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Research paper

Evaluation of the Reliability of Transport Service of Logistics Chains

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Abstract

The article presents the analysis of approaches connected with solving the problems of increasing the effectiveness of managing the processes of goods movement in the supply chains. The attention has been focused on estimating the qualitative component of transport services, and that is the reliability index. The approaches focused on improving the efficiency of providing transport services have been studied. The main parameters influencing the reliability of transport and logistics services are identified: time, qualitative and quantitative characteristics of the goods, as well as the financial component – the cost of the provided transport service. A new methodical approach to estimating the reliability of goods flows in the supply chains is proposed. It is based on the main principles of the theory of automatic regulation and the determination of the reliability of technical systems. A complex index of reliability of transport services of logistics chains is offered: the readiness coefficient and the technical use coefficient. On the basis of structural and parametric identification of the dynamic model of the logistic system of goods transportation, the considered approach allows identifying a large number of constructive and technological parameters which affect the movement of goods flows in the supply chains. The results of the simulation allow one to analyze the influence of the time constant T_{in} which characterizes the response time of the links in the transport and logistics system, that is, the ability of the transport service participant not to respond to any external influences, and the influence of the time constant T_{del} which is responsible for delays, non-productive time losses occurring during the delivery of the goods, on the dynamics of the transitional processes of the goods flow movement for each link in the supply chains. The elaborated method allows developing managing actions aimed at improving the quality of transport services.

Keywords: *reliability, transport services, logistics system, supply chain, cargo flow.*

1. Introduction

The process of material flows advance is one of the main elements of any production; an indispensable stage in the provision of services and an important indicator of the provision of human life needs. The key element of the transport service is the automobile. The quality of the provided services is evaluated both from the client's side: the shipper and the consignee.

One of the quality indicators of the transport service completion is reliability. In conditions of the highly competitive transport service market, this indicator should not be underestimated.

2. Analysis of Recent Studies and Publications

In a number of European firms and companies, the maintenance of material, information and other flows is based on the use of the principles of logistics [1].

Logistics is an important part of the material flows advance into the supply chains, and weaknesses in them often serve as the major source of risk. These problems include: availability of cargo, delivery time, tracking and quality of the goods. Until recently, the efficiency of transport services was mainly considered in terms of transportation costs. Nowadays, the efficiency of supply chains is also evaluated in terms of reliability [2]. Managing the transport service of a delivery means addressing the reliability of the delivery process itself, especially, with regard to delays and uncertainty in time, the quality and availability of the services provided and the risks of failure. All these risks can affect the main objectives of any supply chain: providing the produce of the necessary quantity and quality in the right place at the right time. An insufficient reliability of logistic services comes out of the inefficiency of the basic directions of its functioning – the infrastructure, first of all, the automobile one, and also the storage which is an integral component of chains of deliveries of agricultural production. This is connected with the fact that the harvest is usually collected within a short period of time, while its processing and consumption occurs during a year. The authors of work [3] show that storage is one of the main sources of risk in supply chains. The risk arises from losses during the storage time, as well as from the alternative value of the invested capital. Therefore, it is important to consider the integrity of the chain for balancing the reliability of transport and the organization of storage and processing of the produce.

According to the results of studies that do not require any significant costs, the most promising direction of increasing efficiency and productivity is the introduction of logistics concepts at the production [4]. An example of such concepts is the one that focuses on the execution of orders without any delays – "just in time." This concept is characterized by a reduction in inventories, optimization of transport routes through the use of a logistic

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concept. By coordinating the actions of all participants of the processes of transport services, the competent logistics allows to reduce the cost of the produce, increase the turnover of the capital and use the released funds for other production purposes. The factor of time, the cost and quality of the produce have the main role in determining the success of any production functioning under modern conditions. In turn, the time of the logistics cycle, logistics costs, the level of technical maintenance, the reliability of deliveries can be considered as the criteria for assessing the effectiveness of logistics management at the enterprise [4].

The authors of work [5] note the improvement of transport services for the agro-industrial complex through the improvement of the transportation technology with the use of transport logistics.

In work [6], the authors consider the influence of the time factor on the competitiveness of the enterprise. According to the conducted analysis, the time factor influences:

- the minimization of storage and storage costs due to the coordinated, efficient activities at the enterprise;
- the rapid adaptation to changes in demand through the introduction of a rapid response system that allows to reduce the performance time of operations and the delivery period;
- the elimination of the time of operations, that is, the reduction of the production cycle due to the decrease in the time of the material flow arrival in all the links of the logistic chain.

It can be concluded that the purpose of logistics goes beyond cutting costs and increasing profits, and it should be viewed as a transitional stage in terms of providing better and more reliable logistic services.

The work of the authors [7] is devoted to obtaining synergetic effect and improving the quality of logistic services, from the integration of transport service participants into a single logistic center. In their opinion, the unification into a single logistic chain and the development of an interaction scheme for all the participants will lead to the optimization of the processes of cargo transportation. Increasing the efficiency of the cargo delivery system management using logistic terminals and obtaining a synergistic effect through the optimization of technological and management solutions aimed at the resource saving and synchronization of logistic flows was pro-posed by the author of work [8]. In works [7, 8], the improvement of quality and, consequently, the reliability of transport processes, is considered through the introduction of interaction and coherence of the work of the supply chain participants.

In work [9], the authors note the possibility to provide a qualitatively new level of transport services for participants in the system. The use of innovative logistics as the most effective, market-oriented methodology for managing goods, material, transport and associated flows with the lowest costs has been justified. The authors' main emphasis was made on the formation of transport and logistics clusters (formed, as a rule, according to the regional principle) – as the most optimal form to organize partnership relations, integration and harmonization of interests of all participants. However, the proposed approach is aimed at improving the efficiency of transport services provided at the regional level, through the interaction of all participants in the transport and logistics system.

In work [10], the choice of the structure of the transport process and the evaluation of its quality is made with the use of an integral criterion. The most informative, among a large list of indicators, is time and costs for performing transport operations. However, the proposed option is quite laborious and does not affect the aspect of reliability of the warehouse terminal.

In the study given in [11], the author focuses on the fact that it is necessary to coordinate the level of reliability of the provided services with the customer. Reliability is one of the reasons why the automobile transport is losing an important competitive advantage in the world market of transport deliveries, as well as inside the country, relative to other modes of transport. The effectiveness of the transport system functioning of the transport deliveries depends directly on the identification and use of structural, resource and functional reserves in the transport system.

The reliability of the transport and logistics system can be considered from the point of view of several components:

- time;
- losses of qualitative and quantitative characteristics of cargo;
- costs of the delivery.

The authors of works [12-16] consider the reliability of providing transport and logistics services in terms of time and financial components.

In most cases, the quality of the transport process is analyzed by estimating the quality of the carrier itself.

The methodology for estimating the quality of the provided transport services from the client's view was proposed in [17]. However, the use of the SERVQUAL method is aimed at increasing the efficiency of managing the movement of goods flows connected with the international transport.

The study of supply chain performance indicators, carried out by the authors of [18], has shown the complexity of developing a criterion of the reliable operation of the transport and logistics system. The most significant problems were outlined, including the inconsistency and incompatibility of participants in the supply chain; the absence of one managing center; the complexity of choosing a rational delivery scheme and the consistency of the participants in the supply chain; the dynamism of the system, connected with changes in the parameters of cargo flows.

The importance of forecasting cargo flows for increasing the quality of transport services for production in modern conditions of economic development is substantiated by the author of [19]. In the author's opinion, the accuracy of forecasts of the perspective structure and intensity of cargo flows makes it possible to successfully solve a number of important optimization problems related to improving the efficiency of transport services for production. However, these studies are aimed at determining the necessary level of proportionality in the development of technical equipment and technology for the operation of industrial and trunk railway transport.

The authors of work [20] consider the reliability of the supply chain, based on the forecast values of the demand for transportation and the coordinated work of the links in the supply chain. The analysis of the conducted research has shown that getting the right information is the dominant factor increasing the reliability of the logistic system, allowing one to choose a rational technology of delivery, and making it possible to develop managing actions aimed at increasing the profit from the transport process. But these are only theoretical premises that require practical justification.

The analysis of the examined works shows that the problem of increasing the reliability of the transport service of the logistic system is topical. Considering the complexity of the functioning and interaction of links in the supply chain, there is the question of a more detailed study of this aspect. The proposed approach allows estimating the quality of the functioning of transport and logistics systems at the expense of a complex indicator. It takes into account the parameters of the work of transport service participants, the technical and operational characteristics of the system facilities, the probability of failure of the supply chain links, and the time indicators of the performance of the services provided.

3. The Basic Part of the Study

3.1. The Purpose of the Study

The purpose of the study is to develop a methodical approach to determining the reliability of the logistic supply chain functioning, taking into account the dynamic factor of time.

3.2. The Methodical Approach to the Justification of the Supply Chain Reliability Evaluation

The positive feature of dynamic models is that they allow obtaining a quantitative evaluation of the performance of the logistic system, on the basis of which the decisions on the configuration of the system, the performance of individual components of the chain and the necessary volume of resources, as well as the information and management transmission strategies connected with them, are made.

The distinctive feature of dynamic models is that the listed functioning indicators will be evaluated not in the form of constants, but in the form of time functions that reflect the dynamics of processes occurring in real systems.

The proposed option for estimating the reliability of transport services is based on the theory of automatic regulation and the approach used in technical systems in order to improve the quality of the work performed.

All logistic systems or logistic chains are inertial systems. After receiving the application for services, any link of the system goes to the maximum volume of processing (loading-unloading, transportation, etc.) not instantaneously, but after a certain period of time. Moreover, at the initial moment of time the volume of applications for services has the maximum value and, over time, gradually comes to some average indicator that provides the given level of the functioning of the system links.

The readiness coefficient C_R and the technical use coefficient C_{TU} are offered to be used as the integrated indicator of the reliability of transport services. At the planning stage the readiness coefficient provides an opportunity to estimate the potential capability of the system or its individual elements to fulfill the tasks assigned to them. Taking into account the calculated formulas and the results of modeling the probabilities of failure of the participants in the transport and logistics complex for the production of sugar beets, as described in [21], one can write down the formula for estimating the fact that the logistic links of the system will be capable of working at the given moment of time:

$$C_R = \left(1 - p_{fail,i}\right), \quad (1)$$

where $p_{fail,i}$ – the probability of failure of the i-th participant in the logistic system.

The coefficient of readiness of a logistics link (system) C_R - is the probability that the logistic system of transport services will be capable of working at any moment of time. That is, C_R estimates the potential capability of the technical object, and in our case – logistic links and logistic system. This is the forecast – either "will fulfill" or "will not fulfill."

The technical use coefficient estimates the result of the work fulfillment, i.e. how the fulfillment of processes in each link of the chain or the system, as a whole, corresponds to the established norms. It is calculated taking into account the time spent on performing services and time losses connected with this process. The formalization of the reliability indicator, which takes into account the dynamics of processes, i.e. the development of them over time, with all the delays and time necessary to eliminate them is given further:

$$C_{TU} = \frac{T_{in}}{T_{in} + T_{del}}, \quad (2)$$

where T_{in} – the time constant, responsible for the response time of the logistic system links, i.e. time for the task, an hour;

T_{del} – the time constant, characterizing delays in the logistic links, i.e. non-productive losses of time, an hour.

C_{TU} takes into account the dynamics of the process, that is, its development over time, with all the delays and time necessary to eliminate these delays.

The values of the time constants are determined by carrying out structural and parametric identification of the objects of the logistic system. Using the basic provisions of the theory of dynamic objects identification, a differential equation characterizing the dynamics of the transient process in the logistic system was obtained in work [22]. The solution of this equation makes it possible to simulate the processes of moving material and information flows in the logistic links in the dynamics:

$$y_i(t) = V_i \cdot \left[1 - e^{-\frac{d_{at}}{T}t} \cdot \left(\cos f \cdot t + Amp \cdot \sin f \cdot t\right)\right], \quad (3)$$

where y_i – the parameter of the logistic system functioning according to which the simulation will take place, t;

t – the current time according to which the simulation goes, an hour;

V_i – the forecasted volume of the material or information flow of the i-th participant of the logistic chain of transport services, t;

d_{at} – the damping decrement, it characterizes the oscillating (uneven) character of the transient processes. At $d_{at}<0.7$, the transient process has an oscillatory character, at $d_{at}\geq 0.7$, there is no unevenness:

$$d_{at} = \frac{\left(T_{in} + T_{del} + C_{In1} \cdot C_{In2}\right)}{2\sqrt{T_{in} T_{del}}}, \quad (4)$$

where C_{In1} – the amplification coefficient, characterizing the extent of the influence of the incoming flow V_i on the outgoing one y_i;

C_{In2} – the amplification coefficient, characterizing the extent of the influence of the out-going flow y_i on the incoming one V_i;

f – the frequency of fluctuations of the outgoing parameter due to delays in the passage of applications in the logistic system, 1/hour:

$$f = \frac{\sqrt{1 - d_{at}^2}}{T}, \quad (5)$$

Amp – the deviation value of the outgoing parameter from the average current value during the oscillation process:

$$Amp = \frac{d_{at}}{\sqrt{1 - d_{at}^2}}, \quad (6)$$

T – the time constant, characterizing the response time of the dynamic model of the logistic system, an hour:

$$T = \sqrt{T_{in} \cdot T_{del}}. \quad (7)$$

According to the theory set forth in [22], the time constants and the amplification coefficients are influenced by the technical and operational indicators of the work of the participants in the system, by the time and economic characteristics of the processes of the transport services fulfillment. The correct regulation of the above-listed components of the functioning of the transport and logistics system will allow, in a prompt manner, to make changes in the quantitative and qualitative composition of the logistic links in the chain.

The theoretical studies in [23-24] have shown that the optimal combination of time, financial, labor and technical parameters of the system corresponds to the equal productive capacities of all participants. The restriction on productivity is set by the cargo-

absorbing station. With the advance of material and financial flows in food chains, the composition of which corresponds to the "producer-transport-processing (storage)" scheme, the most significant is the last point.

3.3. The Research Results

Dynamics of exit on the pre-arranged volume of processing of load by the possible participants of transport-logistic complex, provided moving of freight streams is equal on all links of chain, is shown in Fig.1.

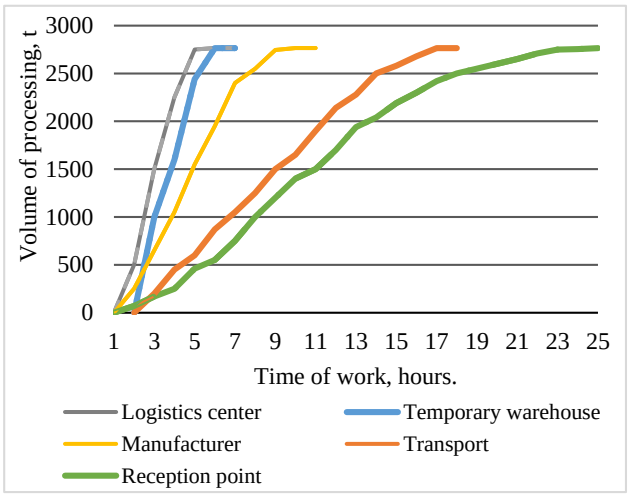


Fig. 1: The dynamics of the process in the logistics chains of the system under the condition $V_{Rp} = V_M = V_{TW} = V_{LC} = V_T : V_{Rp}$ - the volumes of processing of loads is in a receiving point, t, V_M - the volumes of the produced loads, t, V_{TW} - the volumes of cargo processing in the temporary warehouse, t, V_{LC} - the volumes of the processed cargo by the logistics center, t, V_T - the volumes of the transported loads by a transport enterprise, t.

Analysis of the theoretical dependences obtained allows us to draw the following conclusions:

- a load-absorbing point goes to the operating mode for 24 hours;
- a logistics center, works with information flows; daily specifies and corrects the volume of cargo that the load-absorbing point is able to accept. Based on the information received, the logistics center forms the volume of applications for the production of the required quantity of cargo to the cargo-producing enterprise; to load cargo on vehicles in a temporary warehouse; for transportation of goods from the warehouse to the point of reception. As follows from the dependences in Fig. 1 logistics center processes information and goes into the mode of 4.5 hours, sending out orders for logistics units;
- a temporary warehouse - which is a buffer in this logistical system, comes into operation an hour after the logistics center and begins the process of loading vehicles for shipment. The scheduled mode of operation goes by analogy with the logistics centers for an hour;
- cargo points - the manufacturing enterprise starts work with the logistics center, however, the necessary volume of production is agreed upon and adjusted according to the requirements of the cargo picking point and is adjusted during the working shift. As follows from Fig. 1, the company goes into the volume of production of the cargo in 8 hours;
- the transport enterprise takes up an hour after the logistics center starts operating, that is, together with the start of the temporary warehouse and provides transportation of the planned volume of cargo in 16 hours.

From dependences evidently, that by the most inertia link of chain and the least vulnerable to external influence is a receiving point. The most sensitive participant in the system is the logistics center. The received data allow developing administrative influences directed on increase of inertia of links and reliability of transport services.

The adequacy of the model was verified with using standard methods of estimating the Cochran repeatability and Fischer adequacy. The confidence error was 0.95, which indicates a high accuracy of the results. Experimental dependencies were obtained for all links in the supply chain. Analysis of the data on the dependence of the volume of transportation of goods on time is shown in Fig. 2.

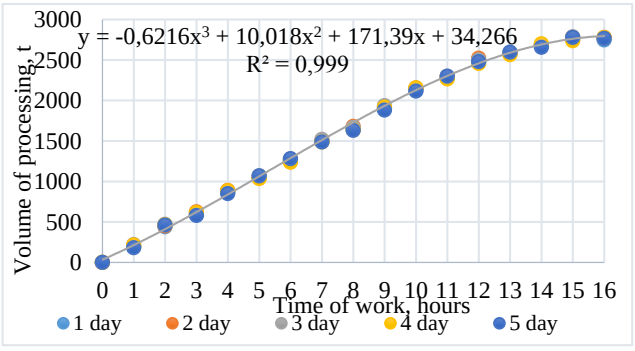


Fig. 2: Checking the model for adequacy for the transport enterprise

The experimental data are described by a polynomial dependence with a high correlation coefficient, which confirms the accuracy of the results obtained.

The results of simulating the influence of the ratio of the volumes of processing of material and information flows by each logistic link in relation to the final point of processing or long-term storage, depending on the response time of the link and the time delays in fulfilling the work, are given in [24]. The dependencies analysis has shown that an increase in the ratio of the volume of deliveries to the volume of processing leads to an increase in the response time and a decrease in delays.

The effect of the combined effect of the two listed factors, when $T_{in} \to \max$, and $T_{del} \to \min$ on the reliability of the logistic links C_{TU}, depending on the change in the ratio of the processing volumes, is shown in Fig. 3.

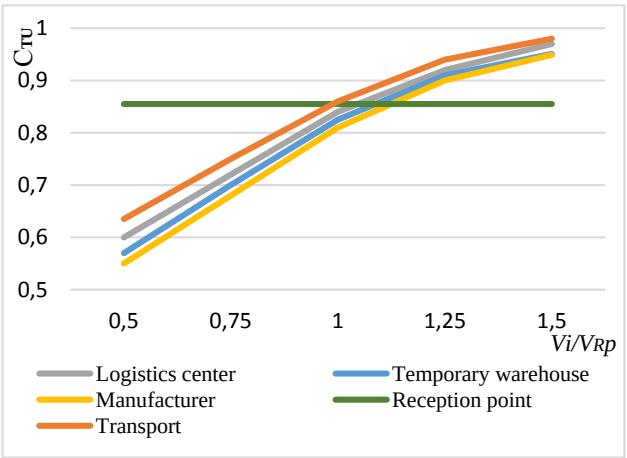


Fig. 3: Dependences of the change of the coefficient technical use of logistic links on the ratio of cargo processing volumes in the supply chain.

The results of obtained regularities and expressions for determining the reliability of the functioning of the transport and logistics complex make it possible to develop a plan for managing the quality of transport services for participants in the supply chain. Operating parameters of the cargo-handling and load-absorbing points of the system, you can reach the established level of reliability of transport services.

4. Conclusion

The use of the offered method allows, at the planning stage of the transport process, to develop and coordinate managing actions for both an individual element of the supply chain and for all the system as a whole. The consistency in the operation of all objects will allow reducing time delays in the work fulfillment, increasing the financial costs connected with the number of participants in each supply chain, selecting the optimal composition of the fleet of vehicles, and providing an adjustable level of reliability of the transport and logistics system.

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