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THE ECONOMIC-MATHEMATICAL MODEL OF THE ORGANIZATION ACTIVITY OF THE MODERN TRANSPORT-LOGISTICS SYSTEM

ЭКОНОМИКО-МАТЕМАТИЧЕСКАЯ МОДЕЛЬ ОРГАНИЗАЦИОННОЙ ДЕЯТЕЛЬНОСТИ СОВРЕМЕННОЙ ТРАНСПОРТНО-ЛОГИСТИЧЕСКОЙ СИСТЕМЫ

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Abstract. In the paper have been defined third party logistics as an external logistics service provider offering single or multiple logistics activities to its customers, which typically is on contract basis. There are developed economic model, the organization of work of the company level 3PL and 4PL.

Аннотация. В данной статье авторами определена сторонняя логистика как система поставки внешних логистических услуг, где клиентам предлагается единая или множественная логистическая деятельность, которая обычно находится на контрактной основе. Разработана экономическая модель организации работы уровня компании 3PL и 4PL.

Keywords: third party logistics, economic model, the company level 3PL and 4PL, customers, logistics operators.

Ключевые слова: логистика третьей стороны, экономическая модель, уровень 3PL компании и 4PL, клиенты, логистические операторы.

Introduction

Complicating technological processes, increasing the diversity of modern economic life and expanding the types and processes of production and consumption of economic goods cause a corresponding increase in the complexity of the organization of logistics chains and approaches to the organization of logistics activities. At the same time, economies of scale (long-term cost reduction per unit of output when the production is enlarged) and the possibility of taking advantage of the growing experience of logistics organization dictate the expediency and profitability of managing the supply chain and related services by different companies from specialized service providers - logistics companies at 3PL level and 4PL. The synergistic effect of the interaction of the above factors can also reach a significant value.

In addition, economies of scale can be manifested not only in the usual opportunities to justify fixed costs by means of more complete exploitation of capital resources (including infrastructure resources), but also by the possibilities for more complete smoothing of stochastic elements in the nature of products in supply chains. In other words, the possibility of joint processing

(transportation, storage and distribution) of products in the supply chains of numerous customer companies of a logistics company of the 3PL and 4PL level allows achieving greater stability of the cargo flows in general, and, therefore, leads to lower requirements for reserves for additional capacity (free storage space, transport resources and information resources).

It is not difficult to see that economies of scale, understood in this broad sense, extends also to information support products in supply chains. In particular, the company level 3PL and 4PL, providing supply chain management for many manufacturers, can allow more advanced information system maintenance of products, as well as more accurate tracking of the condition products at all levels of the logistics chain.

Literature review

Various aspects of transport logistics and the problems of the formation of TSL are presented in the works of foreign and domestic authors such as D. Kloss and D. Bowersox, T. Goldsby, A. Harrison, A. Chernovalov, D. Kurochkin, V. Bulavko, P. Nikitenko, I. Elovoi, etc. Despite the great attention of scientists to the issues of logistics, the current conditions for economic development dictate the need for the development of theoretical aspects of logistics and the constant updating of methods and methodology, the development of new assessment methods that are based on the principles of logics and took into account the specifics of the country's development [1-5].

Analysis of existing methods of assessing the effectiveness of logistics systems has made it possible to identify their shortcomings and bottlenecks for the evaluation of TL. Each method is isolated does not give a full-scale evaluation of the TLF. Existing methods are used mainly to assess the system of cargo transportation and do not allow assessing the related services and all elements of the TL. It should be noted that in most cases, the effectiveness evaluation is carried out for enterprises, logistics operators or regions, i.e. at the micro and macro levels. Therefore, it is urgent to develop a methodology for assessing the economic effectiveness of the TLS of the national economy.

Analysis of works of domestic and foreign experts in the field of logistics and supply chain management dealing with logistics theory issues — Gaifullin B. P., Obukhov I. A. [1], Zaitsev E. I. [2], Dybskaya V. V. [3], James R. Stock, Douglas M. [4], Kozlovsky V. A., Kozlovskaya E. A., Savrukov N. T. [5], Medvedev S. V. [6], Mikoni S. V. [7], Hansfield R., Nicole E. L. [8], Nosov A. L. [9], Myitcha S. Yu. [10], Ballou, R. H. [11] and Ivanov D [12] etc. showed that there is a possibility of a significant increase in the efficiency of the logistics company management system due to the use of informational theoretical and methodological problems related to the development of modern models, principles and methods of making scientifically-based management, design and investment decisions, in order to improve the efficiency of management systems for logistics companies. In particular, the theoretical and methodological foundations for the creation and implementation of information systems in logistics companies, as well as economic-organizational and economic-mathematical models that solve the tasks arising in the process of the logistics company activity are not fully developed. These circumstances predetermined the choice of the research topic.

Research findings and discussion

Mathematical model of organization of work in order to save on capacity reserves through the use of logistics operators level 3PL/4PL.

Consider M companies serving requests for some products of production. Suppose that the company's ordering system number *i (i=1... M)* there are requests for the supply of the product

according to the distribution Puasson with intensity λ_i. Suppose also that the supply chain uses warehousing services in a specific location (related to need to ensure the processing of the product before sending it to the consumer at the loaded enterprise at that location) for a time t_i. Thus, the average quantity of products in the warehouse will be is equal to $\lambda_i t_i$.

At the same time, the process of receipt of applications is random, and therefore the reserve capacity of the warehouse will be determined taking into account place not only the average number of products, but also some kind of additional stock. Denote the total number of products produced, which can be placed to companies number *i* in the reserved them storage areas, through $\bar{n}_i$.

Then the probability that products production company number *i*, which must be placed in the warehouse, will be more than the site allocated to the enterprise, is calculated by the following formula:

$$P(\eta_i \geq \bar{n}_i) = e^{-ë_i} \sum_{k=\bar{n}_i}^{\infty} \frac{ë_i^k}{k!} = 1 - e^{-ë_i} \sum_{k=0}^{\bar{n}_i - 1} \frac{ë_i^k}{k!}. \quad (1)$$

As you would expect, the larger the amount of reserved warehouse $\bar{n}_i$ the less this probability. Suppose that company *i* can long term lease warehouse space in the amount of $\bar{n}_i$ n for the price $s_i(\bar{n}_i)$ for one stored goods. It is natural to assume that the function $s_i(\bar{n}_i)$ decreases, in other words, the price warehouse rent per unit area decreases with the growth of the leased area (wholesale discount). However, the decrease is rather slow, so that the total the amount of rent payments was higher for large areas: in other words, the total the amount of lease payments $s_i(\bar{n}_i)\bar{n}_i$ increases.

At the same time, in case of excess of the stored goods The Company can provide storage of additional volume only for many higher fees S_i:

$$Si > s_i(1) \geq s_i(2) \geq s_i(3) \ldots \quad (2)$$

In this case, the optimal choice for companies at a long-term level leased storage areas $\bar{n}_i$ n will be determined by minimization storage costs, that is, we arrive at the problem of minimizing the next objective function:

$$\min S_i \, e^{-ë_i} \sum_{k=\bar{n}_i}^{\infty} \frac{ë_i^{k(k-\bar{n}_i)}}{k!} + si(\bar{n}_i)\bar{n}_i =$$
$$\min S_i \left(ë_i (1 - e^{-ë_i} \sum_{k=0}^{\bar{n}_i - 1} \frac{ë_i^k}{k!} \right) - \bar{n}_i (1 - e^{-ë_i} \sum_{k=0}^{\bar{n}_i - 1} \frac{ë_i^k}{k!})) + si(\bar{n}_i)\bar{n}_i \quad (3)$$

An example of using the proposed mathematical model.

As an illustration, consider the following example. As Specific costs for renting warehouses we take the function $s_i(\bar{n}_i) = n^{-0,5}$, which gives the costs, expressed in thousands of rubles. per unit of production per month. Thus, renting warehouse space by only one unit products will cost one thousand rubles per month. However, the lease of 100 units' products will cost only 100 rubles per month per unit of output (and will be 10 thousand rubles. generally). As "extraordinary" costs of i S_i, carried in In case of exceeding the quantity of goods received, the area of ordinary rented warehouses, we take the value of 10 thousand rubles for a unit products per month.

Figure .1 shows the storage costs for goods companies in this case for several values of the average expected the number of stored products (ë = 80, 90 and 95). In this case, the optimal the number of leased storage facilities (expressed in units of stored production) is 104 for ë = 80, 116 for ë = 90 and 121 at ë = 95.

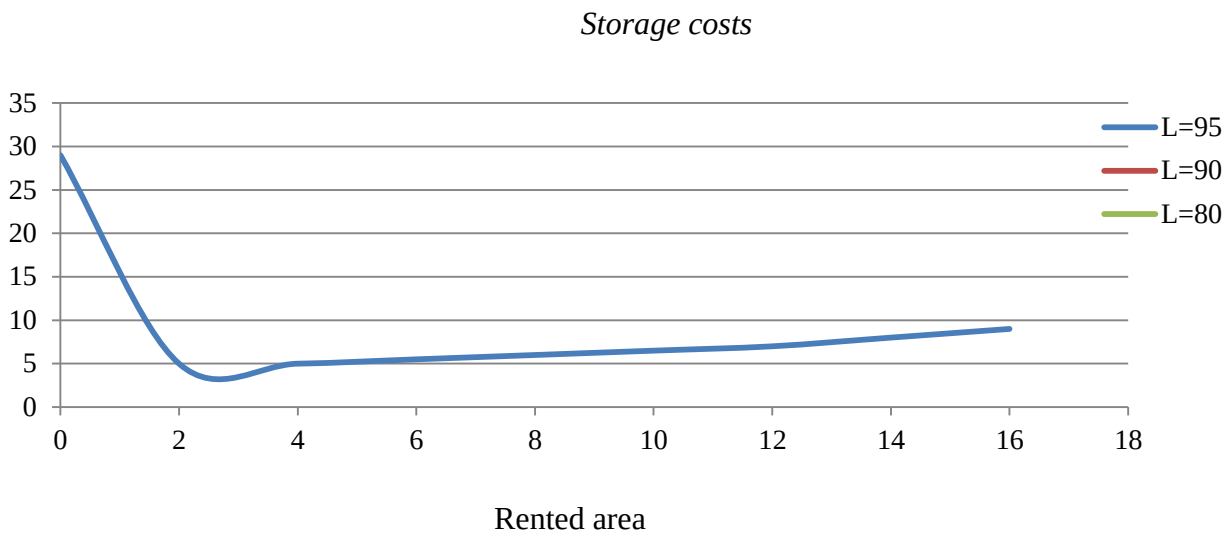

Figure 1. Charts of storage costs, thousand rubles, with several values of the average expected number of stored products (ë = 80, 90 and 95).

Suppose now that the company is turning to services logistics company level 4PL, which is able to provide it corresponding services of warehouses. Since the logistics The company specializes (in contrast to the manufacturing company) in the provision of logistics services, including warehousing services, it, in general, is able to bear the costs of securing warehouse space, much lower than those borne by the company itself (2). We denote by corresponding costs with similar symbols:

$$S > s(1) \geq s(2) \geq s(3) \ldots$$

In addition, suppose that 4PL-company serves all companies *i*, presented in our problem (*i=1... M)*. In this case, arrival warehouse storage in a logistics company will also be expressed Puasson process with parameterë $= \sum_{i=1}^{m} ë_1$.

In particular, the optimal selection of reserved warehouse volumes $\bar{n}$ of the 4PL logistics company is the solution of the problem of minimization of the following objective function:

$$\min S\left(ë(1 - e^{-ë}\sum_{k=0}^{\bar{n}_i-1}\frac{ë^k}{k!}\right) - \bar{n}(1 - e^{-ë}\sum_{k=0}^{\bar{n}_i-1}\frac{ë^k}{k!})) + s(\bar{n})\bar{n} \quad (5)$$

In order to understand whether or not an appeal to the 4PL-company is effective the purpose of obtaining storage services and if it is effective, It is necessary to compare the average costs that, on average, each of the companies number (*i=1,...., M)* in this or that case. In other words, we should compare the value of S in formula (3) with the value of S in formula (5) divided by *M*.

For simplicity, suppose that all companies (including the 4PL-company) bear the same costs for leasing (or maintenance) of a given amount warehouse areas, given by the values in the formula (4). In other words, we assume that the logistics company does not have any advantages before the client companies in the use of storage facilities. AT the benefits we received from the use of logistics services the company in practice will increase even more due to the fact that the logistics company will be able to transfer its lower costs for the organization logistics operations (including storage of goods) in reducing tariffs for of client companies.

In this case, the issue of profit for the company from the use of services logistics company level 3PL or 4PL will be determined by the behavior the following function:

$$F(M) = \min_{\bar{n}} S\left(ë(1 - e^{-ëM}\sum_{k=0}^{\bar{n}_i-1}\frac{M^k ë^k}{k!}\right) - \frac{\bar{n}}{M}(1 - e^{-ëM}\sum_{k=0}^{\bar{n}}\frac{M^k ë^k}{k!})) + s(\bar{n})\frac{\bar{n}}{M}. \quad (6)$$

It is easy to see that this function decreases in M. really, the derivative with respect to M of the function G (n, M), which is minimized on the right-hand side of formula (6) is equal to:

$$\frac{\partial G}{\partial M} = -\frac{n}{M^2}\left(-S\left(1 - e^{-ëM}\sum_{k=0}^{n}\frac{M^k ë^k}{k!}\right) + s(\bar{n})\right) \quad (7)$$

At the same time, minimization in formula (7) implies that the expression in brackets in formula (7) is positive.

Thus, even in the absence of additional benefits from the use of a specialized logistics company level 3PL and 4PL the fact that the logistics company is able to provide services many companies simultaneously, in particular, in the part of providing warehouse services, allows to achieve significant savings in costs for these services.

In this particular example, we can calculate the minimum unit costs, in thousand rubles, for warehousing services F when referring to services of a logistics company of 3PL or 4PL level depending on The number of M similar" companies served by this logistics company. This dependence is shown in Figure 2.

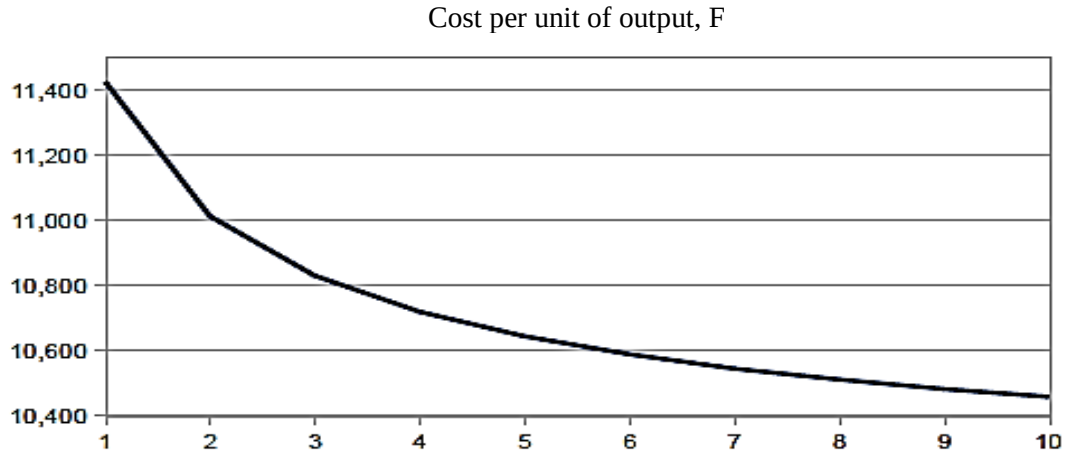

Figure 2. Costs (in thousands of rubles) of storage organization per unit of output in case of reference to a logistics company level 3PL (4PL), depending on the number of similar customers (1-10) in the logistics the company.

The more accurate data on which Figure 2 is based is collected in Table 1 In addition, Table shows the optimal values rented warehouses of a logistics company per one client.

It is easy to see that with an increase in the number of customers in the logistics company level 3PL (4PL) the need for additional storage per client (in comparison with the average required level) is reduced and in the limit does not much exceed the expected value number of client's stored goods (in our example, equal to λ =100).

Table

SPECIFIC STORAGE COSTS (F) AND THE OPTIMAL NUMBER OF LEASED STORAGE AREAS (N, IN UNITS OF STORED PRODUCTION) WHEN USING THE SERVICES OF A LOGISTICS COMPANY LEVEL 3PL (4PL), DEPENDING ON THE NUMBER OF CUSTOMERS OF THE LOGISTICS COMPANY (M)

M	*F*	*n*
1	11,4257	127
2	11,0123	119
3	10, 8292	115
4	10,7185	113
5	10,6431	112
6	10,5879	111
7	10,5437	110
8	10,5102	109
9	10,4810	109
10	10,4570	108

Savings from scale and the possibility of taking advantage of the growing experience of logistics organization dictate the feasibility and profitability of the organization of supply chain management and related services by different companies from specialized service providers - logistics companies of the 3PL and 4PL level.

Among other factors contributing to the advisability of accessing the services of companies of the 3PL and 4PL level, one should mention the cost savings caused by carrying out logistic operations related to transportation in the same company, as well as the possibility of more smoothing of stochastic elements in the nature of the products in the supply chains.

Conclusion

The economies of scale associated with the allocation of fixed capital costs to a larger production process also extend to information systems implemented to better support logistic flows, which also contributes to the expediency of using the services of logistics companies at the 3PL and 4PL levels.

The proposed model of organization of work of the company level 3PL (4PL) assumes the need to ensure the warehousing of the company's products coming with a certain intensity of the Puasson process. The need to lease (or carry current capital costs) of warehouse space to an unknown amount of incoming goods (products) reduces the amount of additional (reserve) warehouse space available over the average expected number of goods received. As a result, in the event of a significant excess of the volume of goods received, the company will have to incur additional significant costs for organizing extraordinary storage. The model shows, however, that using the services of a logistics company at the level of 3PL (4PL) in the organization of storage can significantly reduce the costs incurred by the company due to insufficient provision of reserve storage space. Thus, the services of a logistics company at the level of 3PL (4PL) will be demanded by consumers of transport services even based solely on the possibility of saving on warehouse costs.

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