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АНАЛІЗ ПОКАЗНИКІВ ЕФЕКТИВНОСТІ РОЗПОДІЛЬЧОЇ СИСТЕМИ ДОСТАВКИ ВАНТАЖІВ

У статті описана аналітична модель ієрархічної розподільчої системи, яка дозволяє оптимізувати величину партії поставки вантажів та кількість розподільчих центрів одночасно. Встановлені показники ефективності даної розподільчої системи. Досліджені основні характеристики розподільчої системи доставки товарів та вивчені закономірності процесу постачань автомобільним транспортом для отримання оптимізації фінансових витрат на доставку вантажів. Отримані данні дозволяють аналітично вирішити актуальну задачу логістики.

Ключові слова: *перевезення, ефективність, надійність, модель, логістика, постачання.*

1. Introduction

Ukraine's path to European Community provides the development of high-tech manufacturing and, consequently, increasing trade with foreign partners. This will encourage development of modern logistic delivery system for fast and quality customer satisfaction in accordance with their requirements. According to the international rating assessments, logistics of trade sector of the country is considerably inferior to foreign partners [1, 2]. Situation worsens by aggregate effect of adverse external factors such as fluctuations in prices and demand, a violation of the planned delivery schedules, unbalanced cargo flows, etc. Hence, there is a problem of improvement of goods delivery in distribution systems. Given the multifaceted nature of the distribution system, the amount of entrepreneurial entity involved in the goods delivery, possible technological and organizational solutions, there is a need to develop new methods of improving the efficiency of goods delivery. One of the promising areas of solution to this problem is to increase the reliability of the distribution system [3, 4]. A considerable amount of research in this direction, performed in recent years, do not give answers to many questions related to practical activities. Therefore, the study of patterns of distribution and operation of the cargo delivery system requires further research. It is shown in «Transport Strategy of Ukraine till 2020» and objectives of the Association Agreement between Ukraine, on one hand, and the European Union, the European Atomic Energy Community and their Member States, on the other hand, ratified by the Law of Ukraine № 1678-VII of 16.09.2014.

2. Literature review and problem statement

Works of many domestic and foreign scientists are devoted to improvement in the goods delivery in distribution systems [5–8]. The following areas are highlighted among these works: inventory management [5, 6], design of logistics systems [7]; organization of road transportation [8]. The greatest amount of research is devoted to the issue of inventory management. The authors in [5] pay attention to the complexity and ambiguity of the definition of the components of storage costs, and author of [6] indicates that a significant number of proposed models can't be used in practice because they have some assumptions. In [7] the logistics system design reduced to a sequence of informal solution procedure of delineated set of problems. The majority of works on the theory of logistics are focused on industrial plant or a separate logistics chain [4, 9]. The system of distribution chains are considered in most cases from the standpoint of qualitative analysis. A significant contribution to the theory of terminal traffic was made by the author of [8]. He attempted to combine a network of warehouses with transportation technologies. The used research methodology focuses on centralized transportation management, allows only regressive dependence and simulation model is extremely sensitive to input parameters, which significantly reduces the possibility of studying patterns of the system.

Further development of this research was in [10, 11], where the network of warehouses topology is associated with the organization of transport routes. However, assumptions and cost efficiency criterion significantly limit the ability of research of distribution systems by other criteria. It is specially noted the work [12], in which the author considers the problem of delivery reliability. In his view the effectiveness of delivery chain identifies three characteristics: reliability, efficiency and safety. So, the basis of that work is the theory of reliability, risk and economics. However it is questionable transferring the theory of reliability of technical systems at the organizational and economic without significant processing. Another disadvantage is considering a separate logistics chain, and not their system. In addition, it should be noted that in recent years many publications among logisticians researchers observed active attempts to use the theory of reliability of single-functional mechanical systems for assessing the transport process. But 30 years ago is noted in [13] that this approach is inappropriate for multifunctional complex systems and can lead to false conclusions and unworkable implementation of measures to improve the efficiency of transport. Therefore, the study of patterns of functioning distribution systems and parameters of their characteristics based on their topology associated with road transportation technologies is important.

3. Object, aim and tasks of the study

The object of study is the characteristics of the goods delivery distribution system in international and domestic traffic.

The aim is studying the main characteristics of the goods delivery distribution system and the study of patterns of deliveries by the road transport.

To achieve this aim it is necessary to perform the following tasks:

1. Set the performance of the distribution system.
2. Set their interdependence.
3. Develop a mathematical model of the process.
4. Prove performance criteria of the system.
5. Develop a method optimization.

4. Results of the studying the main characteristics of the cargo delivery distribution system

The system of «production — transportation — consumption» involves how different ways of delivering goods and a variety of transport technologies of transportation. In particular, in the distribution of confectionery products, various beverages, tobacco products and so on it is used «producer — wholesale warehouse — small-scale wholesale warehouse — shop». These companies sends products to wholesale warehouses where goods performed a complete set of items from different manufacturers to small-scale wholesale warehouses, where goods is also completed according to the orders of shops. Thus, a hierarchical system of distribution warehouses is formed. A feature of such systems is the cargo processing in joining nodes of subsystems of different levels that on the one hand reduces the speed of goods delivery, increased costs due to overload and assortment of cargo and requires coordination of schedule, and on the other hand allows pursuant to cargo flow select rational types of transport, thereby reducing transportation costs.

Goods delivery according to modern ideas of leading foreign and domestic scientists should be seen as a set of operations with goods and vehicles. Methodological principle of transport process research is the provision of its recurrence. This allows to divide any carriage by successive regular elements: preparation of vehicles and goods to transportation, provision of vehicles for loading, loading, moving, unloading or handling, warehousing, storage of goods, final operation and so on. The passage of financial and information flows, as practice shows, only affects the delay at the start of operations of the transport process.

Unlike internal domestic traffic, while international traffic there are increasing of the number of elements of the transport process through the implementation of customs formalities and border crossing procedures. Also, the movement of goods in the distribution system requires additional fulfillment warehouse operations and inventory management.

Many works are devoted to studying the individual elements of the process of delivery and distribution of goods. They set out the results of field observations of the performance of individual operations on their duration and cost. However, the rapid development of transport engineering and technology of transportation process, changes in the cost of resources, technical regulations and standards needs further refinement of research results from previous years. In addition, the causes of violations of targets and delays in the delivery of goods, also remains poorly understood. Therefore, research of elements of goods delivery cycle is important.

Analysis of the literature shows that the most effective method for studying topological structures of cargo delivery is simulation. For its reliable implementation it is necessary to examine patterns of changes in key parameters of the distribution system, which is a time, cost and reliable of goods movement that determining the overall efficiency of cargo traffic.

Given that the cost of goods transportation is determined by many factors such as technical characteristics of vehicles, road conditions, balance of cargo in forward and reverse directions of movement, competitive environment, etc., objective characteristic of transportation price value can serve the transportation of cargo to a distance formed in the marketplace.

Economic and legal features of the goods transportation in different countries cause considerable dispersion of tariff rates as the characteristics of transportation price in forward and reverse direction. Therefore, the transportation fare per 1 km in Ukraine — Europe direction is determined according to the rate of turnaround travel (Fig. 1).

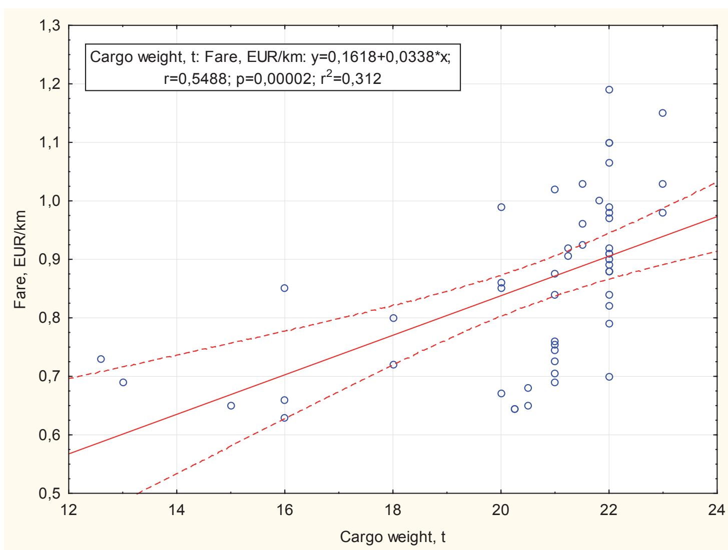

Fig. 1. Dependence of transportation fare in Ukraine — Europe direction by turnaround travel from cargo weight

Dependence of transportation fare in Ukraine — Europe direction by turnaround travel from cargo weight was obtained as a result of processing statistical data:

$$T = 0{,}16 + 0{,}03g. \quad (1)$$

Checking the significance of regression model was performed using Fisher's F-test. Comparing the resulting value ($F = 22$) with tabular F_{cr} $(0{,}01; 1; 51) = 7{,}2$ ($F > F_{cr}$) indicates a statistically reliable estimation of regression equation.

Analysis of the significance of the regression coefficients was performed using Student's t test. Its critical value T_{tabl} (51; 0,05) = 2,01 is more less than (t_b = 4,69), confirming its statistical significance.

For more adequately it is described cargo transportation fare in Ukraine (Fig. 2).

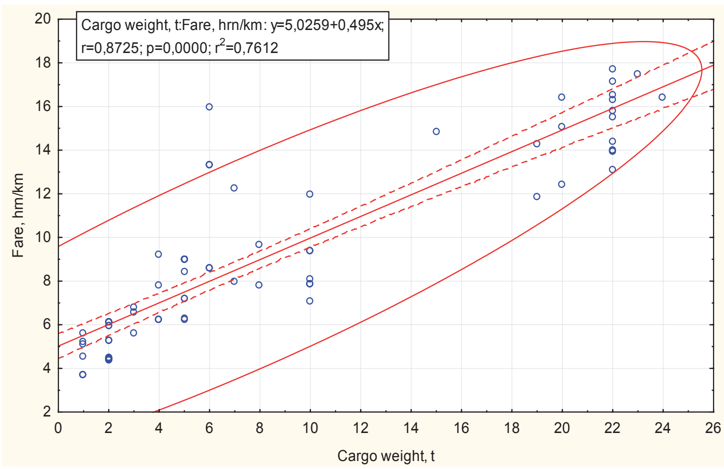

Fig. 2. Dependence of transportation fare in Ukraine from cargo weight

Equation of linear paired regression for the dependent variable of transportation fare based on cargo weight is:

$$T_{tkm} = 5{,}03 + 0{,}49g. \quad (2)$$

Checking the significance of regression model was performed using Fisher's F-test. Comparing the resulting value (F = 312,47) with tabular F_{cr} (0,01; 1; 98) = 7 ($F > F_{cr}$) indicates a statistically reliable estimation of regression equation.

Analysis of the significance of the regression coefficients was performed using Student's t test. Its critical value T_{tabl} (98; 0,05) = 1,99 is more less than (t_b = 17,68), confirming its statistical significance.

Similar researches were conducted for urban transportation. In this case, the cost of cargo transportation was carried out depending on the length of their performance and capacity of the vehicle (Fig. 3).

Equation of linear paired regression for the dependent variable of transportation fare based on capacity of the vehicle is:

$$T_{tkm} = 85{,}56 + 8{,}54q. \quad (3)$$

Statistical analysis confirmed the adequacy of proposed model for determining the fare for urban transportation.

It should be noted that an important element of the distribution system is warehouses. The cost of warehousing goods as part of the total cost of delivery is determined by many factors: type of warehouse, location, economic situation of the region and so on. Processing of statistical data allowed establishing a linear relationship between the fare of the warehouse lease and its area (Fig. 4).

Equation of linear paired regression for the dependent variable of lease fare from warehouse area in Ukraine is:

$$\tau_A = 531{,}27 + 19{,}91S. \quad (4)$$

Checking the significance of regression model was performed using Fisher's F-test. Comparing the resulting value (F = 587,81) with tabular (0,01; 1; 115) = 6,9 ($F > F_{cr}$) indicates a statistically reliable estimation of regression equation.

Analysis of the significance of the regression coefficients was performed using Student's t test. Its critical value T_{tabl} (115; 0,05) = 1,98 is more less than (t_b = 24,24), confirming its statistical significance.

Another important feature of the overall efficiency of transportation is the duration of delivery. As a result of regulation modes of transport participants it is more regulated and predictable.

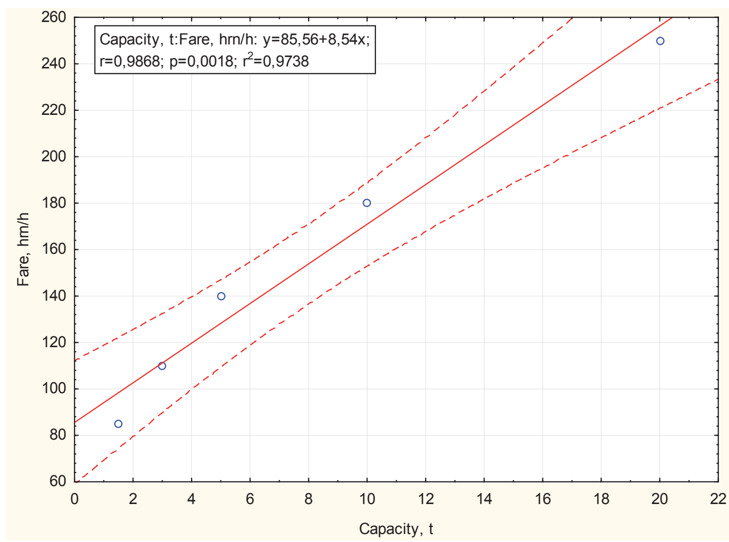

Fig. 3. Dependence of urban transportation fare from capacity of the vehicle

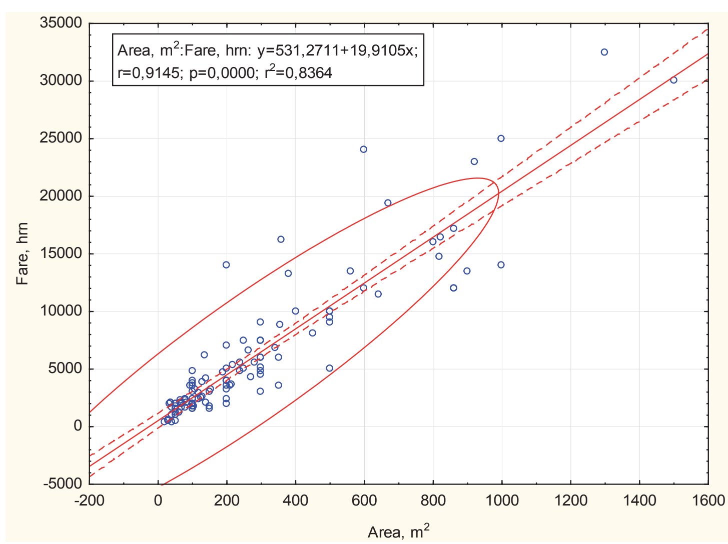

Fig. 4. Dependence of change of lease fare from warehouse area in Ukraine

Some of the features inherent to international traffic, which should take into account the impact of customs and transport conditions ensuring their reliability, which is achieved by reserving 1–2 days in addition to real-time execution of transport operations. This causes some scattering duration of the turnover trip as shown in Fig. 5 on example of Ukraine-Germany direction.

As a result of statistical analysis of observational data it was found that their distribution is consistent with the theoretical normal distribution of the random variable with parameters: expectation — 14,4 days, standard deviation — 2,2 days. Criterion of matching theoretical and statistical data sets ($\chi^2 = 9{,}8$) corresponds to an acceptable level of significance $p = 0{,}05$.

It should be noted that international transportation is usually characterized by a high vehicle mileage rate. The value density of mileage rate in international traffic is shown in Fig. 6. In domestic traffic the expectation value of this rate decreased to 15,9 %.

This distribution of mileage rates is consistent with the theoretical normal distribution of the random variable with parameters: expectation — 0,88, standard deviation — 0,04.

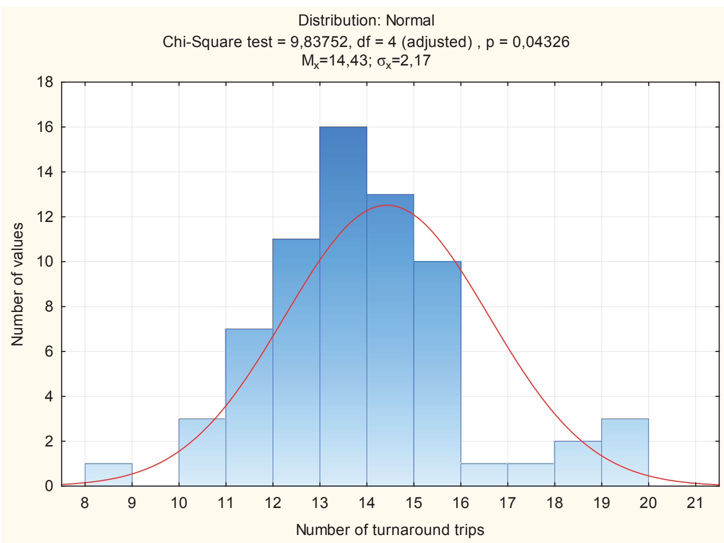

Fig. 5. Density of distribution of turnaround trip duration in Ukraine — Germany direction

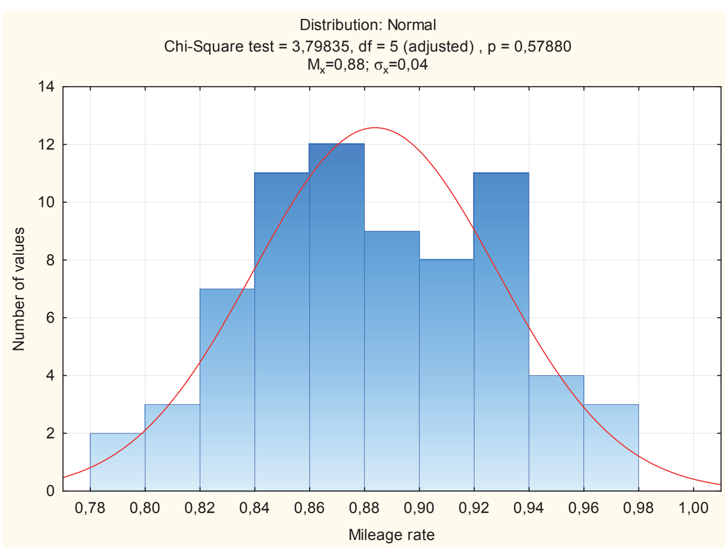

Fig. 6. Density of distribution of mileage rates in Ukraine — Germany direction

Criterion coordination of theoretical and statistical data sets ($\chi^2 = 3{,}8$) corresponds to an acceptable level of significance $p = 0{,}05$.

The feature of line haul transportation is a small proportion of distribution sections of the route.

Characteristic of reliability for goods delivery, which determines the overall efficiency of transportation, was studied using peer review of transportation by Delphi method.

5. Discussion of results of the studying the main characteristics of the cargo delivery distribution system

The results of the analysis determined that the automotive support of international trade is characterized by relatively high reliability (Table 1), which is achieved by redundancy of runtime for production targets and adopted system of insurance.

Table 1

Indicators of cargo transportation reliability

№	Indicator	International transportation, %	National transportation, %
1	The number of travels performed with violation of the planned target	1,5	4
2	The number of flights with claims from customers of transportation	up to 1	up to 1

The dependences and characteristics of change the basic characteristics of the distribution system create the basis for further adequate simulation modeling of goods delivery process in distribution systems, which will examine the impact of different topological organizational structures of distribution and inventory management strategies on the efficiency of deliveries. The results of this simulation, in the opinion of the authors, will enable to determine the optimal volume of goods delivery in concrete terms of delivery system and its effective topological structure for the appropriate transport technologies.

6. Conclusions

As a result of research:

1. Performances of the hierarchical distribution system are determined. There are:
   - the number of distribution centers;
   - parameters of transportation geography;
   - intensity of goods consumption;
   - surface area.
2. Geometric interpretation of the task allows putting in line with the parameters of transportation geography and delivery parameters that tie into a whole transportation volume, distance and cost of transportation, the number of items, their size and the number of distribution centers.
3. Combining the relationships of defined parameters in one equation revealed a mathematical model of the process.

4. Analysis of quantitative and qualitative criteria of the system is shown that the only criterion that most fully and comprehensively reflects their value is the cost of delivery considering its immobilization value.

5. Using the methods of operations research theory, an analytic solution of the problem was obtained, which reduced to solving a system of two nonlinear equations, which is performed by numerical methods and provides optimal number of distribution centers and volume of items.

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АНАЛИЗ ПОКАЗАТЕЛЕЙ ЭФФЕКТИВНОСТИ РАСПРЕДЕЛИТЕЛЬНОЙ СИСТЕМЫ ДОСТАВКИ ГРУЗОВ

В статье описана аналитическая модель иерархической распределительной системы, которая позволяет оптимизировать величину партии поставки грузов и количество распределительных центров одновременно. Установлены показатели эффективности данной распределительной системы. Исследованы основные характеристики распределительной системы доставки товаров и изучены закономерности процесса поставок автомобильным транспортом для получения оптимизации финансовых затрат на доставку грузов. Полученные данные позволяют аналитически решить актуальную задачу логистики.

Ключевые слова: перевозка, эффективность, надежность, модель, логистика, снабжение.

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