

*Volodymyr Sysoiev\**

## **OPTIMIZATION MODELS OF THE SUPPLY OF POWER STRUCTURES' ORGANIZATIONAL UNITS WITH CENTRALIZED PROCUREMENT**

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**ABSTRACT:** *Management of the state power structures' organizational units for materiel and technical support requires the use of effective tools for supporting decisions, due to the complexity, interdependence, and dynamism of supply in the market economy. The corporate nature of power structures is of particular interest to centralized procurement management, as it provides significant advantages through coordination, eliminating duplication, and economy of scale. This article presents optimization models of the supply of state power structures' organizational units with centralized procurement, for different levels of simulated materiel and technical support processes. The models allow us to find the most profitable options for state*

*power structures' organizational supply units in a centre-oriented logistics system in conditions of the changing needs, volume of allocated funds, and logistics costs that accompany the process of supply, by maximizing the provision level of organizational units with necessary material and technical resources for the entire planning period of supply by minimizing the total logistical costs, taking into account the diverse nature and the different priorities of organizational units and material and technical resources.*

**KEY WORDS:** *supply, logistics processes, model, optimization, centralized procurement, organizational units of the power structures*

**JEL CLASSIFICATION:** C61, H44, H57

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## **1. INTRODUCTION**

Improving the management of state power structures' materiel and technical support (MTS) in contemporary conditions requires greater validity, responsiveness, and adaptability of the decision-making process. Today MTS is complex and dynamic, with a variety of commodities and services being purchased in different markets, many suppliers, multivariance of logistics processes implementation, power structures' dynamic needs and financing, and market conditions.

When power structures' organizational units are spatially dispersed throughout the state and their MTS (logistics) hierarchically controlled, it becomes possible to use both centralized and decentralized supply management, which assumes granting rights to management bodies at various levels of the system to purchase certain types of material and technical resources (MTR) in different markets for greater economic benefit.

The state power structure's budget and high volume of needs and the logistical nature of MTS mean that centralized supply management is advantageous for most types of MTR, which through coordination, concentration, responsibility, eliminating duplication, and economy of scale allows significant reduction of logistics costs and improves the level of provision for the power structure's organizational units.

## **2. LITERATURE REVIEW**

The importance of centralized procurement in supply management is confirmed by the growing interest from state enforcement authorities, large companies, and science. Reese and Pohlman (2005), Karjalainen (2009), and Strand et al. (2011) have all carried out research into centralized procurement management on a corporate scale in different spheres of activity.

Considering the importance of effective supply management, the bodies carrying out centralized procurement must have appropriate tools to support their decisions that allow them to choose the most advantageous variants of

supply, taking into account the power structures, dynamics, needs, funding, and market situation of MTS organization. Under conditions of uneven and limited budget financing, as well as variations in the conditions of the MTS process over time, the task of managing the supply of power structures becomes one of optimization, the solution to which requires the application of economic and mathematical modelling methods.

The American scientists Ratliff and Nulty (1996) were among the first to propose the concept of modelling the logistics of supply. They developed a structured (composite) approach to their modelling, based on the diversity and complexity of logistics management and combining different methods of optimization of logistics solutions.

Advanced modelling techniques applied to supply logistics that take into account the streaming nature of logistics processes and procedures in their optimization are discussed in works by Simchi-Levi et al. (2004), Prosvetov (2008), and Brodetskiy (2011, 2012). Publications by Barkalov et al. (2000), Volodina (2003), Semenenko and Sergueyev (2006), and Lukinskiy (Ed.) (2007) propose the model of separate logistics processes (procurement, transportation, inventory management) in supplying an enterprise. Works by Tayur et al. (1999), Shapiro (2006), Ivanov (2009), Monczka et al. (2011), and Schonberger (2011) are dedicated to modelling supply processes in complicated logistic systems (supply chains, logistics networks).

Sarmah et al. (2006) offer a classification of models that reflects the interaction between suppliers and consumers, and also review supply models, taking into account discounts as deterministic factors of the environment. Li and Wang (2007) present an overview of coordination mechanisms in supply chains, based on a system of decision-making that takes into account the nature of consumers' demand. Jaber and Zolfaghari (2008) provide an overview of models of centralized supply for supply chains consisting of a different number of levels (chain links). The disadvantage of most of these of models is the absence of the representation of supply as a complex of interconnected logistics processes; in addition, many of them do not present an optimization, or consider only one type of MTR supply.

Recently business process models based on languages and simulation packages (ARIS, UML, IDEF, et al.) have become widespread, which are used to create automation tools for individual businesses' procurement management, producing rational solutions such as SAP Supplier Relationship Management (SRM), Automated Procurement System (APR), et al.

However, the possibilities of using the logistic processes of business structures' supply models (B2B system) for research and management of power structures' MTR are limited, because they do not take into account the peculiarities of MTR supply, including centralized purchasing for a large number of different types of end users/organizational units. Therefore such models cannot be applied to simulate the logistics processes of power structures' supply.

Known models of management optimization of power structures' supply logistics processes, offered in articles by Pytlak and Stecz (2006), Chistov (2006), Dvurechenskiy and Pitsik (2007), Gallasch et al. (2008), Hester (2009), and Lisovskiy (2012), consider only individual functional areas of logistics (transportation, inventory management, warehousing): they do not take into account the dynamic nature of supply, and use only logistical expenditure as an objective function, which limits their application to controlling the actual MTS process and does not reflect its main goal - to ensure maximum possible supply of power structures' organizational units with necessary types of MTR, in accordance with regulatory requirements and financing limits.

The organizational units' supply of power structures depends on a variety of time-varying parameters in the processes of ordering, purchasing, delivery, and storage of MTR, level of financing, and diverse nature and different priorities of organizational units and MTR, which leads to the complexity of the MTS management process in its entirety, and requires creating effective tools for decision-making, taking into account the dynamics, relationships, and multivariate of logistic supply processes.

The purpose of this article is to develop economic and mathematical models to optimize the supply of power structures' organizational units with centralized procurement, taking into account the dynamics of their needs, financial

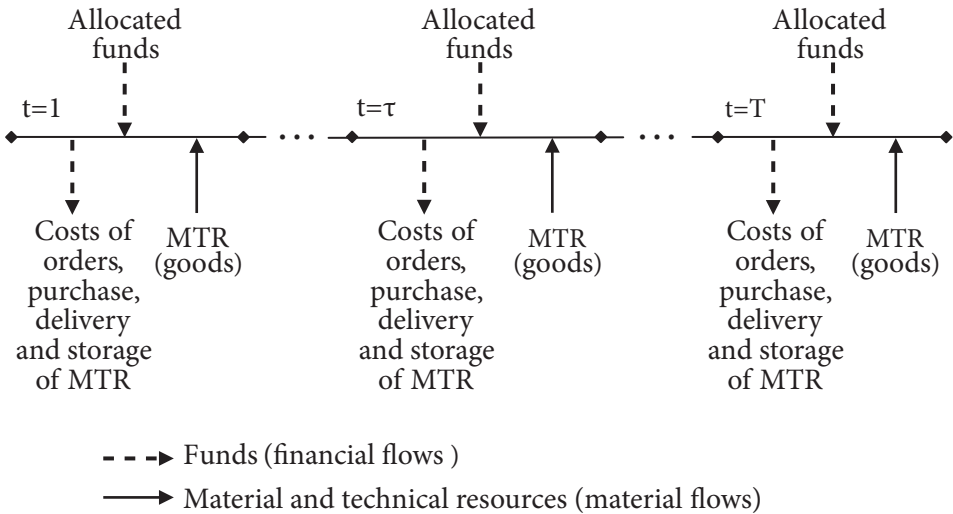
resources allocated for material and technical support, and logistical expenses accompanying the supply process, with limited financing.

### **3. OPTIMIZATION OF SUPPLY MODELS FOR THE VARIOUS OPTIONS OF ORGANIZING LOGISTICS PROCESSES**

Power structures' MTS management systems are strictly limited by the financial resources allocated for them, resulting in the introduction of lower and upper limits for all materials and equipment for each organizational unit that reflect minimum and normative requirements for MTR, allowing organizational units to carry out their activities at minimum and maximum possible levels. The possible irregularity of funding at different time intervals, leading to a lack of financial resources to meet the minimum organizational units requirements in MTR in a certain period of time, is covered by the optimization of financial resources and the use of these resources' insurance stocks, completion of which is accounted for in the values of needs, defined for the subsequent period of time.

The supply process dynamics of power structures' organizational units can be reflected through representing the planning period of the MTS management system in the form of a timing diagram, divided into  $T$  equal time intervals, within each of which financing takes place and procurement activity is carried out (Fig. 1).

**Figure 1.** Time chart of planned supply of power structures' organizational units



Source: Author

The logistics procurement processes of power structures' organizational units are characterized by relevant performance indicators, typically logistical expenditure on MTR (goods), which is determined by the value of the goods, taking into account possible discounts and the costs of transportation and warehousing. Therefore the cost of MTR (goods) and their transportation and storage are calculated per MTR unit, while expenses for each order are based on the type of MTR.

The peculiarity of the centralized procurement supply process of power structures' organizational units is that all the allocated financial resources first go to the principal MTS control authority (centre), which, acting as a single customer, then itself finances all the logistics processes for the supply of the power structures' organizational units that are within its area of maintenance, except for MTR stockpiling in warehouses. To cover the costs of stockpiling the total volume of purchased MTR, including permanently stored reserve stocks, the centre distributes financial resources to the procurement departments of the individual organizational units.

As an indicator of supply management efficiency we select the parameter that describes the level of organizational units' material and technical resources that most fully reflects the capability of the power structure's organizational units to perform the assigned tasks. Considering the multi-stage nature of the MTS process, the organizational multivariance of individual logistic processes, and the limited financial resources, we offer a corresponding normalized performance indicator that takes into account a range of requirements for MTR and provides global optimization of supply.

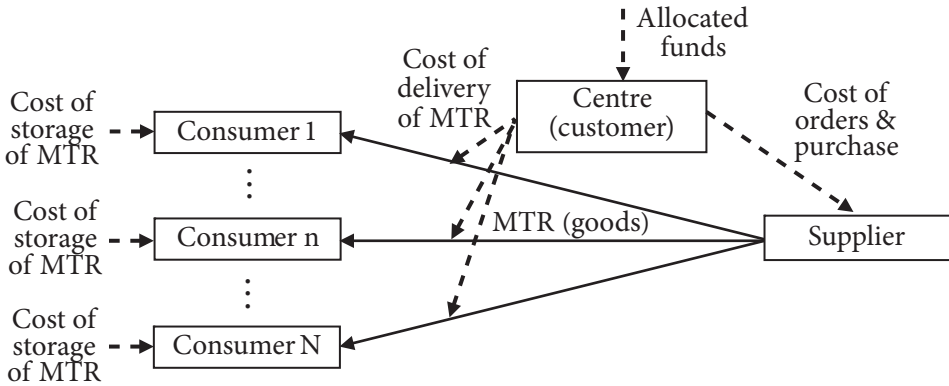
To simplify the modelling of the supply of power structures' organizational units, we introduce the following assumptions:

- parameters of the MTS process (allocated funds, the needs of the organizational unit, MTR prices, cost of orders, transportation, and storage of MTR) are constant during each time interval and can only be changed during the transition from one interval to another;
- irrespective of the volume of one type of MTR purchase during one interval of time, only one order per vendor is issued and only one shipment from one supplier is performed;
- purchase of MTR is carried out at the beginning of each interval of time, so the costs of storing the purchased goods are calculated for the entire period;
- during the entire supply planning period there is a specified level of reserve stocks of each type of MTR in the organizational units' warehouses.

We then build dynamic optimization models of centralized procurement for power structures' organizational units at different levels of simulated MTS processes.

**Option 1:** One centre (customer), many consumers, one type of material and technical resources, one supplier (Fig. 2).

**Figure 2.** Scheme of centralized procurement process (Option 1)



Source: Author

Let us define the basic parameters of the model:

$v_t$  – amount of MTR available from supplier during the  $t$ -th time interval;

$a_{nt}^{\min}$ ;  $n = \overline{1, N}$ ;  $t = \overline{1, T}$  – minimum demand of the  $n$ -th consumer of the MTR during the  $t$ -th time interval;

$a_{nt}^{\text{norm}}$ ;  $n = \overline{1, N}$ ;  $t = \overline{1, T}$  – normative demand of the  $n$ -th consumer of the MTR during  $t$ -th time interval;

$z_n$ ;  $n = \overline{1, N}$   $Z$  – level of stock reserve of MTR, which must be always available at warehouses of the  $n$ -th consumer;

$c_t^{\text{or}}$ ;  $t = \overline{1, T}$  – cost of one order for the purchase of MTR (during the  $t$ -th time interval);

$c_{nt}^{\text{del}}$ ;  $n = \overline{1, N}$ ;  $t = \overline{1, T}$  – unit transportation cost of MTR from the supplier to the  $n$ -th consumer (during  $t$ -th time interval);



$c_{nt}^{\text{stor}}; n = \overline{1, N}; t = \overline{1, T}$  – unit storage cost of MTR in warehouses of the  $n$ -th consumer (during  $t$ -th time interval);

$v_t^{\text{thr}}; t = \overline{1, T}$  – the threshold value amount of MTR, in the case of purchase of which from the supplier a discount is given on the price unit of production during the  $t$ -th time interval;

$c_t^{\text{pwt}}; t = \overline{1, T}$  – unit price of MTR during the  $t$ -th time interval (without discount);

$c_t^{\text{pwt}}; t = \overline{1, T}$  – unit price of MTR during the  $t$ -th time interval (with discount);

$C_t^{\text{alloc}}; t = \overline{1, T}$  – funds allocated for purchase of material and technical resources (during the  $t$ -th time interval).

Consumers (organizational units) differ according to the importance of the tasks they perform, and therefore have different weight coefficients:

$$y_{nt} \geq 0; n = \overline{1, N}; t = \overline{1, T}; \quad (1)$$

$$\sum_{n=1}^N y_{nt} = 1; t = \overline{1, T}, \quad (2)$$

where  $y_{nt}; n = \overline{1, N}; t = \overline{1, T}$  – weight of the  $n$ -th consumer within the  $t$ -th time interval.

Variables of the model are as follows:

$x_{nt}; n = \overline{1, N}; t = \overline{1, T}$  – required amount of MTR that the centre purchases from the supplier for the  $n$ -th consumer (during the  $t$ -th time interval);

$C_t^{av}; t = \overline{1, T}$  – funds that remain in the centre of the MTS management system after the  $t$ -th time interval. For sake of completeness, we assume that  $C_0^{av} = 0$ .

Because suppliers provide discounts for the wholesale purchase of goods, let us set the unit price as the following system of ratios:

$$c_t^{pr} = \begin{cases} c_t^{pwt}d, & \sum_{n=1}^N x_{nt} < v_t^{thr}; \\ c_t^{pwd}, & \sum_{n=1}^N x_{nt} \geq v_t^{thr}; \end{cases} \quad t = \overline{1, T}, \quad (3)$$

where  $c_t^{pr}; t = \overline{1, T}$  – unit price of MTR purchased from supplier (during the  $t$ -th time interval).

The mathematical model of optimal supply for this variant of the MTS process is as follows:

$$\frac{1}{T} \sum_{t=1}^T \sum_{n=1}^N y_{nt} \frac{x_{nt} - a_{nt}^{min}}{a_{nt}^{norm} - a_{nt}^{min}} \rightarrow \max; \quad (4)$$

$$C_1^{av} = C_1^{alloc} - [c_1^{or} + \sum_{n=1}^N (c_1^{pr} x_{n1} + c_{n1}^{del} x_{n1} + \frac{c_{n1}^{stor} x_{n1}}{2} + c_{n1}^{stor} z_n)] \geq 0; \quad (5)$$

$$C_{t+1}^{av} = C_{t+1}^{alloc} + C_t^{av} - [c_t^{or} + \sum_{n=1}^N (c_t^{pr} x_{nt} + c_{nt}^{del} x_{nt} + \frac{c_{nt}^{stor} x_{nt}}{2} + c_{nt}^{stor} z_n)] \geq 0; t = \overline{1, T-1}; \quad (6)$$

$$C_0^{av} = 0; \quad (7)$$

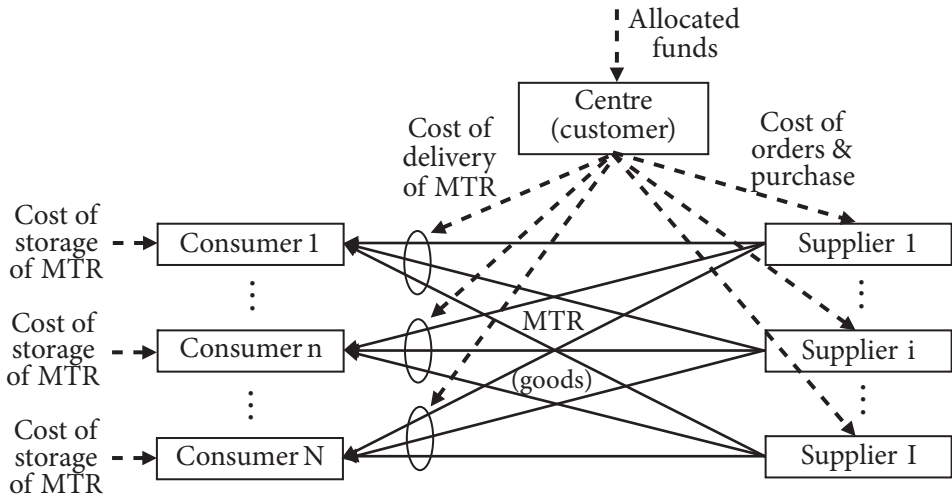
$$a_{nt}^{min} + z_n \leq x_{nt} \leq \min(a_{nt}^{norm}; v_t); n = \overline{1, N}; t = \overline{1, T}; \quad (8)$$

$$\sum_{n=1}^N x_t \leq \min(\sum_{n=1}^N a_{nt}^{\text{norm}}; v_t); t = \overline{1, T}; \quad (9)$$

$$x_{nt} = [x_{nt}] \geq 0; n = \overline{1, N}; t = \overline{1, T}. \quad (10)$$

**Option 2:** One centre (customer), many consumers, one type of material and technical resources, many suppliers (Fig. 3).

**Figure 3.** Scheme of centralized procurement supply process (Option 2)



Source: Author

According to market conditions the centre (customer) can select those suppliers that provide the most favourable conditions with regard to the goods' delivery to the end consumers in each  $t$ -th time interval.

Let us specify the parameters of the model (in view of multiple suppliers):

$v_{it}; i = \overline{1, I}; t = \overline{1, T}$  – amount of MTR available from the  $i$ -th supplier within the  $t$ -th time interval;

$c_{it}^{or}$ ;  $i = \overline{1, I}; t = \overline{1, T}$  – cost of one order of MTR from the  $i$ -th supplier (within the  $t$ -th time interval);

$c_{nit}^{del}$ ;  $n = \overline{1, N}; i = \overline{1, I}; t = \overline{1, T}$  – unit transportation cost of MTR unit from the  $i$ -th supplier to the  $n$ -th consumer in the  $t$ -th time interval.

$v_{it}^{thr}$ ;  $i = \overline{1, I}; t = \overline{1, T}$  – the threshold value amount of MTR when purchased from the  $i$ -th supplier with a discount on the unit price during the  $t$ -th time interval;

$c_{it}^{pwt}$ ;  $i = \overline{1, I}; t = \overline{1, T}$  – unit price of MTR (from the  $i$ -th supplier, within the  $t$ -th time interval, without discount);

$c_{it}^{pwt}$ ;  $i = \overline{1, I}; t = \overline{1, T}$  – unit price of MTR (from the  $i$ -th supplier, within the  $t$ -th time interval, with discount).

Variables of the model:

$x_{nit}$ ;  $n = \overline{1, N}; i = \overline{1, I}; t = \overline{1, T}$  – required amount of MTR that the centre purchases from  $i$ -th supplier for the  $n$ -th consumer (during the  $t$ -th time interval);

$C_t^{av}$ ;  $t = \overline{1, T}$ ;

$\theta_{it}$ ;  $i = \overline{1, I}; t = \overline{1, T}$  – binary variable equal to 0 or 1 depending on the MTR order purchased by the consumer from the  $i$ -th supplier within the  $t$ -th time interval.

Let us set the unit price of goods as the following system of ratios:

$$c_{it}^{\text{pr}} = \begin{cases} c_{it}^{\text{pwt}} , & \sum_{n=1}^N x_{nit} < v_{it}^{\text{thr}} ; \\ c_{it}^{\text{pwt}} , & \sum_{n=1}^N x_{nit} \geq v_{it}^{\text{thr}} ; \end{cases} \quad i = \overline{1, I}; t = \overline{1, T} , \quad (11)$$

where  $c_{it}^{\text{pr}}$ ;  $i = \overline{1, I}; t = \overline{1, T}$  – unit price of MTR purchased from the  $i$ -th supplier in the  $t$ -th time interval.

The mathematical model of supply optimization for the case of multiple suppliers is as follows:

$$\frac{1}{T} \sum_{t=1}^T \sum_{n=1}^N y_{nt} \frac{\sum_{i=1}^I x_{nit} - a_{nt}^{\text{min}}}{a_{nt}^{\text{norm}} - a_{nt}^{\text{min}}} \rightarrow \max ; \quad (12)$$

$$C_1^{\text{av}} = C_1^{\text{alloc}} - \left[ \sum_{i=1}^I (c_{it}^{\text{or}} \theta_{i1} + \sum_{n=1}^N (c_{in}^{\text{pr}} x_{ni1} + c_{ni1}^{\text{del}} x_{ni1} + \frac{c_{n1}^{\text{stor}} x_{ni1}}{2})) \right] - \sum_{n=1}^N c_{n1}^{\text{stor}} z_n \geq 0; \quad (13)$$

$$C_{t+1}^{\text{av}} = C_{t+1}^{\text{alloc}} + C_t^{\text{av}} - \left[ \sum_{i=1}^I (c_{it}^{\text{or}} \theta_{it} + \sum_{n=1}^N (c_{in}^{\text{pr}} x_{nit} + c_{nit}^{\text{del}} x_{nit} + \frac{c_{nt}^{\text{stor}} x_{nit}}{2})) \right] - \sum_{n=1}^N c_{nt}^{\text{stor}} z_n \geq 0; t = \overline{1, T-1}; \quad (14)$$

$$\theta_{it} = \begin{cases} 1, & \sum_{n=1}^N x_{nit} > 0; \\ 0, & \sum_{n=1}^N x_{nit} = 0; \end{cases} \quad i = \overline{1, I}; t = \overline{1, T} ; \quad (15)$$

$$a_{nt}^{\text{min}} + z_n \leq \sum_{i=1}^I x_{nit} \leq \min(a_{nt}^{\text{norm}}; \sum_{i=1}^I v_{it}); n = \overline{1, N}; t = \overline{1, T} ; \quad (16)$$

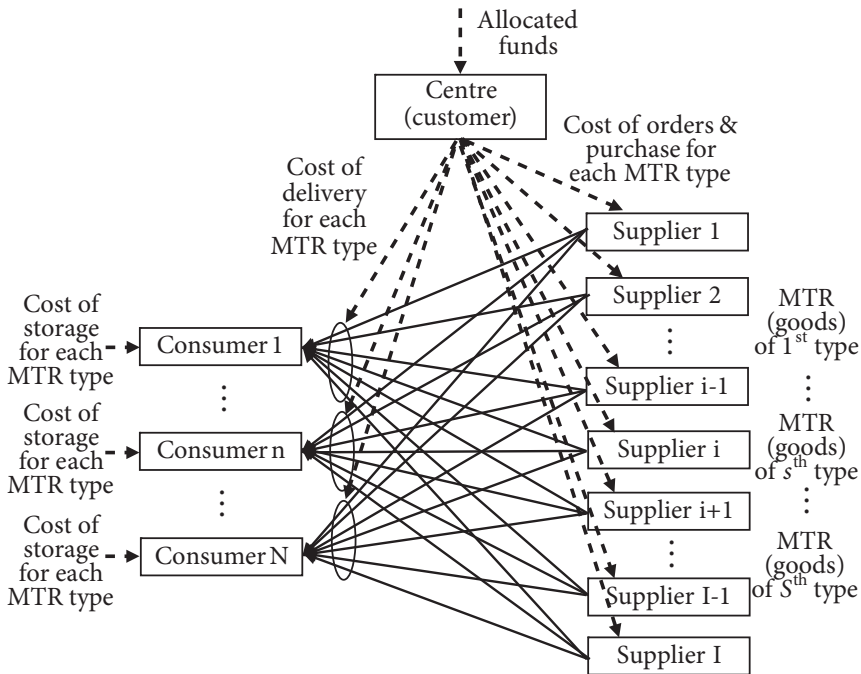
$$\sum_{n=1}^N \sum_{i=1}^I x_{nit} \leq \min(\sum_{n=1}^N a_{nt}^{\text{norm}}; \sum_{i=1}^I v_{it}); t = \overline{1, T} ; \quad (17)$$

$$x_{nit} = [x_{nit}] \geq 0; n = \overline{1, N}; i = \overline{1, I}; t = \overline{1, T}, \tag{18}$$

as well as the constraint (7).

**Option 3:** One centre (customer), many consumers, many types of material and technical resource, many suppliers (Fig. 4)

**Figure 4.** Scheme of centralized procurement supply process (Option 3)



Source: Author

To ensure the activity of each power structure’s organizational units, different types of MTR are necessary, which are purchased by the centre from multiple suppliers in the sales market, taking into account the most favourable conditions for the acquisition of goods from different suppliers and their delivery to the end consumers in each  $t$ -th time interval.

Let us specify the model’s parameters based on the plurality of purchased MTR types and the variety of their suppliers:

$v_{sit}$ ;  $s = \overline{1, S}$ ;  $i = \overline{1, I}$ ;  $t = \overline{1, T}$  – amount of MTR of type  $s$ , available from the  $i$ -th supplier within the  $t$ -th time interval;

$a_{nst}^{\min}$ ;  $n = \overline{1, N}$ ;  $s = \overline{1, S}$ ;  $t = \overline{1, T}$  – minimum demand of the  $n$ -th consumer for the MTR of type  $s$  within the  $t$ -th time interval;

$a_{nst}^{\text{norm}}$ ;  $n = \overline{1, N}$ ;  $s = \overline{1, S}$ ;  $t = \overline{1, T}$  – normative demand of the  $n$ -th consumer for the MTR of type  $s$  within the  $t$ -th time interval;

$z_{ns}$  – level of stock reserve of MTR of type  $s$  that must be constantly available at the warehouse of the  $n$ -th consumer;

$c_{sit}^{\text{or}}$ ;  $s = \overline{1, S}$ ;  $i = \overline{1, I}$ ;  $t = \overline{1, T}$  – cost of one order for the purchase of MTR of type  $s$  from  $i$ -th supplier within the  $t$ -th time interval;

$c_{nsit}^{\text{del}}$ ;  $n = \overline{1, N}$ ;  $s = \overline{1, S}$ ;  $i = \overline{1, I}$ ;  $t = \overline{1, T}$  – unit transportation cost of MTR of type  $s$  from the  $i$ -th supplier to the  $n$ -th consumer within the  $t$ -th time interval;

$c_{nst}^{\text{stor}}$ ;  $n = \overline{1, N}$ ;  $s = \overline{1, S}$ ;  $t = \overline{1, T}$  – unit storage cost of MTR of type  $s$  in warehouses of the  $n$ -th consumer within the  $t$ -th time interval;

$I_s$ ;  $s = \overline{1, S}$  – multiple suppliers offering the MTR (goods) of type  $s$  on the market;

$v_{sit}^{\text{thr}}$ ;  $s = \overline{1, S}$ ;  $i = \overline{1, I}$ ;  $t = \overline{1, T}$  – the threshold value amount of MTR of type  $s$ , in the case of purchase of which from the supplier  $i$ ,  $i \in I_s$ , is given a discount on the unit price during the  $t$ -th time interval;

$c_{sit}^{\text{pwtd}}$ ;  $s = \overline{1, S}$ ;  $i = \overline{1, I}$ ;  $t = \overline{1, T}$  – unit price of MTR of type  $s$  from the  $i$ -th supplier within the  $t$ -th time interval without discount;

$c_{sit}^{pwd}; s = \overline{1, S}; i = \overline{1, I}; t = \overline{1, T}$  – unit price of MTR of type  $s$  from the  $i$ -th supplier within the  $t$ -th time interval with discount.

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

$$w_{nst} \geq 0; n = \overline{1, N}; s = \overline{1, S}; t = \overline{1, T}; \quad (19)$$

$$\sum_{s=1}^S w_{nst} = 1; n = \overline{1, N}; t = \overline{1, T}, \quad (20)$$

where  $w_{nst}; n = \overline{1, N}; s = \overline{1, S}; t = \overline{1, T}$  – the weight of MTR of type  $s$  for the  $n$ -th consumer within the  $t$ -th time interval.

Variables of the model:

$x_{nsit}; n = \overline{1, N}; s = \overline{1, S}; i = \overline{1, I}; t = \overline{1, T}$  – required amount of MTR of type  $s$  that the centre purchases from the  $i$ -th supplier for the  $n$ -th customer within the  $t$ -th time interval;

$$C_t^{av}; t = \overline{1, T};$$

$\theta_{sit}$  – binary variable equal to 0 or 1 depending on the presence of the order for MTR of type  $s$ , purchased by the consumer from the supplier  $i, i \in I_s$ , during  $t$ -th time interval.

Let us set the unit price of goods as the following system of ratios:

$$c_{sit}^{pr} = \begin{cases} c_{sit}^{pwd}, & \sum_{n=1}^N x_{nsit} < v_{sit}^{thr}, \\ c_{sit}^{pwd}, & \sum_{n=1}^N x_{nsit} \geq v_{sit}^{thr}, \end{cases} \quad i \in I_s; s = \overline{1, S}; t = \overline{1, T}; \quad (21)$$



where  $c_{sit}^{pr}$ ;  $s = \overline{1, S}$ ;  $i = \overline{1, I}$ ;  $t = \overline{1, T}$  – unit price of MTR of type  $s$  purchased from the  $i$ -th supplier in the  $t$ -th time interval.

The mathematical model of optimal supply for the case of a plurality of MTR types and a variety of suppliers is as follows:

$$\frac{1}{T} \sum_{t=1}^T \sum_{n=1}^N y_{nt} \sum_{s=1}^S w_{nst} \frac{\sum_{i \in I_s} x_{nsit} - a_{nst}^{\min}}{a_{nst}^{\text{norm}} - a_{nst}^{\min}} \rightarrow \max; \quad (22)$$

$$C_1^{\text{av}} = C_1^{\text{alloc}} - \left[ \sum_{s=1}^S \sum_{i \in I_s} (c_{sit}^{\text{or}} \theta_{sit} + \sum_{n=1}^N (c_{sit}^{\text{pr}} x_{nsit} + c_{nsit}^{\text{del}} x_{nsit} + \frac{c_{ns1}^{\text{stor}} x_{ns1}}{2})) \right] - \sum_{n=1}^N c_{ns1}^{\text{stor}} z_{ns} \geq 0; \quad (23)$$

$$C_{t+1}^{\text{av}} = C_{t+1}^{\text{alloc}} + C_t^{\text{av}} - \left[ \sum_{s=1}^S \sum_{i \in I_s} (c_{sit}^{\text{or}} \theta_{sit} + \sum_{n=1}^N (c_{sit}^{\text{pr}} x_{nsit} + c_{nsit}^{\text{del}} x_{nsit} + \frac{c_{nst}^{\text{stor}} x_{nsit}}{2})) \right] - \quad (24)$$

$$- \sum_{n=1}^N c_{nst}^{\text{stor}} z_{ns} \geq 0; t = \overline{1, T-1};$$

$$\theta_{sit} = \begin{cases} 1, & \sum_{n=1}^N x_{nsit} > 0; \\ & i \in I_s; s = \overline{1, S}; t = \overline{1, T}; \\ 0, & \sum_{n=1}^N x_{nsit} = 0; \end{cases} \quad (25)$$

$$a_{nst}^{\min} + z_{ns} \leq \sum_{i \in I_s} x_{nsit} \leq \min(a_{nst}^{\text{norm}}; \sum_{i \in I_s} v_{sit}); n = \overline{1, N}; s = \overline{1, S}; t = \overline{1, T}; \quad (26)$$

$$\sum_{n=1}^N \sum_{i \in I_s} x_{nsit} \leq \min(\sum_{n=1}^N a_{nst}^{\text{norm}}; \sum_{i \in I_s} v_{sit}); s = \overline{1, S}; t = \overline{1, T}; \quad (27)$$

$$x_{nsit} = |x_{nsit}| \geq 0; n = \overline{1, N}; s = \overline{1, S}; i \in I_s; t = \overline{1, T}, \quad (28)$$

as well as the constraint (7).

The supply management of power structures' organizational units covers the full range of the logistics processes of acquisition, delivery, and storage of necessary materials and equipment, which are carried out during each time interval, taking into account their execution sequence and relationship. The integrated nature of the management of logistic processes determines the formulation of the problem of global optimization of supply, aimed at achieving the maximum level of power structures' organizational units provision over the entire planning period, while minimizing the total logistical costs in conditions of limited funding and the parameters of the dynamics of MTS processes.

In order to simulate the MTS process of power structures' organizational units over time, it is necessary to know the nature of changes in the values of the parameters characterizing the studied components of this process, or their forecasted estimates. Then different scenarios of possible fluctuations in individual parameters at certain time intervals can be examined, reflecting organizational units' activity, changes in the market situation, or features of the organization of the logistics procurement process. The proposed models make it possible to describe in greater detail the parameters characterizing the logistic processes (transportation, cargo processing, and storage of MTR), and so to take into account a wide range of factors that influence the formation of logistical costs in the modelling process.

The simulation identifies the most efficient options, in terms of minimum total logistical costs, of supplying each organizational unit with the centralized procurement of necessary MTR in each separate time interval, taking into account the complex of accepted restrictions of financing, needs, capacity of suppliers, prices, etc., aimed at achieving the maximum provision level of power structures' organizational units over the entire planning period.

#### **4. AN EXAMPLE OF APPLICATION OF THE MODEL**

Optimization models of supply are a nonlinear programming problem. The "Search for solution" procedure (in MS Excel) is used to find local optimum unknown variables.

Let us consider the application of the mathematical model developed for the solution of the nonlinear programming problem of the most complex “Option 3” in the example of logistical systems, consisting of one centre; four suppliers, A, B, C, and D, where A and B supply MTR type R1 and C and D supply MTR type R2; and four organizational units/consumers, I, II, III, and IV, consuming all types of MTR. The weights of all consumers are equal. Cost indicators are shown in conventional monetary units (CMU). Baseline data for a given simulation scenario of the MTS process of the power structure's organizational units are presented in Table 1.

**Table 1.** Baseline data for modelling the logistics process (example)

Parameters	Units	Planned period of time (1 year)											
		1	2	3	4	5	6	7	8	9	10	11	12
$C^{alloc}$	Th.CMU	800,0	800,0	800,0	840,0	870,0	910,0	940,0	950,0	950,0	990,0	990,0	975,0
$V_{R1-A}$	pcs	800	800	800	900	900	900	900	1000	1000	1000	1000	1000
$V_{R1-B}$	pcs	1500	1500	1500	1500	1500	1500	1600	1600	1600	1600	1600	1600
$V_{R2-C}$	pcs	2000	2000	2000	2000	2000	2000	2300	2300	2300	2300	2300	2300
$V_{R2-D}$	pcs	3500	3500	3500	3500	3500	3500	3300	3300	3300	3300	3300	3300
$a_{I-R1}^{min}$	pcs	300	300	300	300	300	300	450	450	350	350	350	400
$a_{I-R1}^{norm}$	pcs	500	500	500	500	500	500	600	600	500	500	500	500
$a_{II-R1}^{min}$	pcs	300	300	300	300	300	300	300	300	300	450	350	350
$a_{II-R1}^{norm}$	pcs	450	450	450	450	450	450	450	600	600	600	450	450
$a_{III-R1}^{min}$	pcs	450	450	450	450	450	550	550	600	600	600	500	500
$a_{III-R1}^{norm}$	pcs	600	600	600	600	600	700	700	700	700	700	600	600
$a_{IV-R1}^{min}$	pcs	700	700	700	700	800	800	800	700	700	700	700	700
$a_{IV-R1}^{norm}$	pcs	900	900	900	900	1000	1000	1000	900	900	900	900	900
$a_{I-R2}^{min}$	pcs	1600	1600	1600	1600	1600	1800	1800	1800	1600	1600	1600	1600
$a_{I-R2}^{norm}$	pcs	2000	2000	2000	2000	2000	2300	2300	2300	2000	2000	2000	2000
$a_{II-R2}^{min}$	pcs	1800	1800	1800	1800	1800	2000	2000	1800	1800	1800	1800	1800
$a_{II-R2}^{norm}$	pcs	2300	2300	2300	2300	2300	2600	2600	2300	2300	2300	2300	2300

$a_{III-R2}^{\min}$	pcs	1400	1400	1400	1400	1400	1400	1700	1700	1700	1500	1500	1500
$a_{III-R2}^{\text{norm}}$	pcs	1800	1800	1800	1800	1800	1800	2000	2000	2000	1800	1800	1800
$a_{IV-R2}^{\min}$	pcs	1800	1800	1800	1800	2100	2100	2100	2000	2000	2000	2000	2000
$a_{IV-R2}^{\text{norm}}$	pcs	2200	2200	2200	2200	2500	2500	2500	2400	2400	2400	2400	2400
$z_{R1}$	pcs	100	100	100	100	100	100	100	100	100	100	100	100
$z_{R2}$	pcs	300	300	300	300	300	300	300	300	300	300	300	300
$w_{R1}$		0,6	0,6	0,6	0,6	0,5	0,4	0,4	0,4	0,6	0,7	0,7	0,5
$w_{R2}$		0,4	0,4	0,4	0,4	0,5	0,6	0,6	0,6	0,4	0,3	0,3	0,5
$c_A^{\text{or}}$	CMU	350,0	350,0	350,0	340,0	340,0	340,0	340,0	340,0	340,0	330,0	330,0	330,0
$c_B^{\text{or}}$	CMU	340,0	340,0	340,0	340,0	340,0	340,0	360,0	360,0	360,0	360,0	360,0	360,0
$c_C^{\text{or}}$	CMU	400,0	400,0	400,0	400,0	400,0	400,0	450,0	450,0	450,0	450,0	450,0	450,0
$c_D^{\text{or}}$	CMU	350	350	350	380	380	380	400	400	400	420	420	420
$c_{R1-A}^{\text{pwtd}}$	CMU	110	115	120	125	130	135	135	135	135	140	145	150
$c_{R1-B}^{\text{pwtd}}$	CMU	100	100	100	120	120	120	140	140	140	160	160	160
$c_{R2-C}^{\text{pwtd}}$	CMU	65	65	65	70	70	70	75	75	75	65	65	65
$c_{R2-D}^{\text{pwtd}}$	CMU	50	55	60	65	70	75	80	85	85	80	75	70
$c_{R1,A-I}^{\text{del}}$	CMU	20,0	20,0	20,0	22,0	22,0	22,0	24,0	24,0	24,0	26,0	26,0	26,0
$c_{R1,A-II}^{\text{del}}$	CMU	22,0	22,0	22,0	22,0	22,0	22,0	20,0	20,0	20,0	20,0	20,0	20,0
$c_{R1,A-III}^{\text{del}}$	CMU	10,0	11,0	12,0	13,0	14,0	15,0	16,0	17,0	18,0	19,0	20,0	21,0
$c_{R1,A-IV}^{\text{del}}$	CMU	14,0	14,0	14,0	15,0	15,0	15,0	16,0	16,0	16,0	17,0	17,0	17,0
$c_{R1,B-I}^{\text{del}}$	CMU	10,0	10,0	10,0	11,0	11,0	11,0	11,0	11,0	11,0	12,0	12,0	12,0
$c_{R1,B-II}^{\text{del}}$	CMU	15,0	15,0	15,0	16,0	16,0	16,0	17,0	17,0	17,0	18,0	18,0	18,0
$c_{R1,B-III}^{\text{del}}$	CMU	6,0	6,0	6,0	6,0	6,0	6,0	8,0	8,0	8,0	8,0	8,0	8,0
$c_{R1,B-IV}^{\text{del}}$	CMU	18,0	18,0	18,0	19,0	19,0	19,0	20,0	20,0	20,0	21,0	21,0	21,0
$c_{R2,C-I}^{\text{del}}$	CMU	14,0	14,0	14,0	15,0	15,0	15,0	16,0	16,0	16,0	17,0	17,0	17,0
$c_{R2,C-II}^{\text{del}}$	CMU	10,0	12	14,0	16,0	16,0	16,0	14,0	14,0	14,0	16,0	16,0	16,0
$c_{R2,C-III}^{\text{del}}$	CMU	20,0	20,0	20,0	20,0	20,0	20,0	22,0	22,0	22,0	22,0	22,0	22,0

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$C_{R2,C-IV}^{del}$	CMU	8,0	8,0	8,0	8,0	8,0	8,0	10,0	10,0	10,0	10,0	10,0	10,0
$C_{R2,D-I}^{del}$	CMU	10,0	10,0	10,0	8,0	8,0	8,0	8,0	8,0	8,0	10,0	10,0	10,0
$C_{R2,D-II}^{del}$	CMU	15,0	16,0	17,0	17,0	17,0	17,0	16,0	16,0	16,0	17,0	17,0	17,0
$C_{R2,D-III}^{del}$	CMU	6,0	6,0	6,0	8,0	8,0	8,0	10,0	10,0	10,0	12,0	12,0	12,0
$C_{R2,D-IV}^{del}$	CMU	14,0	14,0	14,0	15,0	15,0	15,0	14,0	14,0	14,0	15,0	15,0	15,0
$C_{I-R1}^{stor}$	CMU	5,0	5,0	5,0	5,0	5,0	5,0	6,0	6,0	6,0	6,0	6,0	6,0
$C_{II-R1}^{stor}$	CMU	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0
$C_{III-R1}^{stor}$	CMU	5,0	5,0	5,0	6,0	6,0	6,0	6,0	6,0	6,0	5,0	5,0	5,0
$C_{IV-R1}^{stor}$	CMU	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0
$C_{I-R2}^{stor}$	CMU	3,0	3,0	3,0	3,0	3,0	3,0	4,0	4,0	4,0	4,0	4,0	4,0
$C_{II-R2}^{stor}$	CMU	4,0	4,0	4,0	3,0	3,0	3,0	3,0	3,0	3,0	4,0	4,0	4,0
$C_{III-R2}^{stor}$	CMU	5,0	5,0	5,0	4,0	4,0	4,0	4,0	4,0	4,0	5,0	5,0	5,0
$C_{IV-R2}^{stor}$	CMU	2,0	2,0	2,0	2,0	2,0	2,0	3,0	3,0	3,0	3,0	3,0	3,0
$V_{R1-A}^{thr}$	pcs	400	400	400	400	400	400	500	500	500	500	500	500
$V_{R1-B}^{thr}$	pcs	500	500	500	500	500	500	500	500	500	600	600	600
$V_{R2-C}^{thr}$	pcs	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
$V_{R2-D}^{thr}$	pcs	1500	1500	1500	1500	1500	1500	1600	1600	1600	1600	1600	1600
$\delta_{R1-A}^{pwd}$ *		0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,03	0,03	0,03	0,03
$\delta_{R1-B}^{pwd}$ *		0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03
$\delta_{R2-C}^{pwd}$ *		0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04
$\delta_{R2-D}^{pwd}$ *		0,05	0,05	0,05	0,05	0,05	0,05	0,06	0,06	0,06	0,06	0,06	0,06

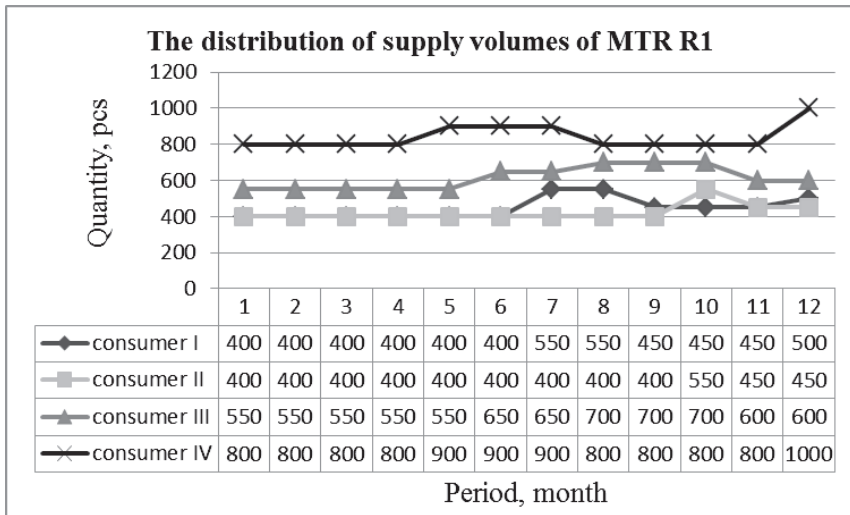
\*  $\delta^{pwd}$  - coefficients, that reflect volume discounts.

Source: Author's data

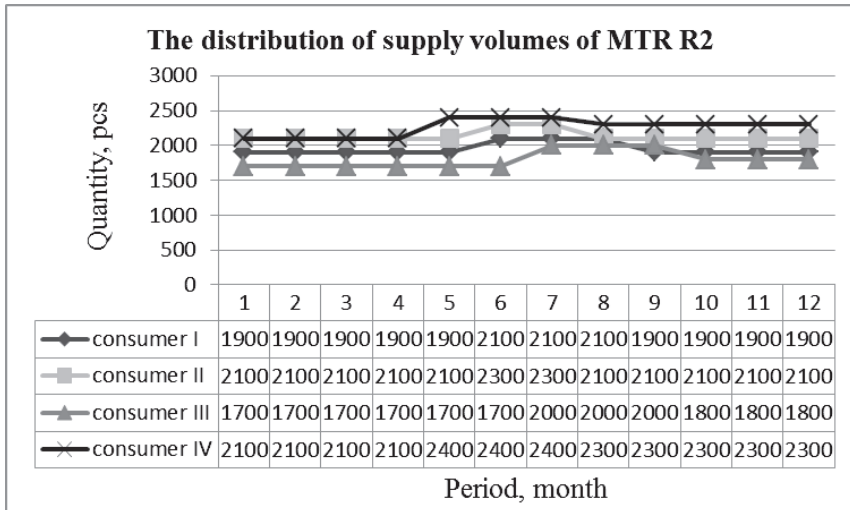
The results of the simulation were the obtained optimum level of organizational units provision, equal to 0.7; the real value of total logistic costs equal to 10811.415 Th. CMU; and distributions in time supply volumes of MTR to consumers, volumes purchased from suppliers, and total logistics costs.

Distribution of the supply volume of each type of MTR to each consumer/ organizational unit is shown in Fig. 5 a) and b).

**Figure 5.** The distribution of supply volumes of MTR (a – R1, b – R2)



a)

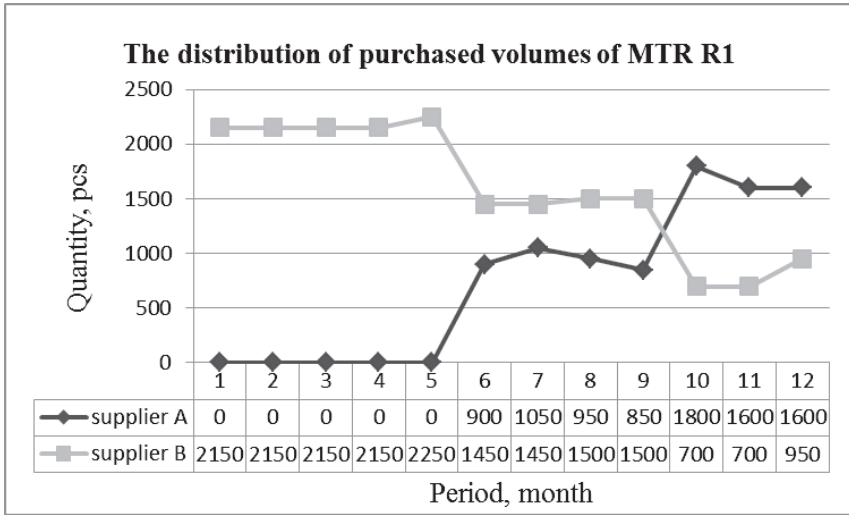


b)

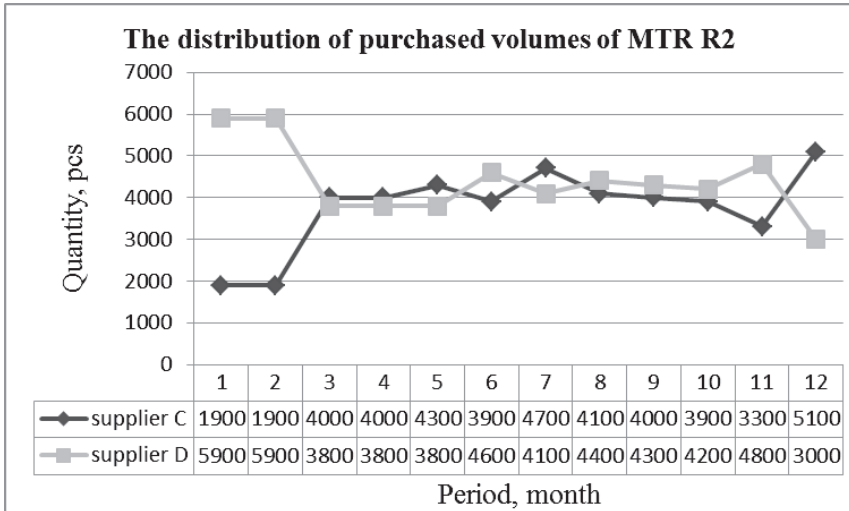
Source: Author's calculations

Distribution of volume of each type of MTR purchased from suppliers is shown in Fig. 6 a) and b).

**Figure 6.** The distribution of purchased volumes of MTR (a – R1, b – R2)



a)

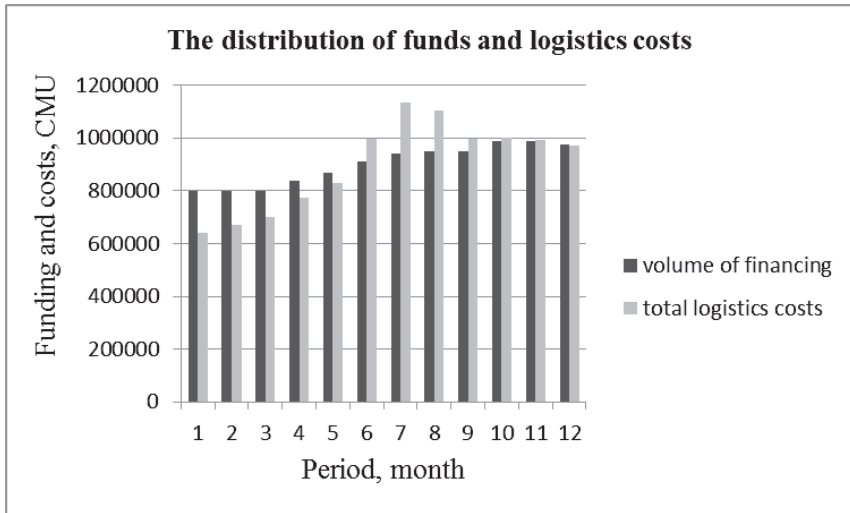


b)

Source: Author's calculations

The distribution of total logistics costs is shown in the background of the distribution of financial resources planned for allocation of the MTS of the power structure's organizational units (Fig. 7), which shows any surplus at the end of each time interval and allows for adjusting the budget for the next time interval.

**Figure 7.** The distribution of funds and total logistics costs



Source: Author's calculations

The optimal values of funds that remain in the centre of the MTS management after each time interval ( $C_t^{av}$ ) are presented in Table 2.

**Table 2.** The optimal values of funds remaining in the centre after each time interval

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	159935	289745	390690	456990	498640	410060	217162	61132	12355	1475	65	3585

Source: Author's calculations



During the modelling of the process of supplying distributions in the time value of logistics costs for the issue of orders, including the purchase of bulk discounts, delivery and storage of both current and insurance stocks of MTR for each type were also obtained.

## **5. CONCLUSIONS**

Under conditions of limited financial resources, parameter changes in the MTS process over time, and the multivariance of the logistics supply process implementation, it is necessary that the management bodies of power structures' organizational units have effective tools when making decisions concerning the MTS system.

The dynamic model developed here reflects the peculiarities of the complex, multi-factor, and multi-step process of the centralized procurement of the MTS of power structures' organizational units, and the different levels of complexity of the simulated supply logistics process. These models make it possible to find the best options for supplying organizational units in the centrally controlled logistics system, under conditions of changing needs, volume of allocated funds, and logistics costs that accompany the process of supply, by maximizing the provision level of the organizational units with necessary MTR for the entire planning supply period through minimizing the total logistical costs, taking into account the diverse nature and different priorities of the organizational units and MTR.

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