THE EFFECTIVENESS EVALUATION OF INDUSTRIAL ENTERPRISES LOGISTICS SYSTEMS

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Abstract

The article is devoted to the research of indicators for evaluating the efficiency of industrial enterprises logistics systems. The author proposed four assessment parameters, such as logistics costs, logistics service, logistics cycle and logistics risks. As a result of the research, a list of logistics costs of industrial enterprises, a list of logistics risks for these enterprises were developed. Based on which indicators of levels of logistics costs efficiency, system resilience to logistics risks, the quality of logistics services and the duration of the logistics cycle were proposed. These levels allowed to develop the integral efficiency assessing indicator of the industrial enterprises logistics systems.

Key words: logistics system, industry, logistics service, logistics risks, logistics costs, logistics cycle.

1. INTRODUCTION

One of the key concepts used in the framework of the research is the concept of "efficiency of the logistics system". According to M. N. Grigoriev, A. P. Dolgov, and S. A. Uvarov, the effectiveness of a logistic system is "the ratio between a given (the target indicator of the result of the functioning of the system and the actually realized one" (Grigoriev et al., 2014), that is, the degree of actual achievement of the result logistics activity. In addition, the effectiveness of the logistics system can be interpreted as an indicator (or a system of indicators) that characterizes the quality level of the logistics system at a given level of overall logistics costs (Dybskaya & Sergeev, 2016).

Currently, there is no universal system of indicators and methods for evaluating the effectiveness of the micrologistical system of the building materials industry enterprises, which would take into account the specific features of a particular enterprise, the quality of logistics services to consumers and the threat of the external environment. The most common tool for evaluating the effectiveness of the functioning of logical systems is the determination of logistics costs or profits from the implementation of logistics operations (Sergeev, 2011). So, there is an approach according to which "the efficiency of a logistics system is a criterion characterizing

the profitability of its work. To compare logistic or transport-technological systems, it is advisable to calculate their effectiveness relative to gross income or average income" (Salum, 2006). However, this approach does not take into account the logistics services to consumers and focuses only on the costly component of the efficiency of the logistics system.

Some scientists (Sergeev, 2011; Baranovsky & Shishlo, 2008), agree that in the conditions of the formation of a market economy, the assessment of the efficiency of the logistics systems of enterprises must be carried out taking into account the assessment of logistics services to consumers. The authors M.N. Grigoriev, A.P. Dolgov and S.A. Uvarov hold a similar opinion, therefore they developed an integral criterion of optimality, or a criterion of the minimum of the total logistic costs of the logistic system, taking into account the quality of customer service.

There is an approach (Yashin & Ryashko, 2014), where in addition to the specified indicators for evaluating the performance of micrologistical systems, indicators of the total duration of logistic processes in the system and the overall performance of the business system are included.

However, in modern conditions of a rapidly changing external environment of an enterprise, assessing the efficiency of its micrologistical system, it is necessary to take into account and analyze the risks that arise in the implementation of logistic operations. These differences lie in a significant variation of such parameters as the time for the implementation of logistics operations and the quality of logistics services. In addition, there are various types of logistical risks that affect the receipt of finished products in time and the required quality. Therefore, approaches to evaluating the performance of micrologistical systems, based only on the assessment of logistics costs, profits from logistics activities and quality of service, are already insufficient for a comprehensive analysis of the functioning of the micrologistical system.

In this paper the method of effectiveness evaluation of industrial enterprises logistics systems is represented based on sequential calculation levels of logistics costs, quality of logistics service, logistics cycle and logistics risks.

2. THE METHOD OF EFFECTIVENESS EVALUATION OF INDUSTRIAL ENTERPRISES LOGISTICS SYSTEMS

The method developed by the author for assessing of the effectiveness of industrial enterprises logistics systems includes the definition of the following levels:
1) the effectiveness of logistics costs C;
2) the quality of logistics services S;
3) the duration of the logistic cycle D;
4) system resilience to logistical risks R.

Further, we will analyze in detail the steps of determining the indicated indicators for evaluating the effectiveness of the micrologistical systems and an integral indicator of the efficiency.

2.1. Determination of the logistics costs efficiency level

The study of logistics costs first began in foreign literature in the 60s. XX century M. Kufel. He considered them as the costs of moving materials in the enterprise. From his point of view, "logistics costs are a category of costs, meaning the monetary expression of the use of the property of an enterprise caused by planning, execution and control (except for technological processes) of movement in time and space of all forms of materials" (Kufel, 1990). At the same time, the author did not single out the costs of maintaining stocks of raw materials, materials, finished products, packaging, post-sale service. Since the 90s. XX century the problem of studying and determining logistics costs was addressed in the work of such scientists as D. R. Stoke and D. M. Lambert (Stoke & Lambert, 2001), D. D. Bowersox, D. Closs (Bowersox & Closs, 1996), I. A. Elovoi (Elovoi, 2008), R. B. Ivut (Ivut, 2004), I. I. Poleshchuk (Poleshchuk, 2007) and others.

Some scientists (Elovoi, 2008; Poleshchuk, 2007) note that "a significant part of the logistics costs are transaction costs", i.e. the costs associated with the conclusion of transactions in the logistics chain. According to N. K. Moiseeva, logistics costs represent "the monetary expression of the used labor, means and objects of labor, financial costs and various negative consequences of force majeure events, which are caused by the pro-movement of material values in the enterprise and between enterprises, as well as maintaining stocks" (Moiseeva, 2008). Thus, this author adds the possibility of force majeure situations in the logistic system. Thus, it can be said that logistic costs are the cost of resources acquired and (or) required by an organization in the process of carrying out logistic activities.

There are many different approaches to the selection of characteristics of the classification of logistics costs. In the framework of the developed method for assessing the micrologistical system of the industrial enterprises, it is proposed to use simultaneously two such attributes to determine logistical costs, such as:
1) the functional area of logistics;
2) the level of management of the logistics system.

At present, when calculating the logistics costs of an enterprise, difficulties may arise due to the inability of the existing accounting and statistical reporting system of enterprises to isolate many components of logistics costs, and the lack of methods for calculating logistic risks. Therefore, employees associated with all elements of the micrologic system of an enterprise should be involved in calculating and allocating logistics costs, while managing the overall logistics costs remains with the management of the enterprise.

The experience of the companies shows that the analysis of logistics costs can be carried out as a percentage of standard, volume or resource indicators, for example:
  – "logistics costs in terms of sales;
  – individual components of logistics costs in relation to common of carving;
  – enterprise logistics costs in terms of standards or environments his level in the industry;
  – logistical costs in relation to the relevant items of the enterprise budget;
  – current budget logistics resources in relation to estimated costs " (Sergeev, 2011).

According to research conducted by Herbert W. Davis, a logistics consultant for a number of years, the share of logistics costs in sales of industrial enterprises in foreign countries is approximately 9% (Herbert, 2015). This value is proposed to be taken as the standard (optimal) and taken into account when determining the level of efficiency of logistics costs as follows:

$$C = 1 - \frac{P_{act} - P_{norm}}{P_{norm}}$$

where P_{norm} – the industry average (normative) value of the share of total logistic costs in the revenue from the sale of products of the industrial enterprise;
P_{act} – the actual value of the share of total logistics costs in revenue from the sale of industry products:

$$P_{act} = \frac{C_{log}}{R_s}$$

where C_{log} – total logistics costs, R_s – revenue from sales.

2.2. Determination of the logistic service quality level Q

"Service" is understood as customer service, which, in turn, creates added value for all participants in the supply chain. Many links in logistics systems and logistics intermediaries are service organizations, in which services are inextricably linked with the product. These links include various shipping companies, wholesalers and retailers, physical distribution organizations, etc. At the same time, the cost of services can significantly exceed the costs directly on production.

Currently, there is no single definition that reveals the essence of taking a logistics service. Based on the sources studied, it can be said that the logistic service is a complex of logistic services accompanying the movement of the logistic flow from the supplier of raw materials and materials to the consumer.

For logistic optimization of the service, it is necessary to accurately assess the quality of services using a system of indicators ranked according to their importance to consumers, and to minimize negative differences between expected consumers and actual values of service quality indicators.

Based on the research conducted, it is proposed to use the following system of the logistics services quality indicators for industrial enterprises (table 1).

Table 1. Developed system of the logistics services quality indicators for industrial enterprises

Indicator	Definition	Calculation formula
1	2	3
Completeness of logistics service K_1, %	An indicator that reflects the ratio of the number of logistic services provided to the number of potential logistics services.	$K_1 = \dfrac{m}{M} \cdot 100\,\%,$ where m – the number of logistic services provided;

		M - the number of theoretically possible logistics services.
Reliability fulfillment of the order, K_2, %	Indicator that reflects the reliability of management of all logistic flows in the system.	$$K_2 = \frac{O_{cont}}{O_{comp}} \cdot 100\ \%,$$ where O_{cont} – the number of orders executed in full compliance with the contract; O_{comp} – number of completed orders
Flexibility K_3, %	Indicator that reflects the ability to consider the wishes of customers by manufacturers: the ability to change the way the order is delivered, the possibility of obtaining information about the status of the order, etc.	$$K_3 = \frac{N_{ch}}{N_{req}} \cdot 100\ \%,$$ where N_{ch} – the number of changes made to orders; N_{req} - the number of customer requests for changes in the order
Reliability K_4, %	The indicator that determines the ability of the system to maintain the ability to work for a certain time	$$K_4 = \frac{O_{ex}}{O_{total}} \cdot 100\ \%,$$ where O_{ex} – number of orders accepted for execution; O_{total} – total orders
The share of "ideal orders" K_5, %	The indicator of the number of "ideal orders", i.e., those orders that were delivered to customers according to their bids in the right quantity, at the right time and of ideal quality	$$K_5 = \frac{O_{ideal}}{O_{total}} \cdot 100\ \%,$$ where O_{ideal} – number of "ideal orders"; O_{total} – total orders
Ready for order fulfillment K_6, %	An indicator that determines the ability of an enterprise to perform its functions when equipment, personnel is in working condition	$$K_6 = \frac{O_{term}}{O_{comp}} \cdot 100\ \%,$$ where O_{term} – the number of orders, the terms of which correspond to the terms of the contract; O_{comp} – number of completed orders

Order Fulfillment Ratio K_7, %	Indicator of the volume of materials and products produced in relation to the ordered value	$$K_7 = \frac{T_p}{T_o} \cdot 100\ \%,$$ where T_p – quantity of materials and products ordered and produced, $м^3$; T_o – total number of ordered materials and products, $м^3$
No claims K_8, %	Indicator reflecting the number of orders completed without customer complaints about the delivery, quantity, quality of materials and products, disruptions in delivery times, delays in delivery, driver behavior, shipping documents, etc.	$$K_8 = 1 - \frac{C_{rec}}{O_{total}} \cdot 100\ \%,$$ where C_{rec} – number of claims received; O_{total} – total orders

Source: Lapkouskaya, 2017.

To determine the level of logistics services, it is also necessary to calculate the rating (weight) of each indicator (Bi), where the sum of the weights of the indicators of the quality of the logistics service; i is the index of a specific indicator; n is the number of indicators. The determination of the weights should be carried out by a qualified group of experts from among the specialists and consumers of the enterprise under study. The group should be a representative sample of the total number of professionals and consumers. For this purpose, a matrix is created that allows you to prioritize among indicators. Comparison of indicators produced by the method of pair (binary) ratios. From the point of view of experts, the more important criterion is assigned the value "1", the less important - "0". After that, the result for each of the indicators is summed up and all amounts are reduced to one denominator, i.e., to the total number of indicators. Thus, we get the weight of each indicator. The matrix for calculating the rating of each indicator has the form presented in table 2.

Table 2. The matrix for calculating the weights of the logistics service quality indicators

Indicator	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8
K_1								
K_2								
K_3								
K_4								
K_5								
K_6								
K_7								
K_8								
Sum								

The calculation of the logistics services quality indicators is carried out according to the formulas presented in table 1. After calculating the private indicators $K_1 - K_8$, it is proposed to calculate the integral indicator of the quality level of the logistics service based on the arithmetic average weighted by the following formula, since the average value is calculated in this case using grouped data.

$$S = \frac{\sum_{i=1}^{8} K_i \cdot B_i}{\sum_{i=1}^{8} B_i}, \qquad \sum_{i=1}^{8} B_i = \frac{n-1}{2}.$$

The developed approach to assess the quality of logistics services can also be used separately, outside the assessment of the enterprise's logistics system.

2.3. Determination of the logistics cycle duration level D

The unification of logistics processes, which is aimed at improving the quality of logistics services and reducing logistics costs, is to a greater extent realized through the typification of logistic technologies of operational and transactional components. Typing of economic relations in the logistics system leads to the recurrence of relations, which streamlines the process of product distribution and helps reduce risks. In this case, we can talk about the presence of a cyclic connection between the links of the logistics system. Cyclic communication not only provides for the presence of feedback in the control system of each link, but in general is itself a complicated, mediated type of feedback.

Cyclic communication is present in all logistic systems in various forms and combinations. Thus, a high level of logistic services to the manufacturer of products with raw materials and materials contributes to the normal flow of the production process, which in turn leads to the creation of conditions for a high level of supply of finished products. In this case, the competitiveness of the manufacturer increases, its market position improves, which leads to an increase in demand for materials from the supplier. Such processes are studied by the theory of cycles — a systems theory that studies patterns in the formation of the structure of cycles in the processes of functioning of various types of systems.

Logistic cycles are formed due to the repetition in time and space of the necessary and sufficient sequences of logistic operations. A full logistic cycle is one of the basic concepts in logistics — this is the "order lead time — the time interval between placing an order and delivering an ordered product or service to an end user" (Dementiev, 2013). The logistics cycle, as a rule, includes the time of transfer, processing, placement, production and (or) picking, transportation of the order and the time of receiving goods by the consumer. Each of these steps takes time. The duration of the stages and the total duration of the logistic cycle may have temporary deviations.

The duration of the stages of the logistics cycle, according to D. Bowersox and D. Kloss, J. Stock and D. Lambert, are given in table 3.

Table 3. The duration of the stages of the logistics cycle in the organization

Stage of logistics cycle	D. Bowersox, D. Closs		J. Stock, D. Lambert	
	Value range	Expected range	Value range	Expected range
	0,5–3,9	1	0,5–3,9	1
Preparation of the order and its transfer, h	1–4	2	1–4	2
Order receipt and processing, h	1–20	2	1–9	1
Picking or making an order, h	2–10	4	1–5	3
Order transportation, h	0,3–3,0	1	0,3–3,0	1
Order receipt by the consumer, h	5–40	10	3,5–20	8

Source: Bowersox & Closs, 1996; Stock & Lambert, 2001.

In the structure of a full logistic cycle for industrial enterprises, time can be allocated for the preparation of products for production requirements. For the consumer, the most important is the execution time of the four last points, since for him they are either partially controlled or unmanaged.

The main goal of managing the logistics cycle of an industrial enterprise is to ensure coherence in all levels of the logical system to meet the deadlines for order fulfillment. Any delay at any stage will be in danger at all subsequent stages of the cycle. If such delays or, on the contrary, premature execution of logistic operations occur periodically, this leads to the creation of additional stocks of raw materials and finished products. At the same time, high performance of each element of the logistic system is important only if it contributes to increased integration in the logistic system.

Thus, an increase in the efficiency of the duration of a complete logical cycle leads to an increase in the efficiency of the functioning of the entire logistics system of an industrial enterprise.

The duration of logistic processes in the T_{lc} logistics system includes the total time from receiving an order to the delivery of finished products to consumers, which can be presented:

$$T_{lc} = T_o + T_s + T_{pr} + T_{tr} + T_{st} + T_d,$$

где T_o– time of the order, h; T_s– time of supply of raw materials, h; T_{pr} – time of production of materials or products (including design), h; T_{tr}– time of domestic transport operations, h; T_{st}– time of storage of raw materials and finished products, h; T_d – time of delivery of finished materials and products, h.

To go to the specific indicator of the duration of the logistics cycle, it is proposed to use the indicator of the level of the duration of the logistics cycle D, which is determined by the formula.

$$D = \frac{T_{pr}}{T_{lc}}.$$

At the same time, as a compared parameter, time of production was chosen because it is governed by technical maps for production processes, standards and technical regulations and is relatively constant.

2.4 Determination of the system resilience level to logistics risks R

Logistics activity, starting from the process of moving goods and ending with the processes of their movement in the market space, includes various elements, the functioning of which is influenced by many factors, which means that certain risks arise.

In order to assess the logistics risks of industrial enterprise and the level of stability of the system to them, it is proposed to apply an integrated approach to risk classification and combine parameters such as an element of the enterprise logistical systems and a type of logistic flow within the framework of this method. Thus, each functional area of logistics is accompanied by material, informational and financial flows, each of which has certain logistical risks.

Assessment of the *resilience level of industrial enterprises logistics systems to logistical risks* is proposed to be carried out according to next formula.

$$R = 1 - \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} S_{ij}}{V_e},$$

where R – the level of system resilience to logistical risks;

S_{ij} – the maximum possible amount of loss (loss, loss of profit) on the logistical risk of the i-th flow of the j-th element of the system, monetary unit;

V_e – the amount of equity, monetary units.

Quantitative assessment of losses S_{ij} for an individual logistics risk of the i-th flow of the j-th element can be determined by the formula "loss assessment" (Ivut, 2004), interpreted for logistics risks:

$$S_{ij} = (p_{Hij} \pm \Delta_{ij}) \times K_{tij} \times C_0 \times D_{ij} \times p_{oij},$$

where p_{Hij} – the normative probability of the occurrence of the logistical risk of the i-th flow of the j-th element, the fraction of a unit;

Δ_{ij} – the share of increase or decrease in the logistical risk of the i-th flow of the j-th element for a specific case, the share of a unit

K_{tij} – coefficient taking into account the time of occurrence of the logistical risk of the i-th flow of the j-th element in relation to the normative probability, the share of a unit;

C_0 – the volume of investment in the logistics system, monetary units;

D_{ij} – the share of the part of the logistic system to which the given case of the logistical risk of the i-th flow of the j-th element, the unit share, is applied

p_{oij} – the probability of covering the negative impact of a specific logistical risk of the i-th flow of the j-th element in a given part of the logistic system, a fraction of a unit.

The most difficult moment in assessing the level of logistical risks is the determination of the probability of occurrence of each logistical risk taken for analysis. This problem can be solved in two ways:
1) on the basis of expert opinions, accept the likelihood of a situation causing a logistical risk;
2) to accept some standard level of probability of logistical risk in the logistic system with its possible increase or decrease considering the actual time level of risk manifestation (Lapkouskaya, 2018).

Within the framework of the developed methodology, it is proposed to establish a standard level of probability p_{Hij} of logistical risk in the logistic system with its possible increase or decrease considering the actual time level of risk manifestation using expert opinions. To do this, the following scales can be used (tables 4, 5, 6).

Table 4. The scale of probabilities of occurrence of risk p_{Hij} in the industrial enterprises logistics systems

Risk probability	Very low	Low	Medium	High	Very high
Probability value	0,05	0,10	0,20	0,40	0,80

Table 5. The scale of accounting for the occurrence time of logistical risk in the industrial enterprises logistics systems

Time of risk	Absolutely known	Known	Predictably	Unpredictable	Suddenly
The value of the time coefficient of risk occurrence K_{tij}	0,01	0,05	0,1	0,15	0,2

Table 6. Probability scale of coverage of the logistical risk negative impact in the micrologistical system links

Coverage of the negative risk effect in the link of the logistics system	Minor	Small	Medium	Significant	Full Coverage
The value of the probability of coverage of the risk negative impact p_{oij}	0,05	0,10	0,20	0,40	0,80

The share of the part of the logistic system to which this case of logistical risk Dij applies is assumed to be 0.2, since the developed method for assessing the

micrologistical system provides for the evaluation of the five main elements of the industrial enterprises logistics systems.
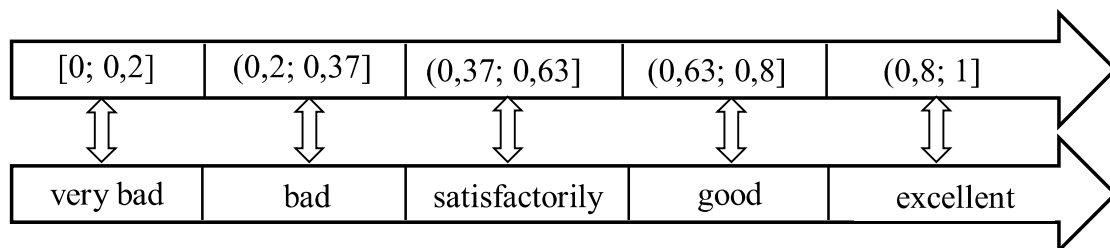
Thus, the efficiency index of the industrial enterprises logistics systems, can be calculated by the following formula based on the geometric mean, since the components of the index are in this case represented as relative values:

$$I_{ls} = \sqrt[4]{C \times S \times D \times R} \ .$$

The integral index is in the range from 0 to 1, the closer it is to 1, the more effective the micrologistical system. If it is impossible to determine one of the components of the integral indicator, its value is assumed to be 0.5.

The evaluation of the industrial enterprises logistics systems and the interpretation of the resulting micrologistical system efficiency index can be made on the Harrington desirability scale (Figure 4).

Figure 1. The scale of desirability for effectiveness evaluating of the industrial enterprises logistics systems

[0; 0,2]	(0,2; 0,37]	(0,37; 0,63]	(0,63; 0,8]	(0,8; 1]
very bad	bad	satisfactorily	good	excellent

The developed method for effectiveness evaluating of the industrial enterprises logistics systems in contrast to the existing methods:

 − is based on logistic integration, that is, it includes indicators of the efficiency of all functional elements in the industrial enterprises logistics system;

 − considers the logistical risks emerging in the industrial enterprises logistics system at its main links and the ability of the system to withstand these risks;

 − includes the use of quantitative, qualitative and temporal indicators for evaluating the effectiveness of the industrial enterprise logistics systems.

This method includes the sequential determination of four indicators for evaluating the effectiveness of logistics system:

 − the level of efficiency of logistics costs based on their aggregate developed for industrial enterprises for all elements of the micrologistical system;

 − the level of quality of logistic service using the developed system of private indicators of its quality (total number - 8) and integral indicator based on weighted average arithmetic using the expert method and the method of pair comparisons;

 − the level of the duration of the logistics cycle on the basis of determining the temporal characteristics of its stages in the enterprise (purchase, transportation, production, warehousing, distribution) for the main types of products;

 − the level of resilience level of industrial enterprises logistical systems to logistical risks based on the developed systems' risk for the industrial enterprise, assessment of losses from these risks for all logistic flows (material, informational and financial) and system elements, as well as on the basis of the developed scales in the micrologistical system, scales for accounting for the time of occurrence of risk,

scales for the probability of covering the negative impact of logistical risk in a specific element of the system);

    —   the integral indicator of the efficiency of the micrologistical systems in industry based on the geometric mean, since the component values of this efficiency index are presented as relative values.

3. CONCLUSION

The developed author's method of the logistics system effectiveness evaluation of industrial enterprises allows:

    —   to analyze the performance of micrologistical systems in the industry;

    —   to conduct a comparative analysis of the development of micrologistical systems of various industries;

    —   to determine the value and weight of each link of the logistics system of the enterprises;

    —   to identify the weak links of the enterprise logistical system in terms of logistics costs, logistics services and logistics risks;

    —   to find growth reserves in the development of the enterprise logistical system by comparing the results of the work of the systems links.

The presented assessment method can be used to develop strategies for the development of logistics systems of industrial enterprises, as well as to justify investments in certain elements of logistics systems. Further research will concern the development of economic and mathematical models for assessing the relationship between the development of the four developed indicators of the effectiveness of logistics systems and economic indicators of enterprise development based on multiple regression analysis.

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