ICCPT 2019: Current Problems of Transport: Proceedings of the 1st International Scientific Conference, May 28-29, 2019, Ternopil, Ukraine

Methodological approach to estimation of efficiency of the facing of the stock complex of transport and logistic centers in Ukraine

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Abstract: It was determined that one of the main directions of modern transport policy is the transition to transport logistics in the transport and logistics system, which allows us to provide comprehensive services to consumers of transport services, creating conditions for the development of combined transport, reducing the environmental influence on the environment. It is established that in order to carry out the successful implementation of the entire complex of works and reduce the cost of operations in the transport and logistics centers, as an important component of it, it is necessary to implement transport and technological processes, which must be based on progressive techniques and advanced methods. While constructing a mathematical model of an object, it was taken into account that the value of the general criterion of effectiveness depends on the values of the characteristics of the criteria of the effectiveness of the active elements of the system. The technological process of functioning of the warehouse complex of the transport and logistics centers, which is proposed in this paper, allows us to see the whole chain of operations from the moment of arrival of the vehicle with the load to the warehouse until the moment the consignment is shipped to the recipient. The approach to determine the efficient organization of the work of the warehouse complex of the transport and logistics center according to the criterion includes the total costs affected by: the intensity of the types cargo flows, the cost of one unit work and one hour work of one worker, the time of execution of the operation, the amount of resources involved to perform each operation. It has been developed the analytical models of determination of the estimation parameter are developed. In order to obtain the most reliable data on changes in the parameters of the warehouse process it has been determined the required number of observations is determined. Based on the analysis of the order flow parameters of most transport and logistics centers of Ukraine, it has been found that the intensity of the input, internal and output flow of cargo is distributed according to the exponential law. This conclusion was confirmed by an appropriate level of confidence. The conducted experiment, using the principle of constructing a full-factor plan for the experiment, obtained the results of research on the proposed criterion for determining the efficient organization of the transport and logistics centers warehouse complex for three variants. On the basic data it has been constructed the obtained regression models (linear and power) are constructed. An analysis of these models shows that the regression model in linear form with non-zero coefficients is the most adequate one, since the value of the indicator R^2 is the largest and it is equal to unity. On the received models the values of the criterion of efficiency are defined as total costs, for each variant. On the basis of the received changes in total costs for the organization of the warehouse complex, significant influence of the intensity of the incoming flow of goods has been identified, which in turn requires higher expenses of resources in the zone of acceptance of goods.

Keywords: transport and logistics system, transport and logistics center, warehouse complex, technological operations, mathematical model, vantage.

1. Introduction

The current state of development of the logistics market of any country, including Ukraine, depends on the state of its economy. The volumes provided in the field of logistics services directly depend on the level of activity of their consumers, the dynamics of production, the domestic and foreign trade. In the example of the countries of the European Union (EU), the logistics sector, in its broadest sense, ranks the 3rd among the sectors of the economy. The underestimation of the role of logistics in Ukraine as a factor which affects to the efficiency and competitiveness of the economy worsens its position in international ratings. In 2018, in the World Bank's Logistics Performance Index (LPI) ranking, Ukraine has ranked the 66th in terms of the logistics efficiency index [1]. The logistical component of the Gross Domestic Product (GDP) in developed countries is on average 10-15% (in the EU and the United States of America it is 12-16%, in China - 26%, in Japan - 6%). As for Ukraine, most experts relate the level of its economy to the level of Third World countries, in which logistics costs can reach 40% of GDP. For Ukraine this indicator ranges from 30-35%. At the same time, 70% of logistical expenses are accounted for transport ($ 7 billion), 25% for storage ($ 2.5 billion) and about 5% for managing logistics flows ($ 0.5 billion) [2].

According to shown information, we can assume that one of the main directions of modern transport policy is the transition to transport logistics in the transport and logistic system (TLS), which allows us to provide comprehensive services to consumers of transport services, to creat conditions for the development of combined transport, to reduce the environmental influence on the environment [3]. The structure of the TLS of Ukraine should consist of a set of interconnected elements of interaction at the regional and local levels. As the main elements of the system, it is possible to separate transport infrastructure objects: regional distribution centers; terminal complexes; transport and logistics centers (TLSs) [4].

Taking into account the current trends in the development of logistics services, it can be argued that the main elements of commodity flow management were TLSs. In general, such centers play a coordinating and integrated role in the circulation and transportation of goods [5]. The introduction of the new modern technologies requires the creation of a network of infrastructure objects such as TLS, which perform functions of interaction between modes of transport and organization of material distribution in the economic region. They are the basic for material flow management, providing interaction between senders, consumers, carriers, and others [6].

As part of the formation of an effective system of TLS, it has been considered 3PL-operators of TLSs and shippers of Ukraine and an assessment of the quality of logistics services was performed. Thus, the current state of the market can be defined as following: 40% - logistics is in a state of stagnation; 37% - at the stage of formation and development; 21% - at the stage of formation; 2% - at the redistribution stage [7]. Consequently, customers and providers of logistics services seek to optimize costs, introduce new technologies, improve the quality of logistics services, and establish the effective communication between customers and suppliers of logistics services for increasing the level of loyalty of end-users [8]. The main obstacles to the development of the TLS market are seen by international companies in Ukraine in imperfect legislation - 79%; the factor of corruption - 69%; in the customs office - 66%; low quality of infrastructure - 66%; in the absence of professional staff- 28%; market monopolization - 17%. Ukrainian companies also highlighted the factors of imperfect legislation and corruption factors - 68% and 61%, respectively, 50% of incomplete infrastructure, 43% of respondents see difficulties in customs, 43% of respondents feel that they have 29% problems, and 18% say about monopolization. All these factors can greatly affect the development of TLS. Taking all everything into account the experts highlight the implementation of EU legal acts and regulations [3,9].

Properly organized technological process of work of the TLS should ensure: a clear and timely quantitative and qualitative acceptance of goods; efficient use of means of mechanization of loading and unloading and transport and warehouse work; consistent and rhythmic performance of warehouse operations [10], which contributes to the systematic loading of staff and the creation of favorable working conditions; rational warehousing of goods, which ensures maximum use of warehouse volumes and areas; preservation of goods; clear organization of centralized delivery of goods.

The main tasks of the functioning of the TLS include: improving the coherence of the various modes of transport in the organization of mixed and intermodal transportation; proper organization of complex transport services for clients; expanding the types of services provided and improving their quality; attraction of additional volumes of transportation of transit cargoes; shortening the time of delivery of transit cargoes by reducing downtime at the points of transshipment of cargoes for other modes of transport and at border crossings; expansion of international cooperation; attracting new customers. The largest logistics operators in the volume of their own and the rented area, where logistics operations are carried out, are presented in the Table 1 [4].

Table 1. Powerful logistic operators providing warehousing services in Ukraine

Name of Company	Area, thousand square meters	Type of service
«ZAMMLER»	75	local
«Kuehne+Nagel»	67	international
«Raben»	53	international
«Ekol»	58	international
«FM Logistic»	55	international
«УВК»	50	local
«Logistic Plus»	27	local
« NP Logistics »	27	local

The analysis of recent researches and publications shows that the general problems of the creation and development of transport logistics and freight transportation in the TLS are represented by the following authors: Mirotin L.V. [9], Gladley J., Elovoy I.A. [11], Lifar V.V. [12], Bowersox Donald J. [13], Tankov K. M. [14], Naumov V.S. [15], Kricavsky Ye.V. [16].

Problems of the formation of a transport logistics network in Ukraine, taking into account the functioning of the warehouse complex of the TLS, have been devoted to their work by such scientists: Prokofieva T.A. [17], Popova N.V. [18], Bentzen K. [19], Aleshinsky E.S. [20], Veremeenko E.G. [21], Kampf R. [22], Stopka O. [23], Nagornyi Ye.V. [24].

Thus, it can be argued that the revival of the logistics market entails an increase in demand for warehouses and leads to an increase in consumer requirements for the quality of provision of services for the storage and processing of goods in warehouse complexes. [25]. The structure of most TLSs operating in Ukraine is allowed for a wide range of transport and logistics services. This is especially true for a sufficiently high-quality warehouse service. There are scientific developments of theoretical foundations on the introduction of modern technologies in the logistics and storage (terminal) systems of such scientists as Nagorny Ye.V., Shramenko N.Yu., Aleshinsky Y.S., Mirotin L. V. and other [15]. In work on improving the delivery of cargo TLS focuses on the development of the infrastructure component of the TLS without determining the optimal values of technological parameters of the operation of warehouses [26, 27]. The analysis has revealed the problem of forming an efficient organization of the TLS warehouse complex in the TLS of Ukraine.

2. Materials and Methods

In order to carry out the successful implementation of the entire complex of works and reduce the cost of operations in the TLS, as an important component of it, it is necessary to implement transport and technological processes, which must be based on progressive techniques and advanced methods. To solve this problem, the author proposes the development of theoretical foundations for the formation of an efficient management of material flows management in order to reduce the cost of functioning of the TLS due to the introduction of an efficient organization of work.

In this paper, the technological process of the operation of the TLS warehouse complex is considered as a sequence of operations:

1) the arrival of cargo on the warehouse (preparation of technical means for receiving the cargo, documents, familiarization of the workers with the plan of unloading);
2) checking the integrity of the packaging of the goods in the vehicle (TC) (checking the attachment and the presence of appropriate seals and markings, revealing external damage);
3) unloading of cargo by loading and unloading mechanisms (LUM);
4) acceptance and loading of the cargo in the reception area (moving of the respective consignments in the allocated areas of the receiving zone and its placement);
5) acceptance of cargo by quantity and quality (opening of containers, counting by quantity and verification with documentation, withdrawal);
6) selection and transfer of cargo to the storage and acquisition zone;
7) preservation of the cargo in the warehouse;
8) the collection of batches of cargo and dispatch from the storage and reception zone (a batch of cargo is formed for the corresponding order: the quantity of cargo and type of packaging is determined; packaging is carried out in packing and sealing; documents are prepared);
9) the movement of the finished cargo unit to the departure zone;
10) checking of cargo by quantity, and also compliance with documents;
11) cargo load in the vehicle and the transfer of documents.

Determination of the effective organization of work conducted by the estimated parameter - the total cost, which form a set of values of the corresponding costs for each element of the scheme of the technological process:

$$C = \{C_1, C_2, ..., C_n\}, \tag{1}$$

where $C_1, C_2, ..., C_n$ - the corresponding expenses for each technological operation of the TLS warehouse complex, US \$; i - the number of the corresponding operation, $(n = 11)$.

Costs of the second operation are the functions of the following elements:

$$C_n = \{I_p, S_p, S_R, t_{VO,} N_P\}, \tag{2}$$

where I_P – the intensity of the corresponding cargo flows, t/h.; S_P – cost per unit of work, US \$/t.; S_R – cost per hour of work of one worker, US \$/h.units; t_{VO} – the time of execution of the corresponding operation, h.; N_P – the number of resources involved to perform the operation, units.

Each of the presented elements of the corresponding flows is characterized by a list of components, the intensity of the flows of cargo has three components:

$$I_P = \{I_{VP}, I_{VV}, I_{VIP}\}, \tag{3}$$

where I_{VP} – the intensity of the input cargo flow, t/h.; I_{VV} – the intensity of the internal flow of cargo, t/h.; I_{VIP} – the intensity of the outflow of the cargo, t/h.

When constructing a mathematical model of an object, it has been taken into account that the value of the general criterion of effectiveness depends on the values of the characteristics of the criteria of the effectiveness of the active elements of the system. For each dependence in the model, the conditions for their application must be determined.

According to the technological process of the warehouse complex TLTS total costs are:

$$C = \sum_{i=1}^{11} C_i, \tag{4}$$

where C_1 - the cost of the arrival of the goods to the warehouse, US \$; C_2 - costs for checking the integrity of packing of goods in TK, US \$; C_3 - expenses for unloading of LUM cargo, US \$; C_4 - expenses for acceptance and packing of the cargo in the reception area, US \$; C_5 - costs for acceptance of cargo in quantity and quality, US \$; C_6 - costs for the selection and transfer of cargo to the storage and assembly area, US \$; C_7 - costs for the storage of cargo in the TLC warehouse, US \$; C_8 - packing and delivery costs from storage and reception area, US \$; C_9 - costs of moving the finished cargo unit to the sending zone, US \$; C_{10} - the cost of checking the cargo by quantity and compliance with the documents, US \$; C_{11} - costs of loading of cargo in TC and transfer of documents, US \$.

Using the norms and resources for carrying out operations, as well as their cost characteristics, we receive the following analytical expressions for costing the cost.

The cost of the arrival of cargo on the TLS is:

$$C_1 = \left(\frac{I_{VP} \cdot S_{PRV}}{N^O{}_{PR}} + N^O{}_{PR} \cdot S^O{}_{RPR} \right) \cdot t_{PR}, \tag{5}$$

where S_{PRV} – cost of preparation for the receipt of cargo (determination of the order of unloading and location of the cargo in the reception area, preparation of facilities for LUM, auxiliary equipment, etc.), US \$/t.; $S^O{}_{RPR}$ – cost of one hour of work of one worker involved in the preparation for acceptance of cargo, US \$/units; $N^O{}_{PR}$ – the number of workers involved in the operations for preparing for the receipt of goods, units; t_{PR} – the time of carrying out operations for preparation for acceptance of cargo, h.

Costs for checking the integrity of packaging in TC:

$$C_2 = \left(\frac{I_{VP} \cdot S_{PV}}{N^O{}_{PV}} + N^O{}_{PV} \cdot S^O{}_{RPV} \right) \cdot t_{PRV} + I_{VP} \cdot S_{PVb} \cdot k^{TZ}{}_b \cdot t_{PRVb}, \tag{6}$$

where S_{PV} – the cost of checking the integrity of the packing of the cargo, US \$/t.; $S^O{}_{PRV}$ – cost per hour of work of one worker involved in operations for checking the integrity of the packing of the cargo, US \$/units; $N^O{}_{PV}$ – the number of workers involved in the operations for checking the integrity of the package, units; t_{PRV} – time of operations for checking the integrity of the package, h.; S_{PVb} – cost of execution of work on registration of acts concerning damaged cargo, US \$/t.; $k^{TZ}{}_b$ – the level of cargo detected with damage, in relation to the total quantity, when checking the TAP; t_{PRVb} – time of execution of operations on drawing up of acts concerning damaged cargo, h.

The cost of unloading the LUM cargo:

$$C_3 = \left(\frac{I_{VP} \cdot S_{RV}}{n_{NRM} \cdot N^O{}_V} + N^O{}_V \cdot S^O{}_{RV} \right) \cdot t_{RV}, \tag{7}$$

where S_{RV} – cost of unloading cargo, US \$/t.; $S^O{}_{RV}$ – the cost of performing the work by the relevant workers when unloading the goods from TP, US \$/h.; $N^O{}_V$ – the number of workers involved in the work, units; n_{NRM} – number of LUM, units; t_{RV} – time of discharge of cargo with TC, h.

Costs of acceptance and packing of cargo in the reception area:

$$C_4 = \left(\frac{I_{VP} \cdot S_{PRU}}{N^O{}_{PRU}} + N^O{}_{PRU} \cdot S^O{}_{RPRU} \right) \cdot t_{PRU}, \tag{8}$$

where S_{PRU} – cost of acceptance and packing of cargo in the reception area, US \$/t.; $S^O{}_{RPRU}$ – the cost of one hour of work of one worker involved in the acceptance and stowage operations, US \$/units; $N^O{}_{PRU}$ – the number of workers involved in the operations for the acceptance and loading of cargo, units; t_{PRU} – time of acceptance and loading operations, h.

The cost of receiving the cargo by quantity and quality:

$$C_5 = \left(\frac{I_{VP} \cdot S_{PKY}}{N^O{}_{PKY}} + N^O{}_{PKY} \cdot S^O{}_{RKY} \right) \cdot t_{PRY} + I_{VP} \cdot S_{PKYb} \cdot K_b \cdot t_{PKYb}, \quad (9)$$

where S_{PKY} – cost of checking cargo by quantity and quality, US $/t.; $S^O{}_{RKY}$ – cost per hour of work of one worker involved in operations for checking quantity and quality of cargo, US $/units; $N^O{}_{PKY}$ – the number of workers involved in operations for checking the quantity and quality of goods, units; t_{PRY} – time of carrying out operations on checking quantity and quality of cargo, h.; S_{PKYb} – cost of execution of works on registration of acts to damaged cargo when checking quantity and quality of cargo, US $/t.; k_b – the level of cargo found to be damaged in relation to the total quantity when checking the quantity and quality of the cargo; t_{PKYb} – time of execution of operations on drawing up of acts concerning damaged cargo and detection of losses, h.

Costs of selection and movement of cargo to the storage and picking zone:

$$C_6 = \frac{I_{VP} \cdot a_{zb} \cdot S_{ZB} \cdot t_{ZB} + I_{VP} \cdot a_{zk} \cdot S_{ZK} \cdot t_{ZK}}{N^O{}_{ZBK}} + N^O{}_{ZBK} \cdot S^O{}_{ZBK} \cdot \frac{t_{ZB} + t_{ZK}}{2}, \quad (10)$$

where S_{ZB}, S_{ZK} – accordingly, the cost of picking up and moving the cargo to the storage and assembly area, US $/t; $S^O{}_{ZBK}$ – the cost of one hour of work of one worker involved in operations for the selection and transfer of cargo to the storage and assembly area, US $/units; a_{zb}, a_{zk} – respectively, the proportion of cargo sent to the storage and assembly area; $N^O{}_{ZBK}$ – the number of workers involved in operations for the selection and transfer of cargo to the storage and assembly area, units; t_{ZB}, t_{ZK} – respectively, the time of execution of operations for the selection and transfer of cargo to the storage and assembly area, h.

Costs for the storage of cargo in the TLS warehouse:

$$C_7 = I_{VP} \cdot S_Z \cdot a_{zk} \cdot t_Z, \quad (11)$$

where S_Z – the cost of storing the cargo in the storage zone, US $/t.; t_Z – time of storage in the storage area, *h*.

Costs of picking up the shipment from the storage and reception area:

$$C_8 = \frac{I_{VV} \cdot S_{KZB} \cdot t_{KZB} + I_{VP} \cdot a_{zk} \cdot S_{KZP} \cdot t_{KZP}}{N^O{}_{KZBP}} + N^O{}_{KZBP} \cdot S^O{}_{KZBP} \cdot \frac{t_{KZB} + t_{KZP}}{2}, \quad (12)$$

where S_{KZB}, S_{KZP} – accordingly, the cost of manning the shipment from the storage and reception zone, US $/t.; $S^O{}_{KZBP}$ – the cost of one hour of work of one worker involved in the operations for the assembly of consignments from the storage and receiving zone, US $/units; $N^O{}_{KZBP}$ – the number of workers involved in operations for the assembly of consignments from the storage and receiving zone, units; t_{KZB}, t_{KZK} – respectively, the time for completing cargo shipments from the storage and reception area, h.

Costs of moving the finished cargo unit to the departure zone:

$$C_9 = \left(\frac{I_{VIP} \cdot S_{PZV}}{N^O{}_{PZV}} + N^O{}_{PZV} \cdot S^O{}_{RPZV} \right) \cdot t_{PZV}, \quad (13)$$

where S_{PZV} – the cost of moving a finished cargo unit to the dispatch zone, US $/t.; $S^O{}_{RPZV}$ – the cost of one hour of work of one worker involved in the operations for moving the finished cargo unit to the sending zone, US $/units; $N^O{}_{PZV}$ – the number of workers involved in operations for the movement of the finished cargo unit into the departure zone, units; t_{PZV} – time of execution of operations on moving the finished cargo unit to the dispatching area, h.

Costs for checking cargo by quantity and compliance with documents:

$$C_{10} = \left(\frac{I_{VIP} \cdot S_{PP}}{N^O{}_{PP}} + N^O{}_{PP} \cdot S^O{}_{RPP} \right) \cdot t_{PP}, \quad (14)$$

where S_{PP} – the cost of checking the cargo by quantity and compliance with the documents, US \$/t.; S^{O}_{RPP} – cost of one hour of work of one worker involved in cargo checks by quantity and compliance with documents, US \$/units; N^{O}_{PP} – number of workers involved in cargo inspection operations by quantity and compliance with documents, units; t_{PP} – the time of execution of operations of checking of cargo by quantity and compliance with documents, h.

Costs of cargo loading in TC and transfer of documents:

$$C_{11} = \left(\frac{I_{VIP} \cdot S_{NV}}{n_{NRM} \cdot N^{O}_{PP}} + N^{O}_{N} \cdot S^{O}_{RN} \right) \cdot t_{RN}, \tag{15}$$

where S_{NV} – cost of loading load, US \$; S^{O}_{RN} – the cost of carrying out work by the corresponding workers at loading of the cargo on TC, US \$/h.; N^{O}_{N} – the number of workers involved in the work, units; t_{RN} – time of load loading on TC, h.

Total expenses are reflected in the form (4) and calculated by formulas (5) - (15), imagine how the target function:

$$C = f\left(I_{P}, S_{P}, S_{R}, t_{VO}, N_{P}\right) \rightarrow \min. \tag{16}$$

We establish a system of constraints for the warehouse complex for a specific target function on the basis of experimental and organizational data with the values of the relevant factors which have been identified during the analysis of statistical data of the functioning of the warehouse complexes of the TLC of Ukraine.

$$\begin{cases} 7{,}6 \le I_{VP} \le 36{,}05\ t/h; \\ 0{,}23 \le I_{VV} \le 2{,}53\ t/h; \\ 1{,}4 \le I_{VIP} \le 12{,}3\ t/h; \\ 0{,}36 \le S_{P} \le 17{,}86\ US\$/units; \\ 5{,}36 \le S_{R} \le 12{,}5\ US\$/h; \\ 0{,}25 \le t_{VO} \le 2{,}0\ h; \\ 1 \le N_{P} \le 4\ unit. \end{cases} \tag{17}$$

Planning an experiment on the study of cargo flows at the warehouse complexes of the TLC of Ukraine has been used to find the optimal conditions for the organization of work. While doing this, we were using the normalization of experimental data on flow of goods in a warehouse complex. This operation is necessary to obtain reliable data on studies of changes in costs while improving warehouse work.

3. Results

Experiment planning has been used for finding optimal conditions, construct interpolation formulas, choosing the meaningful factors, evaluating and refining the constants of theoretical models, and so on.

It has been used a complete factor experiment - a set of several measurements, which responds to the following conditions:

- the number of measurements is k^{n}; where k - the number of levels of variation of factors; n - number of factors;
- in the process of measuring the value of the factors combined in all possible options.

The advantages of a full factor experiment are the following :

the simplicity of the solution of the system of equations of estimation of parameters,

the statistical redundancy of the number of measurements, which reduces the impact of the errors of individual measurements on the estimation of parameters.

Levels of variation of factors I_{VP}, I_{VV}, I_{VIP} pare have been given in Table 2.

Table 2. Levels of variation of the intensity of the cargo in the warehouse complex with the basic option during the peak of flows

Parameter	Minimum value	Maximum value
Intensity of the input cargo flow, t/h.	7,60	36,05
Intensity of the internal cargo flow, t/h.	0,23	2,53
Intensity of the output cargo flow, t/h.	1,4	12,3

In order to obtain the most reliable data on changes in the values of the factors of the warehouse process, it has been determined the required number of observations:

$$n = \frac{\sigma^2 \cdot t_\beta^2}{\varepsilon^2 + t_\beta^2 \cdot \frac{\sigma^2}{N}}, \quad (18)$$

where n – sample size; t_β – probability indicator for a given confidence level; equal $\beta_\partial = 0,95, t_\beta = 1,96$ – mean-square deviation of the results of observations; ε – calculation error; N – total number of observations, $N = 40$ units.

Calculation of indicators $\varepsilon, P_\partial, \sigma$ and μ has been carried out according to the following formulas:

$$\varepsilon = \mu \cdot (1 - P_Д), \quad (19)$$

where μ – mathematical expectation; $P_Д$ – confidence level at $P_Д = 0,95, t_\beta = 1,96$.

Mean-square deviation of observational results:

$$\sigma = \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} (x_i - \mu)^2}, \quad (20)$$

where x_i – mean value for i-th observation; μ – mathematical expectation.

$$\mu = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i, \quad (21)$$

The results of calculations are given in Table 3.

Table 3. Results of calculations of sample size

Indexes	Intensity of the input flow of cargo, IVP, t / h	Intensity of the internal flow of cargo, IVV, t / h	Intensity of the initial flow of cargo, IViP, t / h.
Mathematical expectation, μ	22,06	1,58	6,69
Mean square deviation,σ	7,17	0,55	2,21
Calculation error, ε	1,1	0,08	0,33
Sample size, N	32	33	33

The criterion χ^2 or the "Pearson square" is used to verify the significance of the relationship between the two variables - this is the simplest criterion that allows you to compare frequency distributions, regardless of whether they are normalized or not. Frequency refers to the amount of occurrence of an event. Using the program Statistica.exe, calculations were made to identify the laws of distribution of input parameters: I_{VP}, I_{VV}, I_{ViP}.

Calculated numerical values of Pearson's criterion were compared with tabular ones.

$$x_{calcul.}^2 \le x_{tabl.}^2, \quad (22)$$

where $x_{calcul.}$ – Pearson Criterion Calculated; $x_{tabl.}$ – criterion Pearson table.

Then, it is assumed that under these conditions a hypothesis regarding the model of the distribution of covariates is adopted and it does not deny observation and can be used in subsequent calculations. Proceeding from this, we accept the normal law of distribution of covariates of their intensities for the input factors of cargo flows (Fig. 1-3).

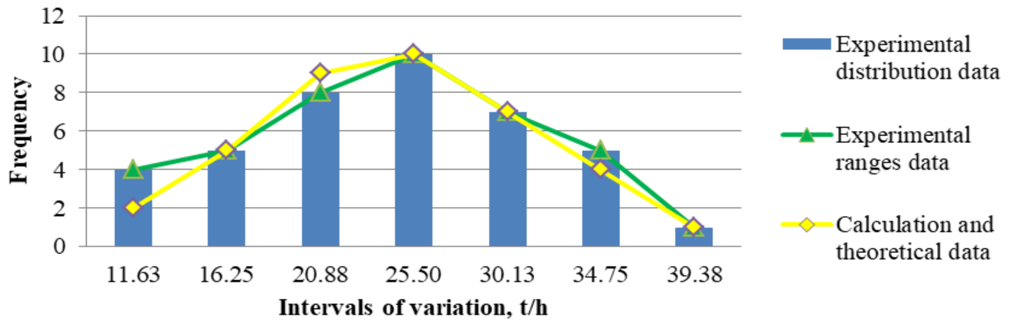

Figure 1. Distribution of the values of the intensity of the input cargo flow according to the normal distribution law: the degree of freedom is 4; the significance level is 0,05; critical value of the Pearson criterion is 9,49; estimated value of the Pearson criterion is 2,36.

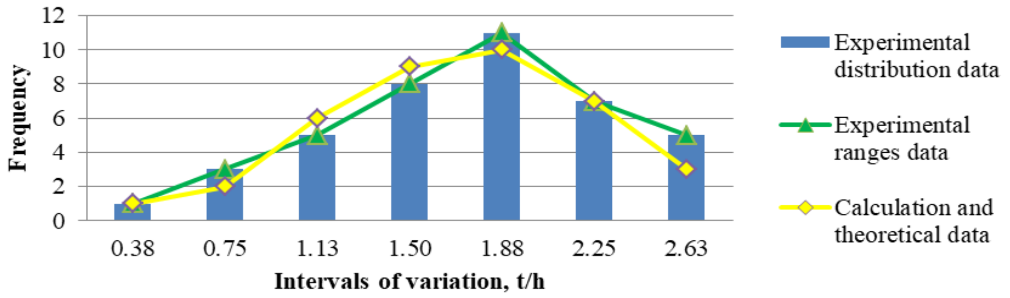

Figure 2. Histogram of the distribution of the values of the intensity of the internal cargo flow according to the exponential distribution law: the degree of freedom is 4; the significance level is 0,05; critical value of the Pearson criterion is 9,48; estimated value of the Pearson criterion is 2,21.

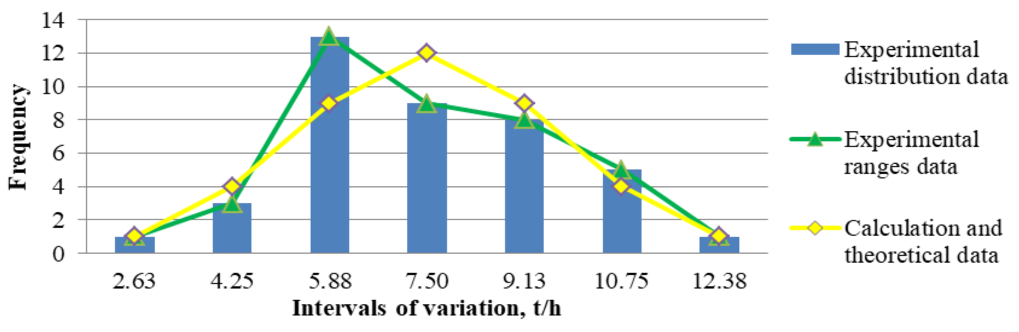

Figure 3. Histogram of the distribution of the values of the intensity of the outflow of the cargo according to the exponential distribution law: the degree of freedom is 4; the significance level is 0,05; critical value of the Pearson criterion is 9,49; estimated value of the Pearson criterion is 3,14.

For the experiment the intervals of the variation of the corresponding input factors were substantiated as follows: on the basis of the previous studies, it has been established that the intensity of the input flow of the cargo varies from 7.6 to 36.05 t / h; the intensity of the internal cargo flow varies from 0.23 to 2.53 t / h; the intensity of the outflow of the cargo varies from 1.4 to 12.3 t / h. and it is distributed according to the normal law of the distribution of the covariates (Fig.1-3), which is confirmed by the corresponding values of the confidence level and the Pearson criterion.

Using the MS Excel program and the HIOBR function, we define a table value x^2, which is 9.49. Since the calculated value for the first indicator (Fig.1) x^2 is 2.36, the condition $x^2_{calc\leq} x^2_{table}$ is satisfied, that is 2.36 <9.49. While conducting experimental studies on road transport, the confidence level should be at least 95%. As a result it has been confirmed the distribution hypothesis In calculations for the second indicator (Fig.2) the table value x^2 was 9.48, that is, 2.21<9.48, and, consequently, the condition is fulfilled. The confidence level should be at least 95%. As a result it has been confirmed the distribution hypothesis In calculations, the value for the third indicator (Fig.3) x^2 was 3.13, that is, 3.13 <9.48, and, consequently, the condition is fulfilled. The confidence level should be at least 95%. As a result it has been confirmed the distribution hypothesis.

Based on the received and processed experimental data (Figures 1-3), we shall form a database to detect changes in the criterion of efficiency of the organization of the warehouse complex. For the formation of cargo flows, we shall operate with the minimum and maximum values in the peak period (Figure 4).

Table 4. The value of the input parameters of the experiment in the base version during the period of peak traffic in the warehouse complex

Series of experiments	Levels of variation		
	Intensity of the input flow of cargo, t/h	Intensity of the internal flow of cargo, t/h	Intensity of the outflow of cargo, t/h
1	11,63	0,23	1,40
2	11,63	0,23	12,3
3	11,63	2,53	12,3
4	11,63	2,53	1,40
5	39,38	0,23	12,3
6	39,38	0,23	1,40
7	39,38	2,53	1,40
8	39,38	2,53	12,3

According to the experiment carried out using the mathematical models of total costs (formulas (5-15)) and the principle of constructing a full-factor plan of the experiment, the results of the research were obtained to determine the efficient organization of the work of the TLC warehouse complex for three variants (table5): the basic (initial), and the second and third an option to improve the organization of warehouse work. As a result it has been used the proposed efficiency criterion. The second option is to increase the number of workers by one in each section to execute the corresponding work in the warehouse. The third option is to increase the loading and unloading mechanisms involved in the warehouse work up to two in each section to execute the relevant work in the warehouse complex. All other resource options are left in the base version.

Table 5. Results of calculations of total costs when organizing the work of the warehouse complex of the TLS under various options

Series of experiments	Total expenses, US $		
	The first option is basic	The second option: with an increase in the number of workers	The third option: when increasing the number of loading and unloading mechanism
1	53,87	77,89	62,38
2	100,86	96,41	90,84
3	103,81	97,39	92,31
4	59,92	78,88	63,85
5	391,73	293,49	406,65
6	347,84	274,98	378,19
7	350,79	275,96	379,66
8	394,67	294,47	408,12

On the basic data it has been constructed the obtained regression models (linear and power) An analysis of these models shows that the regression model in linear form with non-zero coefficients is the most adequate, since the value of the indicator R^2 is the largest and is equal to unity. On the received models the values of the criterion of efficiency are defined - total costs, for each variant Table 6.

Table 6. Results of calculation of the criterion of efficiency for different variants of organization of the warehouse complex

Series of experiments	Total expenses, US $		
	The first option	The second option	Third option
1	57,01	77,89	62,38
2	100,90	96,41	90,84
3	103,84	97,39	92,31
4	59,96	78,88	63,85
5	392,41	293,46	406,64
6	348,53	274,95	378,19
7	351,47	275,93	379,66
8	395,36	294,45	408,12

On the basis of the received changes in total costs for the organization of the warehouse complex, significant influence of the intensity of the incoming flow of goods has been identified, which in turn requires higher expenses of resources in the zone of acceptance of goods. Minimizing time costs and reducing non-production downtime allow to increase the efficiency of the entire warehouse complex of TLSs.

4. Discussion

When conducting an assessment of the effectiveness of the proposed solutions, the values of total costs for the three option were compared by determining the economic effect:

$$E_k = C_{cost} - C_k \tag{18}$$

where C_{cost}, C_k – respectively, total expenses for one and other variants, US $ ($k = \overline{1,3}$).

The results of calculating the economic effect for all possible comparative combinations are given in Table 6.

Table 6. Results of determining the economic effect with different variants of comparisons

Series of experiments	Value of economic effect, US $		
	When comparing the second and first options	When comparing the third and first variants	When comparing the second and third options
1	20,88	5,37	15,51
2	-4,49	-10,06	5,57
3	-6,45	-11,53	5,08
4	18,92	3,89	15,02
5	-98,95	14,23	-113,18
6	-73,58	29,66	-103,24
7	-75,54	28,19	-103,73
8	-100,91	12,76	-113,67

The results of the determination of the economic effect have shown that the second option (an increase in the number of workers) will have an effect (22.88 US $) when compared with the first only with the minimum intensity values of the corresponding flows of cargo. The third option (increasing the number of LUM) compared with the first one is effective only with an increase in the intensity of the initial flow of cargo to the maximum level, the effect - 11.53 US $. And when comparing the second and third variants, the effect decreases for the third with an increase in the intensity of the input stream - the maximum effect is 113.67 US $.

5. Conclusions

The technological process of functioning of the warehouse complex of the TLS, proposed in this paper, allows to see the whole chain of operations from the moment of arrival of the vehicle with the load to the warehouse until the moment the consignment is shipped to the recipient. The necessary types of resources involved in these processes are also taken into account. In order to determine the efficient organization of the warehouse complex, it has been proposed the criteria such as total costs affected by the following parameters: the intensity of the varieties of cargo flows: the cost per unit of work and one hour of work of one worker, the time of execution of the corresponding operation, the number of resources involved to perform each operation.

Based on the analysis of the order flow parameters of most TLSs of Ukraine, it has been found that the intensity of the input, internal and output flow of cargo are distributed according to the exponential law. This was confirmed by an appropriate level of confidence. According to the conducted studies and the proposed criteria, it has been determined the effectiveness of organizing the work of the TLS warehouse complex for the three options.

The results of the research can be used for improving the work of the warehouses not only of the TLS, but also other enterprises in Ukraine and in other countries.

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