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**Kateryna Semenchuk,
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RESEARCH OF MATERIAL AND TECHNICAL RESOURCES INVENTORY MANAGEMENT IN PROJECTS SUPPLY CHAINS

The object of research is the processes of material and technical support of projects in the field of supply chain management. One of the most challenging areas faced by logistics and project managers is determining the appropriate level of supply chain inventory management when implementing projects. Today, there is a demand for the development and implementation of dynamic supply chains, the essence of which is to increase the service level by increasing the speed of response to customer requests and flexibility in excess components (high stock levels, unbalanced duration of supply cycles), taking into account the uncertainty of demand.

The analysis of the justification of the value of the supply chain, namely of such components as logistics costs, the cost of storing inventories and deficit costs, is carried out. Models of inventory management in the supply chain with centralized and decentralized service are presented. Calculations of the indicators of the standard deviation of demand and the duration of the supply cycle, the values of the cyclic and safety stock are presented. For the situation of centralized service of the resource flow, the influence of the demand dependence on the stock level was investigated.

The study used the theory of supply chain management and project management, which made it possible to take into account the variability of demand and the duration of supply. As a result of the work, models of the volume of insurance stocks in conditions of uncertainty in demand and the duration of the supply cycle of resources are proposed. In order to ensure the optimal strategy of resource provision, the concept of «service level» was investigated. The service level of the first kind (cyclical service level) and the service level of the second kind (saturated demand) are considered.

The results of this research provide an opportunity to improve project efficiency in the face of volatile demand, reduced product life cycle and increased competition. Such changes require supply chains to develop strategies that are focused on the end user, that is, an integrated supply chain management strategy is required.

Keywords: project management, supply chain, resource provision, inventory management, service level.

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1. Introduction

Management of any enterprise through projects is carried out in various areas. Project management involves achieving the goals of the project while limiting time, budget, resources, and the like. Fierce competition in the markets of suppliers and consumers of resources, the search for new forms of business management requires the use of a symbiosis of logistics and project management (PM) methods.

Practice has shown that the efficiency of using the logistic approach is manifested at a high service level organization at a low cost, that is, saving money and material resources. The question of determining the composition of logistics functions and operations, strategy of inventory management in supply chains (SC) occurs even at the stage of developing a business plan for a project. Among the methodologies, the joint use of which is in a state of development, include supply chain management and project management.

PM in supply chains empowers pharmaceutical professionals to include forecasting, customer skills, planning, control and risk management. Successful PM in supply chains turns ideas into practical endeavors. Therefore, it is relevant to study the management of inventories of material and technical resources for the project.

2. The object of research and its technological audit

The object of research is the processes of material and technical support of projects in the field of supply chain management.

It is known that the object in SC is a material flow, considered in three states – material resources, work in progress, finished goods. Strategic business decisions in SC, often associated with the implementation of various logistics projects, and effective operational management and development projects are integral components of SC management.

One reason for the ineffective state of the processes of material and technical support of projects is the imperfection of the theoretical basis for increasing the efficiency of movement of flows of material resources, ensuring the target results of the project.

3. The aim and objectives of research

The aim of research is to improve the efficiency of inventory management of material and technical resources in project supply chains.

To achieve this aim, the following objectives have been set:

1. Determine the main indicators related to the planning processes and the delivery of resources to the project.
2. Explore the concept of «service level» that affects the inventory management policy of the project.
3. Conduct supply chain modeling in the face of uncertainty in demand and the duration of the project supply cycle.

4. Research of existing solutions to the problem

Organizations such as the Association for Supply Chain Management (ASCM), the Project Management Institute (PMI), the Council of Supply Chain Management Specialists (Council of Supply Chain Management Professionals, CSCMP) and Operations Management Association (APICS) [1]. As a result of the collaborative efforts of scientists and practitioners, the supply chain capabilities of business structures have expanded from the integration of forecasting, planning and execution of operations into smooth management from the beginning to the end of the supply chain [2].

Among the sources of literature on the study of supply chains identified in the resources of the world scientific periodicals, one can single out [3, 4], in which there is a lack of consideration of the issues of organizing logistics management within the framework of project activities.

In work [5], the supply chain is investigated, the organization of which is stimulated by the demand for the supply product. Also, scientists pay attention to the organization of business processes in industrial supply chains [6, 7]. Research [8] is devoted to the process of resource management for a project based on determinism, that is, an accurate determination of economic conditions, but when organizing a system of supplying resources to projects on market conditions, the uncertainty factor plays a huge role, limiting the use of deterministic models [9]. In such situations, it is necessary to use other approaches, taking into account the uncertainty of demand and delivery times. Both of these quantities fluctuate over time and may not be constant and strictly fixed. The most common is the probabilistic approach to solving this problem. When constructing probabilistic models, it is assumed that demand has the characteristics of standard statistical distributions (normal, Poisson, etc.). These models take into account the service level, that is, the probability of a stock shortage during one replenishment cycle. Thus, the main calculated indicators in SC modeling are the size of the order, the average deviation of demand and the duration of the functional cycle, the value of the cyclic and safety stock [10].

Supply chain management (SCM) and PM are among the methodologies, the joint use of which is in a state of development [11]. The theoretical foundations and practical skills of these areas of knowledge make it possible to obtain a synergistic effect in resource provision in project activities.

Thus, according to the results of the analysis of modern research devoted to the issues of inventory management processes in projects, it can be concluded that the works devoted to PM, focused on resource provision of the project, without taking into account changes in demand and the duration of the supply cycle. The aforementioned justifies the prospects for considering the features of the SC operation in project activities.

5. Methods of research

To achieve the set aim of research, in defining the tasks, their formulation and solution, a systematic approach, the theory of stocks and logistics, the theory of probability and PM were used.

To solve the first and second objectives, a systematic approach, the theory of reserves and project management was used. The modeling of supply chain processes is based on the methodology of mathematical modeling and the theory of probability.

6. Research results

The potential of logistics and PM is revealed in providing:

- material and technical – purchase and supply of resources, materials, equipment, and the like;
- financial – search and attraction of investments;
- informational – systematization and accumulation, information processing;
- HR – selection of a team for a project, personnel development;
- legal – legal support for the project throughout its life.

The question of determining the strategy of inventory management in the SC, the composition of logistics functions and operations occurs even at the stage of developing a business plan for the project. During the implementation of the project, logistics covers almost the entire range of resource and functional support from initiation processes to closure. Logistics in PM should be considered broader than resource management in projects, namely, as a strategic concept for project management. Management of these processes based on logistics is reflected in the concept of «Project logistics management». This is a systemically organized process of managing investment, material, service, financial, information flows to a project, which are implemented in a sequence of phases, stages and life cycle works according to the rules of logistics using supply chains and interaction of participants [12, 13].

According to the Project Management Body Of Knowledge (PMBOK) [14], the resource provision of the project provides for procurement management, but the logistic approach to determining the volume of resource reserves for the project is not considered in detail, including taking into account uncertainty.

The development of logistics methods in the context of project inventory management is forecasting, optimization and monitoring of the state of resources by determining the performance indicators of the supply chain, taking into account the strategy of minimizing risks and increasing the efficiency of the project as a whole [15, 16].

In Table 1, in accordance with the process approach, each group of PM processes is supplemented with some functions that are of priority importance in SCM, namely in planning and control processes.

Table 1

Projects management processes

Initiation	Planning	Performance	Control	Closure
Assessment of the implementation of project alternatives, approval of the project idea	Development of a project management plan and business plan; definition of drug elements	Dissemination of information between project stakeholders	Monitoring project implementation	Closing the project
Development of the project charter	Structuring the project, creating a hierarchical structure of work (HSW) structure of the SC	Team recruitment; team development	Project team management	Closing contracts
A project manager is assigned	Schedule work, estimate the duration of work	Schedule management	Managing schedule changes	Assessment of achievements by duration
Economic development forecast	Technical and economic indicators of the project; budget development	Project implementation	Monitoring project performance indicators	Assessing budget achievements
–	Quality planning; quality management baseline	Quality assurance	Quality control	Quality achievement assessment
–	Resource planning for the project; provisional resource calendar	Organization of the delivery of resources for the work of the project; resource requirements	Resource allocation control	Freeing resources
–	Estimation and forecasting of project resources, optimization of stocks in the project supply chain	Regulating the level of project stocks; determination of supply volumes and frequency	SC inventory control; response to deviations from the planned level; stock maintenance	–
–	Planning of purchases, supplies to the project; preparation and signing of contracts between SC participants	Request information from suppliers; ordering resources; information on the fulfillment of orders of the SC participants; settlements on the fulfillment of obligations between the md participants	Administration of contracts	Expiration of contracts
–	Risk management planning, qualitative and quantitative risk analysis, risk response plan; defining methods of dealing with risks	Deviation of the values of indicators from the planned level	Tracking and risk management; risk register	–

The main indicators related to the processes of planning and supplying resources to the project, taking into account the theory of drug inventory management, are:

1. *Lead Time (LT)* – period from the moment of placing an application for a resource from the supplier until the moment of the possibility of shipment to the consumer.

2. *Planning Time-frame* – period for which it is supposed to implement a plan or program of action. For the supply chain – the period during which demand will be provided with a given service level after the goods arrive at the warehouse.

3. *Order Frequency (OF)* – period between two nearest orders.

4. *Deficit in inventory management* – event that shows the excess of demand for a resource over the available stock.

5. *Weighted Average Cost of Capital (WACC)* – average interest rate for all sources of financing of the company.

6. *Total Cost (TC)* of the supply chain.

7. *Service Level (SL)*.

SC components are the service level, logistics costs, the daily cost of stocks (Fig. 1) [17, 18].

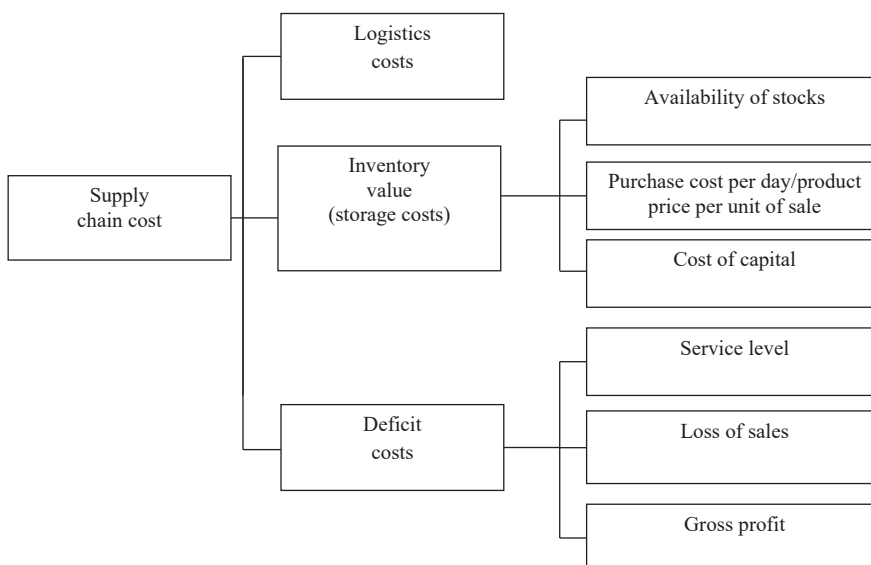


Fig. 1. Component indicators of the value of the supply chain

To determine the optimal resource provision strategy, one should take into account the economic trade-off between the cost of material shortages and the cost of maintaining surplus stocks. The key task is to determine the service level [19, 20].

Service Level is an indicator of the quality of service for counterparties in the supply chain.

There are two main types of service levels:

1. The service level of the first kind or the Cycle Service Level (*CSL*) is a statistical indicator reflecting the probability (*P*) that during the cycle of replenishment of stock (from placing an order to receiving products) there will be no resource shortage:

$$CSL = P(\text{Demand} \leq \text{Inventory}),$$

where *Demand* is the demand for the period for which *CSL* is calculated, *Inventory* is the volume of stocks at the beginning of the period for which *CSL* is calculated.

2. Service level of the second kind or saturation of demand (*Fill Rate, FR*) – the share of demand is guaranteed to be covered by the available stocks during the period of their replenishment:

$$FR = (1 - \text{lostDemand} / \text{forecastDemand}) \cdot 100 \%,$$

where *lostDemand* is the projected lost demand in natural units; *forecastDemand* is projected demand in natural units.

The cycle service level determines either the probability that there will be no shortage within a given time interval or, equivalently, the proportion of time intervals without a shortage. The length of the time interval depends on the type of inventory management policy.

Saturated service level shows the proportion of customer orders that were satisfied with the available inventory.

The optimal service level of the I or II kind is the service level at which the total losses in storage of stocks, losses in writing off expired products, losses from freezing of funds, as well as losses from potential shortages are minimal. Losses from freezing of funds (the cost of alternative investments) are determined in the form of an annual percentage rate of the cost of inventories in purchase prices. Usually, this percentage is determined as the current rate on deposits for legal entities, in which the funds are their own and the only alternative way to use them is to open a deposit. If there is a possibility of investing in business expansion with a certain rate of return, then the cost of alternative investments can be recognized as the rate of return. If the funds are attracted (credit), then they can be used to repay the loan, while the cost of alternative investments is determined as the interest rate on the loan.

Obviously, there is a relationship between the first and second indicators (Fig. 2).

Fig. 2 shows what the service level of the first and second kind looks like with a different amount of safety stocks, expressed in units of the standard deviation of demand (the level of stock is equal to the average demand plus *n* units of its standard deviation σ).

Thus, the main calculated indicators in probabilistic models are the average deviation of demand and the duration of the functional cycle, the value of the cyclic and safety stock [20, 21].

In accordance with the type and options for servicing the flow of resources, it is possible to distinguish between *decentralized and centralized allocation of resource stocks in the project* (Fig. 3).

In the case of *decentralized allocation of resources in the project*, the main indicator that affects the service level is the deviation of the order volume (demand) and the duration of the order execution cycle (lead time).

The standard deviation of a combination of random events (the volume of the order and the duration of the order execution cycle are subject to uncertainty) on the *i*-th object is equal to:

$$\sigma_{DLT}^i = \sqrt{T_i (\sigma_D^i)^2 + (\bar{D}_i)^2 (\sigma_L^i)^2}, \quad (1)$$

where T_i – average duration of the functional cycle of the *i*-th warehouse (in units of time); \bar{D}_i – average demand (in units of demand); σ_D^i – average deviation of the volume of demand established by a unit time interval; σ_L^i – average deviation of the duration of the functional cycle.

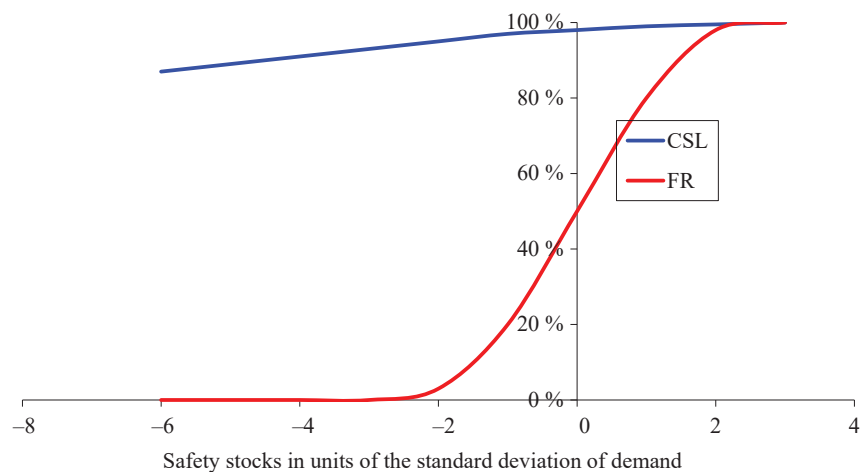


Fig. 2. Relationship between indicators of the service level of the first and second kind: CSL – Cycle Service Level, %; FR – Fill Rate, %

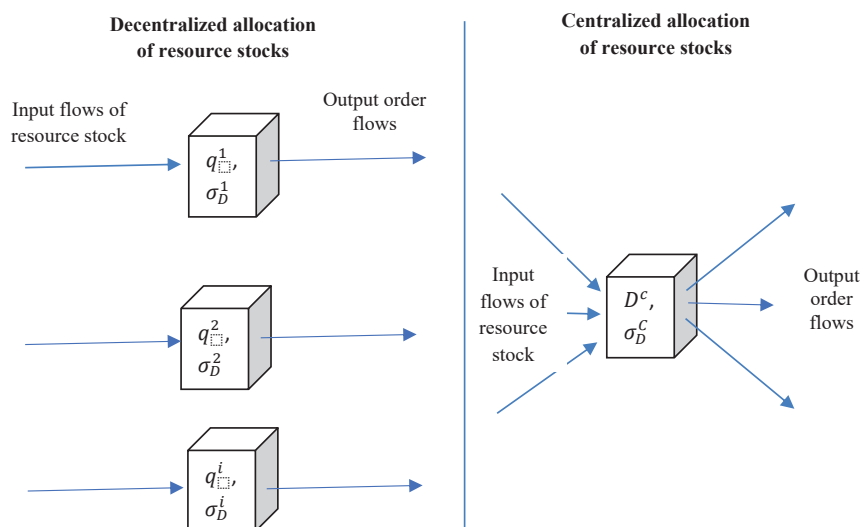


Fig. 3. Options for allocating resources in the supply chain

In the case of decentralized customer service, the duration of the functional cycle is constant, therefore $\sigma_L^i = 0$, and as a consequence:

$$\sigma_{DLT}^i = \sqrt{T_i (\sigma_D^i)^2} = \sigma_D^i \sqrt{T_i}. \quad (2)$$

Let's find the safety stock (SS):

$$\begin{aligned} SS &= \sum_{i=1}^n (f \cdot \sigma_{DLT}^i) = \sum_{i=1}^n (k_{CSL}^i \cdot \sigma_{DLT}^i) = \\ &= \sum_{i=1}^n k_{CSL}^i \left(\sqrt{T_i (\sigma_D^i)^2 + (D_i)^2 (\sigma_L^i)^2} \right). \end{aligned} \quad (3)$$

Total Cycle Stock (TCS) is set by the formula:

$$TCS = \sum_{i=1}^n \frac{q_i}{2} + SS. \quad (4)$$

In order to *centrally service the flow of stocks*, let's consider a supply chain that concentrates the flow of stocks in one accumulation and distribution center that performs the function of aggregating stocks and is able to serve all the stated demand. The total (aggregated) demand (D^c), formed by all consumers of services for the storage and distribution of stock (multi-item stock flow), subject to the normal distribution law. The nature of the demand for products can be dependent and independent:

$$D^c = \sum_{i=1}^N q_i^*; \quad (5)$$

$$\sigma_D^c = \sqrt{\sum_{i=1}^N (\sigma_D^i)^2 + 2 \sum_{i>j} \rho_{ij} \sigma_D^i \sigma_D^j}, \quad (6)$$

where ρ_{ij} – correlation coefficient.

Let's assume that demand is an independent quantity (correlation coefficient $\rho_{ij} = 0$) let's obtain:

$$\sigma_D^c = \sqrt{\sum_{i=1}^N (\sigma_D^i)^2}. \quad (7)$$

The average lead time in the consolidation center is equal to T^c with the standard deviation σ_T^c . Demand D_{DLT}^c is concentrated in a central hub:

$$\sigma_{DLT}^c = \sqrt{T^c (\sigma_D^c)^2 + \left(\overline{D^c} \right)^2 (\sigma_T^c)^2}. \quad (8)$$

Let's assume that the lead time (T^c) is constant:

$$\sigma_{DLT}^c = \sqrt{T^c (\sigma_D^c)^2} = \sigma_D^c \sqrt{T^c}. \quad (9)$$

Let's find the value of the safety stocks (SS^c):

$$SS^c = f \sigma_{DLT}^c = K_{CSL}^c \sigma_{DLT}^c = K_{CSL}^c \sqrt{T^c (\sigma_D^c)^2 + \left(\overline{D^c} \right)^2 (\sigma_T^c)^2}. \quad (10)$$

In case the lead time is the order duration (T_c) is constant:

$$SS^c = K_{CSL}^c \left(\sigma_D^c \sqrt{T^c} \right). \quad (11)$$

The total cycle stock is:

$$TCS^c = \frac{D^c}{2} + SS^c. \quad (12)$$

Thus, the volumes of orders and stocks for each type of project resources are determined by their specifics, fluctuations in the delivery system, the importance for the project's work and significantly affect the cost of the resource supply chain (total cost, TC):

$$TC_i = U_i \cdot D_i + c_{oi} \cdot \frac{D_i}{q_i} + c_{hi} \cdot \left(\frac{q_i}{2} + SS_i \right), \quad (13)$$

where U_i – cost of the resource; c_{oi} – cost of placing orders (delivery) of the i -th resource; c_{hi} – costs of maintaining the reserves of the i -th resource; D_i – annual demand for the i -th resource; q_i – economic size of the order of the i -th resource; SS_i – safety stock of the i -th resource.

Then, the cost of a multi-product supply chain with a decentralized allocation of resource stocks is equal to:

$$TC = \sum_{i=1}^N TC_i. \quad (14)$$

The cost of a multi-product supply chain with a centralized allocation of resource stocks:

$$TC^c = \sum_{i=1}^N U_i \cdot D_i + c_o \cdot \frac{\sum_{i=1}^N D_i}{D^c} + c_h \cdot TCS^c, \quad (15)$$

where c_h – cost of maintaining the inventory of a consolidated batch of resources; TCS^c – a common cyclical fund with a centralized location of a multi-product supply chain.

Let's consider the process of material and technical provision of resources (fertilizers) to an agribusiness project. The main product of the project is high-quality winter wheat. To ensure the key phases of winter wheat growth, depending on soil fertility, it becomes necessary to apply nitrogen and phosphate fertilizers throughout the year. The estimated size of the area to be treated with fertilizers is 100 hectares. Fertilizer supply chain logistics coordinates the activities of sea carriers, warehouses, railways and road transport. For the accumulation and storage of fertilizers, the pier and near-rail regional integrated bases with a cargo turnover of 100, 60, 45 and 10 thousand tons per year are used. The pier warehouses are used for receiving, storing and delivering mineral fertilizers to consumers from river or sea vessels. Railroad – for receiving fertilizers from railway transport, storage and shipment to vehicles of various dry and liquid mineral fertilizers, dusty and fine lime materials, chemical plant protection products, highly active toxic substances, intended for supply in a centralized manner to farms of several adjacent areas.

In the supply chain, two supply options are considered. The first provides for direct deliveries of fertilizers to the end consumer from independent suppliers (Table 2). The second is the accumulation and delivery to consumers, if necessary, of a consolidated batch of fertilizers (Table 3). Fertilizer demand varies with climatic factors and current soil conditions. The cost of fertilizers and the cost of logistics will change.

Table 2

Calculation of the total cost of the supply chain of mineral fertilizers with decentralized maintenance of the stock flow (service level – 99 %)

Indicators	Symbol	Unit	Value		
			1 warehouse	2 warehouse	3 warehouse
Annual demand for the i -th resource purchased from the warehouses of independent suppliers	D_i	t	36	50	20
Resource cost	U_i	USD/t	300	350	200
Costs of placing orders (delivery)	C_o	USD/t	40	35	30
Inventory maintenance costs (per month)	C_h	USD/t	25	25	25
Economic order size	q_i	t	5.6	11.5	19.2
Average duration of the functional supply cycle through the i -th warehouse	\overline{T}_i	day	92	83	101
Average monthly demand	\overline{D}_i	kg	3000	5000	8000
Average deviation of the volume of demand during the functional supply cycle	σ_D^i	kg	100	120	150
Average deviation in delivery cycle time	σ_L^i	day	2	2	3
Average deviation for a combination of random events (order quantity and lead times are subject to uncertainty)	σ_{DLT}^i	t	2.46	7.16	8.68
Safety stock	SS_i	t	7.38	21.48	26.03
General safety stock	$\sum SS_i$	t	54.89		
General cyclical fund	TCS	t	72.94		
Total supply chain cost	TC	USD	34566.66		

Table 3

Calculation of the total cost of the supply chain of mineral fertilizers with centralized maintenance of the stock flow (service level – 99 %)

Indicators	Symbol	Unit	Value		
			1 type of fertilizer	2 type of fertilizer	3 type of fertilizer
Annual demand for resources, consolidated in the accumulation and distribution warehouse	D_i	t	36	50	20
Resource cost	U_i	USD/t	300	350	200
Costs of placing orders (delivery)	C_o	USD/t	30		
Inventory maintenance costs (per month)	C_h	USD/t	50		
Economic order size	q_i	t	5.6	11.5	19.2
Total order size	D^c	t	36.3		
Average lead time through the resource consolidation center	T^c	day	19.2		
Total monthly demand	D^c	kg	10000		
Average deviation of the volume of demand during the functional supply cycle	σ_D^c	t	0.22		
Average deviation for a combination of random events (order quantity and lead times are subject to uncertainty)	σ_{DLT}^c	t	0.96		
Safety stock	SS^c	t	2.89		
General cyclical fund	TCS^c	t	7.89		
Total supply chain cost	TC^c	USD	32782.1		

A comparative analysis of the characteristics of decentralized and centralized maintenance of a multi-product flow of fertilizer stocks to an agricultural project site shows that if the methodology of centralized maintenance of the stock flow is applied, a decrease in the total cost of the supply chain is observed. This did not change the target service level.

7. SWOT analysis of research results

Strengths. The approach proposed in the study makes it possible to determine the amount of stocks for each type

of resource in a project that has a significant impact on the procurement planning processes and the procurement of resources. The use of tools of modern concepts of logistics and project management, the theory of reserves and the theory of probability allow to obtain positive results.

Weaknesses. The disadvantage of this study is the lack of analysis of parameters that affect the duration of the supply cycle, namely the time and volume of supplies, which will be the topic of the next study.

Opportunities. The peculiarity of the proposed approach consists in determining the timing and volumes of supplies

during the implementation of the project, which, in conditions of uncertainty, contributes to the identification of a deficit or excess of reserves. Thanks to the methodology proposed by the authors, the safety and cyclical stock in the delivery system for the project works is determined with centralized and decentralized maintenance of the stock flow. The results of this study make it possible to increase the efficiency of the project's effectiveness through an integral consideration of the theory of supply chain management and PM.

Threats. The study does not require any material and technical base for its implementation, but only statistical information on the initial flows of resources, purchases and the timing of the supply cycle for the required resources. This information is difficult to access for project managers, so calculations are time consuming.

8. Conclusions

1. The main indicators related to the processes of planning and supplying resources to the project have been determined, namely, the delivery time, the planning horizon, the frequency of orders, the deficit in inventory management, the cost of capital, the cost of the supply chain and the service level.

2. The concept of «service level» has been investigated, which affects the project inventory management policy. There are two main types of service levels in the supply chain – service level of the first kind or cyclical service level and the service level of the second type or saturation of demand.

3. Conceptual modeling of supply chains with decentralized and centralized options for organizing the flow of resource stocks has been carried out. The total cost of the supply chain has been determined, taking into account the possibility of fluctuations in the demand for resources and cases of non-compliance of delivery times with the terms set according to the delivery plan.

Modern project team managers responsible for supplying resources are increasingly making decisions about the organization of supply chains. They determine the volumes of supplies, balance the total supply of resources and the output (distribution) flows of resources for carrying out work on the project. In real business practice, there is always an element of randomness and uncertainty, the timing and volume of deliveries may fluctuate. Inventory management is carried out to ensure the planned progress of the project. The effectiveness of inventory management is closely related to the effectiveness of procurement and supply planning.

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