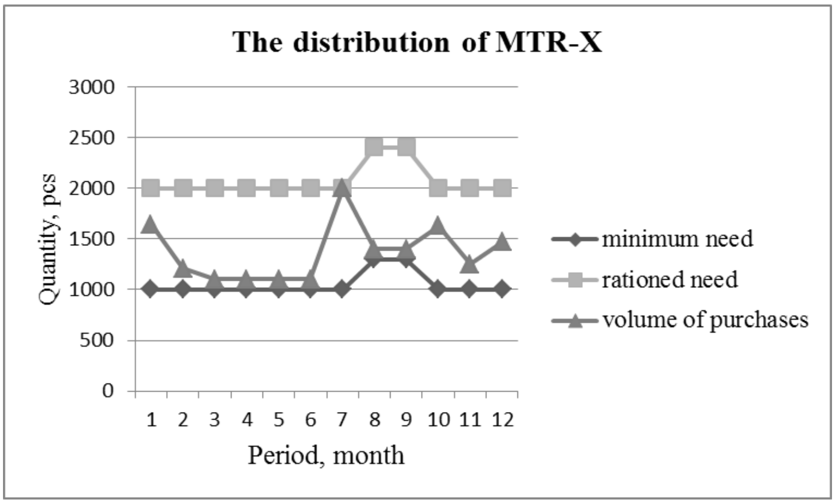
As a result of modeling, the optimal level of provision of organizational unit of armed forces equal to 0.2988, real value of total logistic costs equal to 9,449,853.3 CMU, and distributions in time purchase volumes of MTR, total logistic costs, funds remaining at consumers after each period time, and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

Distribution of purchase volumes of MTR of each type is shown at the background of dynamics of change in levels of minimum and rationed need organizational unit for these types of MTR (Fig. 3).

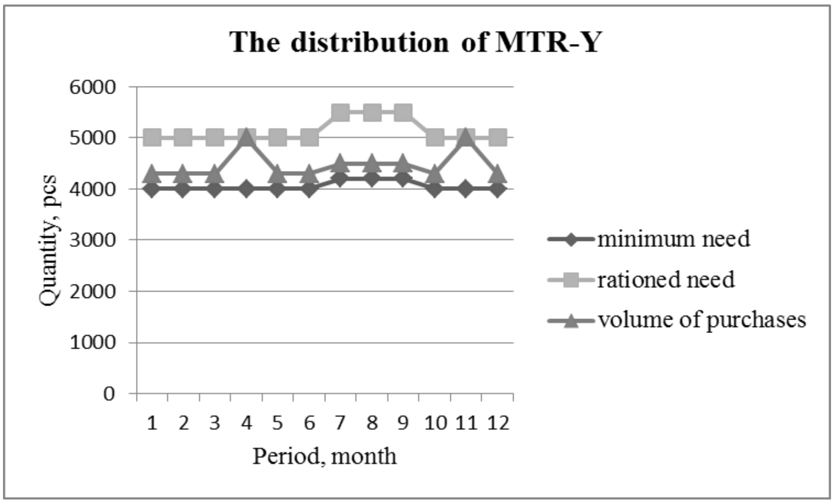
Table 1. Initial data for modeling the logistics process (example)

Parameters	Units	Planned period of time (1 year)											
t	month	1	2	3	4	5	6	7	8	9	10	11	12
C^{alloc}	Th.CMU	690,0	700,0	700,0	740,0	770,0	810,0	840,0	850,0	850,0	840,0	840,0	820,0
$v_{X\text{-}A}$	pcs	800	800	800	900	900	900	900	1000	1000	1000	1000	1000
$v_{X\text{-B}}$	pcs	1500	1500	1500	1500	1500	1500	1600	1600	1600	1600	1600	1600
$v_{Y\text{-C}}$	pcs	2000	2000	2000	2000	2000	2000	2300	2300	2300	2300	2300	2300
$v_{Y\text{-D}}$	pcs	3500	3500	3500	3500	3500	3500	3300	3300	3300	3300	3300	3300
$v_{Z\text{-E}}$	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	4500	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	350	350	350
c_E^{or}	CMU	250	250	250	250	250	250	250	280	280	280	280	280
$c_{X\text{-}A}^{pwtd}$	CMU	120	120	120	130	130	130	140	140	140	145	145	145
$c_{X\text{-B}}^{pwtd}$	CMU	110	115	120	125	130	135	135	135	135	140	145	150
$c_{Y\text{-C}}^{pwtd}$	CMU	60	60	60	60	60	60	70	70	70	70	70	70
$c_{Y\text{-D}}^{pwtd}$	CMU	65	65	65	70	70	70	75	75	75	65	65	65
$c_{Z\text{-E}}^{pwtd}$	CMU	40	45	50	55	60	65	65	60	55	55	55	55
$c_{X\text{-}A}^{del}$	CMU	18	18	18	18	18	20	20	20	20	24	24	24
$c_{X\text{-B}}^{del}$	CMU	20	20	20	22	22	22	22	22	22	22	22	22
$c_{Y\text{-C}}^{del}$	CMU	10	12	14	16	16	16	14	14	14	16	16	16
$c_{Y\text{-D}}^{del}$	CMU	12	12	12	12	12	12	15	15	15	15	15	15
$c_{Z\text{-E}}^{del}$	CMU	10	10	10	10	8	8	8	8	8	10	10	10
c_X^{stor}	CMU	10	10	10	10	12	12	12	12	12	8	8	8

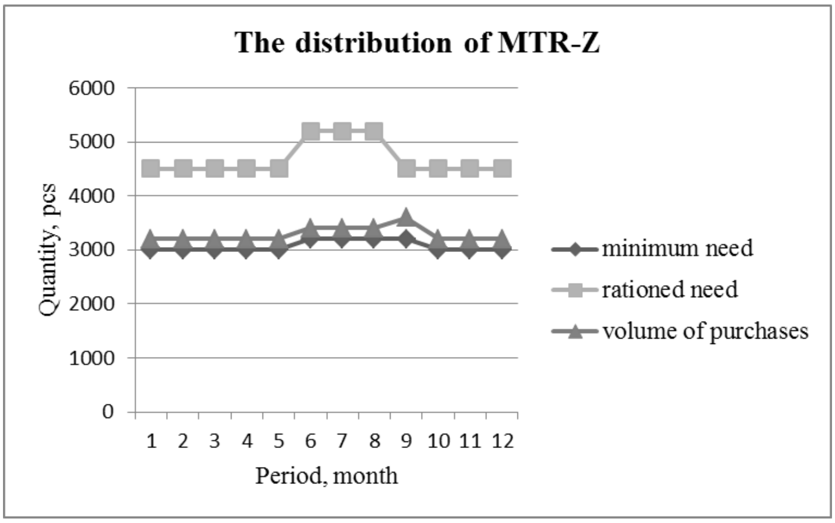
c_Y^{stor}	CMU	4	4	4	5	5	5	5	5	5	6	6	6
c_Z^{stor}	CMU	6	6	6	8	8	8	10	10	10	12	12	12
$v_{X\text{-}A}^{\text{thr}}$	pcs	800	800	800	800	800	800	800	800	800	800	800	800
$v_{X\text{-B}}^{\text{thr}}$	pcs	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
$v_{Y\text{-C}}^{\text{thr}}$	pcs	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
$v_{Y\text{-D}}^{\text{thr}}$	pcs	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
$v_{Z\text{-E}}^{\text{thr}}$	pcs	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
$\delta_{X\text{-}A}^{\text{pwd}}$	%	5	5	5	5	5	5	5	5	5	5	5	5
$\delta_{X\text{-B}}^{\text{pwd}}$	%	3	3	3	3	3	3	3	3	3	3	3	3
$\delta_{Y\text{-C}}^{\text{pwd}}$	%	4	4	4	4	4	4	4	4	4	4	4	4
$\delta_{Y\text{-D}}^{\text{pwd}}$	%	5	5	5	5	5	5	5	5	5	5	5	5
$\delta_{Z\text{-E}}^{\text{pwd}}$	%	8	8	8	8	8	8	8	8	8	8	8	8



a)



b)



c)

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

Distribution of total logistic costs is shown at the background of the distribution of funds planned for logistics of organizational unit at armed forces (Fig. 4), that allows to see their remains arising at the end of each time period (Fig. 5), and to make certain adjustments in budgeting process.

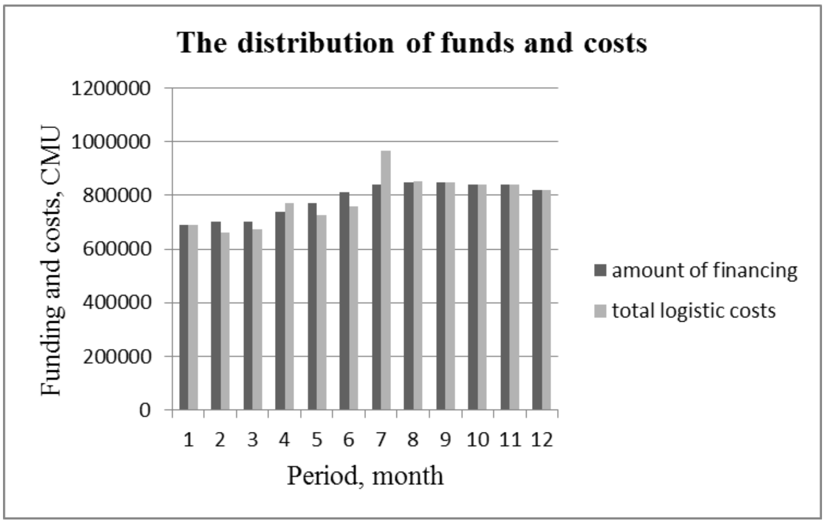


Figure 4. The distribution of total logistic costs and funds

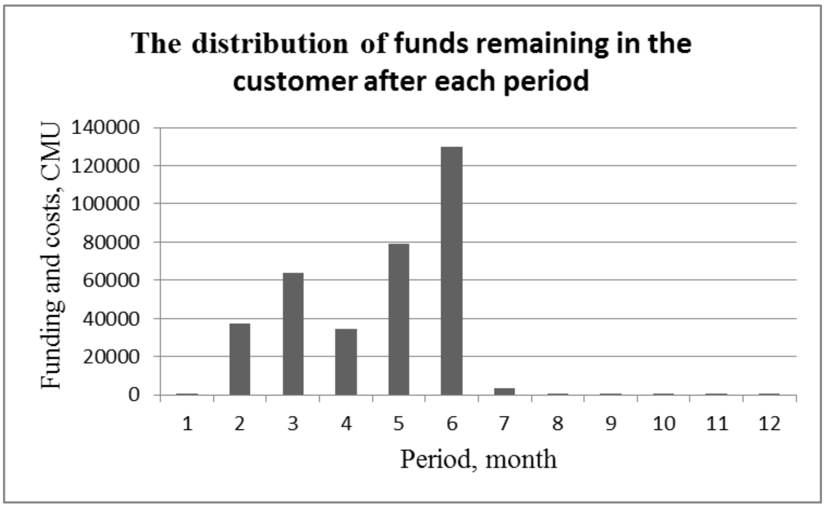
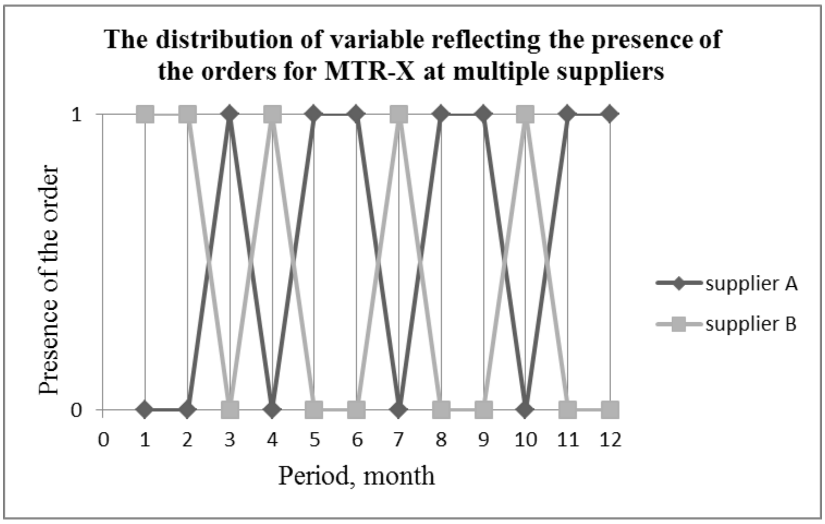
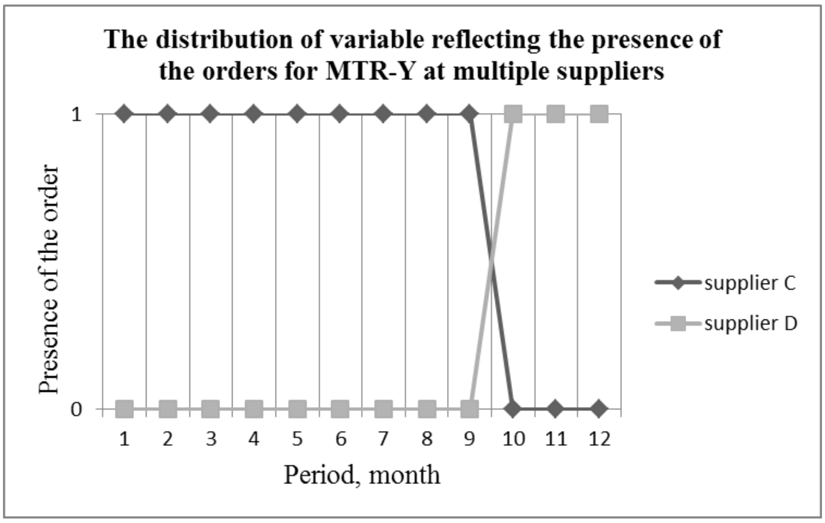


Figure 5. The distribution of funds remaining in the customer after each period

Distribution of variable reflecting the presence of the orders at certain supplier is only shown for types of resources purchased at multiple suppliers (Fig. 6).



a)



b)

where value “1” - presence of the order, “0” - absence of order

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

Proposed model shows good response to change of any model parameter through time that allows to identify the cause-and-effect relationships between main components of supply process and to select the most beneficial options arranging of logistics processes at any time period.

On the adequacy and accuracy of the model evidenced by the fact that at multiple model runs with different initial plans, deviation in target function values was less than 0.001.

Conclusions

In terms of limited funding and dynamics of logistics process, efficient supply management of organizational units at 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 relationship). Modeling of logistics process in time allows the use predictive estimates, which characterize the trends of change in parameters (used in models to describe the process components under study). (**At that, it is possible to review**) 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 change 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., for delivery and storage). By results of modeling, they choose the most efficient (in terms of the least logistics costs) options of supply – within each individual time period, subject to decisions made during previous period, and aimed at achieving the maximum provision of organizational units at armed forces (over the entire planned period). In addition, the obtained values of total (**logistical**) 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.

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

The model is efficient tool for supporting the 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 to optimize the level of provision of organizational units with required MTR (for the entire planning period of supply, regarding the change of need, scope of funds allocated for logistics and logistic costs accompanying the supply process).

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