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REGULARITIES OF THE FLOW OF SINGLE FREIGHTAGES FOR THE INTERCITY FREIGHT TRANSPORTATION

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Abstract. *It was experimentally proved that a number of single intercity freightages in Ukraine is distributed by the Poisson law. And a single freightage flow in conditions of its occurrence corresponds to the simplest flow and is actually the simplest one. Due to the fact this flow is the result of a big number of different shippers' activityies, formation of an single intercity freightage is a rare event for each of them.*

Key words: *flow, single freightage, intercity freight transportation, Kolmogorov-Smirnov test.*

ЗАКОНОМЕРНОСТИ ПОТОКА РАЗОВЫХ ЗАЯВОК НА МЕЖДУГОРОДНЫЕ ГРУЗОПЕРЕВОЗКИ

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Аннотация. *Экспериментальным путём доказано, что количество разовых заявок на перевозку грузов в междугородном сообщении в Украине распределяется по закону Пуассона, и поток разовых заявок, который по условиям своего возникновения соответствует простейшему потоку, является результатом деятельности большого количества разных грузоотправителей, для каждого из которых формирование заявки на перевозку груза – редкое и фактически простейшее событие.*

Ключевые слова: *поток, разовая заявка, междугородная грузоперевозка, критерий Колмогорова-Смирнова.*

ЗАКОНОМІРНОСТІ ПОТОКУ РАЗОВИХ ЗАМОВЛЕНЬ НА МІЖМІСЬКІ ВАНТАЖОПЕРЕВЕЗЕННЯ

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Анотація. *Експериментальним шляхом доводиться, що кількість разових замовлень на перевезення вантажів у міжміському сполученні в Україні розподіляється за законом Пуассона, та потік разових замовлень, який за умовами свого виникнення відповідає найпростішому потоку, є результатом діяльності великої кількості різних вантажовідправників, для кожного з яких формування замовлення на перевезення вантажу – рідкісна і фактично найпростіша подія.*

Ключові слова: *потік, разове замовлення, міжміське вантажоперевезення, критерій Колмогорова-Смирнова.*

Introduction

In conditions of global informatization of the society the use of advanced technologies by institutions and organizations has become widespread. The road transport enterprises are not an exception, however large amounts of information that are received by them is an electronic data stream that are processed, using the latest information and communication technologies.

The use of progressive tools for processing and transmission of information is of particular relevance in the field of long-distance freight traffic, since almost half of the market is made up of orders generated at random and received by freight forwarders through various sources, the main of which today is the Internet.

Using the capabilities of the electron-foot space, the cargo owners who need a one-time transportation of their products place special orders on logistics sites, while the carriers monitor their availability and make decisions on their implementation. An aggregate of orders received by the transport and information portals during one day form their flow, the nature of which is random. In this regard, the researchers of the transport service process of the random market component market of intercity cargo transportation face the problem of a detailed study of the nature of the incoming flow of single orders by establishing the patterns of its formation. Meeting this challenge will create an opportunity for auto companies to develop and use in its activities flexible models of behavior on the market of transport services.

Analysis of publications

Study of random processes in the nets of data stream transmission has attracted the attention of scholars since the 10's of the XX century; evidence of this is the work of A. Erlang [1] and K. Palm [2]. The feature of the first studies is discrete time periods within which the streams are considered to be random events. This indicates the restricted possibilities to use the proposed in work [1, 2] dependencies for the purpose of describing the current realities of the intercity transportation market random component functioning.

Rapid development of information technology in 50-60s of the XX century led to further study of the random flow of orders. Among the scientific achievements of the given period, the research of A. Hinchin [3, 4] who managed to systemize and describe the features of streams of random events, using the methods of mass service theory draws special attention.

For example, in work [4] it is proposed to use the Puasson or a simple flow as a model of input stream. A. Hinchyn showed that the main condition for submission of a flow of random events of Poisson law is meeting three conditions: stationary, ordinariness and lack of aftereffect. However, in work [4] it is also noted that in practice it is difficult to establish whether the flow has the above properties. So, there are other conditions under which the flow can be considered to be the most simple or close to it. In particular, it is proved that when the flow is the sum of a large number of independent rare events, the impact of each of them based on their collective sum is negligible; the total flow of random rare events is similar to the simplest one. In work [5] they study the similarities between Poisson flow and the amount of stationary ordinary flows with a limited aftereffect, and in work [6] for unsteady flows with no aftereffects. Presented in works [5, 6] the theoretical principles were experimentally confirmed.

Relevance of research of flows of random events in the transport sector was dealt with in works [7, 8]. However, the attention of scientists in these studies was focused on organizational and technological features of the process of customer freight service, but not on the study of patterns of a flow of orders generated by the needs of cargo owners.

Thus, analysis of theoretical positions presented by the authors in [3–8] showed that study of any flow processes is an interesting challenge not only for its theoretical acquisition, but also for the purpose of applied nature. In addition, the researchers of transport service of a random component of the market of intercity cargo transportation should focus special attention on the experimental verification of regularities of orders that form the demand for it.

Purpose and problem statement

The flow of orders for cargo transportation is a sequence of similar events occurring one after the other at random times. Analysis of the literature showed that among the properties appropriate of a flow of random events they specify the stationary ones, unavailability of aftereffect and ordinariness; however, it is quite difficult to prove and test these properties on example of a flow of single orders for long-distance trucking, This is especially due to the complexity of gathering evidence that would reflect not only the information on the number of single orders announced to perform, but also the timing of their execution. In this regard, in the framework of this article one should

examine the patterns of the input stream of single orders and test the hypothesis concerning its appropriateness to the Poisson law according to the nature of its origin, namely as a result of the imposition of a large number of rare events.

It should be noted that the statement of compliance of the input stream of single orders with Poisson law has feasible arguments for its verification. However, a separate single order placed by a cargo owner to be performed within a day is a rare event, and the number of shippers who have an occasional need for traffic during the day is significant. The rarity of order formation for a single shipper is due to the market of one-off orders, because with a large number of cargo shipments there is typically concluded a long-term contract with a forwarding or haulage company, which excludes frequent orders from the market of single orders. Accordingly, a flow of a large number of single orders from various shippers across the country within a day forms the total flow, which in terms of its origin corresponds to the simplest one. Experimental confirmation of this hypothesis will make it possible to use the simplest flow patterns to research the market of single orders.

One of the main tasks of experimental verification of any claims is to determine the manner of its implementation. At this point, special attention deserves collection and processing of resources of transport-information portals that are related to the long-distance freight haulage.

Since the domestic Ukrainian market of single orders for intercity freight haulage is well represented by the Internet site «lardi-trans.com» [9], the information on this site is offered to be considered as a primary source of information concerning incoming single orders for long-distance freight haulage.

In organizing the collection of statistical information reasoned determination of indicators that correspond to it plays an important role. Any indicator that has to do with long-distance shipping can provide its qualitative or quantitative description. However, the inclusion of the entire set of indicators that can be used to describe the process under study, the list of parameters, which should be mandatory for collection is not correct. After all, focusing on all characteristics of the process in question, the researcher can neglect a detailed study of its most significant parameters. In order to avoid such situations in the pilot study there is determined the following composition of the basic parameters of single orders for transportation of goods subject to mandatory recording: the direction of traffic; the type of cargo; the volume of cargo shipment.

The choice of the above parameters has a background. Thus, based on setting the direction of freight haulage there is a possibility of providing the characteristics of differences of cargo haulage flows according to their geographical location, and this information is extremely useful for the carrier, because based on it one can estimate the competitive level of each of the areas of transportation beforehand. The type of cargo and its volume are the main factors for selecting the type of vehicle, its service conditions, the method of carrying out loading and off-loading work in the performance of long-distance transportation. With regard to the volume of freight shipments that are discussed in this study, it should be noted that they are limited to 20 tons. This limitation explains previous studies, in which it was revealed that about 70% of long-distance freight traffic is carried by vehicles with the carrying capacity of 20 tons and their share is nearly 90% of the total freight for one-off contracts [9].

An equally important issue in organizing the collection of statistics is to determine the calculation period for carrying out the pilot study. Today, the market of transport services experiences a high level of competition that is why the situation of its overcrowding by freight carriers is inevitable. In this regard, one could argue that the entire amount of single orders that are advertised to be performed on the specialized logistics sites within the period of their work during one day is accepted for execution by carriers on the same day. Accordingly, the laws of the input stream of single orders are advisable to be investigated during one day that is the billing period for collecting statistics is considered to be one day. Also, one should comprehend that due to constantly updated information as for the amount and parameters of orders declared for execution on logistics sites, the capabilities of researchers to trace the process of their income is limited, which explains a small sample size that experimenters are able to collect and process. Therefore, in the framework of study the period of collecting empirical data is limited to ten days.

After collecting statistical data, they are subject to careful processing, the main feature of which is that the orders for intercity transportation are grouped on a regional basis. That is, in the framework of the study it is considered that the administrative center of the region has the highest proportion as for its size and almost fully reflects the level of socio-economic development of the region and therefore to display the picture of long-distance cargo flow distribution they select the regions of Ukraine and the Autonomous Republic of Crimea with the centers in respective cities.

The results of statistical data processing are presented in the form of a matrix, the name of rows and columns of which is the starting and destination points respectively. Each cell of the matrix shows the number of single orders declared for execution within one day in one or another direction. The amount of matrix elements according to a particular row reflects the intensity of the daily occurrence of single orders for a specific destination (specific area). Thus, the result of collecting and processing statistical data is ten daily matrices of single orders, the number of items of each of them is equal to 625 units, and at this 25 matrix elements that are located at the intersection of similar points of departure and destination have zero value. This is due to the exception of the study review of single orders for intraregional freight transportation.

Based on the data obtained there is performed the verification of hypothesis as for the conformity of an input stream of single orders to the Poisson flow. A well-known fact in the study of objects the inspection of which is characterized by small samples is that in these cases it is inappropriate to use such criteria of consent as the Pearson criterion, and the criterion of Kolmogorov-Smirnov [10]. Therefore, in this study the verification of statement as for compliance of an input stream of single orders with the Poisson flow is suggested to be performed by using the Kolmogorov criterion by determining the maximum deviation between the empirical and theoretical distribution functions, the critical value of which for 10 days of observation at the level of significance 0.05 is 0.409 [12]. Using Kolmogorov criterion will make it possible not only numerically but also visually assess the results obtained, using its graphic image.

Thus, to carry out the inspection at the first stage of the pilot study there are at random selected the points between which they examine the process of incoming flow of single orders with 10 corresponding values of intensities of incoming to the website single orders. On the second stage, there is carried out the verification of the total flux of intensity of all the country regions they investigate every region of the country according to 10 totals of the number of orders received for this area for the whole day regardless of the direction of cargo transportation. Two-step verification of the hypothesis of correspondence of a single stream flow of orders to Poisson flow will make it possible to explore not only the flow consisting of rare daily orders of various shippers, but also create an opportunity to assess the total amount of daily flows of events for each area of the country.

Experimental verification of compliance of a stream of single orders for long-distance cargo transportation with the Poisson flow

Consolidation of the pattern of distribution of long-distance freight traffic by reducing the number of single orders received during the day for particular communities to appropriate regions has created the ability to quickly assess the level of loading of each of the regional areas of transportation, but it does not simplify the process of testing the hypotheses about the nature of input streams for each of 600 possible directions of cargo transportation. In this regard, one of the main objectives of the first phase of study is to determine the number of experiments sufficient to adequately test the hypothesis concerning the appropriateness of the incoming flow of single orders for long-distance cargo transportation to the Poisson flow.

To solve this problem, it is assumed that n-experiments are performed in each series of which there is tested the hypothesis of the Poisson flow with equal significance level of 0.05. At this, the probability to reject the hypothesis on condition that it is logical that will be equal to 95 %. Then, the assertion that for the selected level of significance the number of n-experiments will equal

$$n = N \cdot 0{,}05, \qquad (1)$$

where N – the total number of possible areas of transportation, units. that is

$$n = 600 \cdot 0{,}05 = 30 \text{ од.} \qquad (2)$$

Then, based on the central boundary theorem, at equal to 0.95, there is determined the number of possible cases to refute the hypothesis concerning the appropriateness of incoming flow of single orders to the Poisson flow l among the aassigned number of experiments.

$$l \le n \cdot (1-\alpha) + x_\beta \cdot \sqrt{n \cdot \alpha \cdot (1-\alpha)}\,, \qquad (3)$$

where x_β – table-value, $x_\beta = 1{,}65$ [11]. Then equals

$$l \le 3{,}46\,. \qquad (4)$$

The obtained value indicates that with the probability of 95 % the number of possible cases of rejection of the hypothesis concerning the appropriateness of the incoming flow of single orders to the Poisson flow with the level of significance equal to 0,05 for 30 experiments will not exceed 3,46 units.

The next step of the pilot study is the selection of 30 areas of freight haulage from 600 and their possible options that will participate in the experiment. This step is performed in the software MS Excel environment, using an appropriate function of the random figure generator. Thus, on the basis of 10 values of intensity of single orders input for 30 randomly selected areas of transportation there is performed calculation of the theoretical and empirical distribution functions of Poisson and the maximum deviation between these values is determined respectively.

$$\Delta = \left| k_i - \frac{(\lambda t)^{m_i}}{m_i!} \cdot e^{-\lambda t} \right|\,, \qquad (5)$$

where k_i – the cumulative frequency i – of the above specified interval, units; λ – the average intensity of the input of a flow of single orders, units / per day; t – the period of orders receipt, $t = 1$ per day; m_i – the sample value i of that interval, units. The calculation results for selected areas of transportation are given in table 1.

Graphical interpretation of calculation results of the pilot study for areas of transportation characterized by the medium and the largest deviation between the empirical and theoretical poisson distribution function in fig. 1 and 2.

Table 1 The maximum values of deviation between the empirical and theoretical Poisson distribution function for 30 randomly selected areas of freight haulage

Direction of cargo shipping	Maximum deviation value
Kharkiv-Khmelnitskyi	0,106
Khmelnitskyi Poltava	0,181
Zhytomyr Zakarpattya	0,019
Khmelnitskyi, Chernihiv	0,099
Luhansk, Poltava	0,125
Luhansk, Kherson	0,101
Khmelnitskyi Lviv	0,127
Lviv-Zaporizhia	0,312
Chernivtsi, Mykolaiv	0,005
Mykolaiv, Donetsk	0,139
Khmelnytskyi Cherkasy	0,091
Dnipropetrovsk, Lviv	0,196
Lviv, Ivano-Frankivsk	0,190
Odessa, Lviv	0,103
Zhytomyr, Chernihiv	0,061
Kyiv, Mykolayiv	0,142
Rivne-Sumy	0,233
Sumy - Transcarpathia	0,082
Kherson Khmelnitskyi	0,094
Kirovohrad, Chernihiv	0,123
Sumy, Donetsk	0,110
Chernigov, Mykolayev	0,086
Khmelnitsky Ivano-Frankivsk	0,207
Lugansk Vinnitsa	0,070
Cherkasy, Chernihiv	0,234
Zaporizhzhia-Dnipropetrovsk	0,169
Kharkiv, Sumy	0,200
Rivne-Zaporizhia	0,100
Volyn Zhytomyr	0,292
Mykolaiv, Kharkiv	0,109

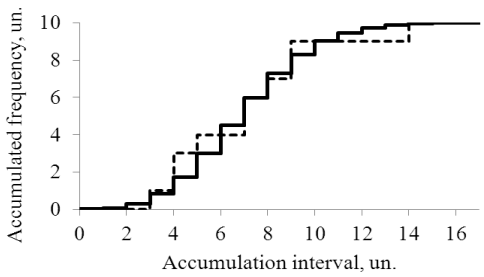

Fig. 1. Schedule of empirical and theoretical Poisson distribution function for the direction of transportation «Khmelnitsky Lviv» ▬ – theoretical Poisson distribution function; ▬ ▬ empirical distribution function

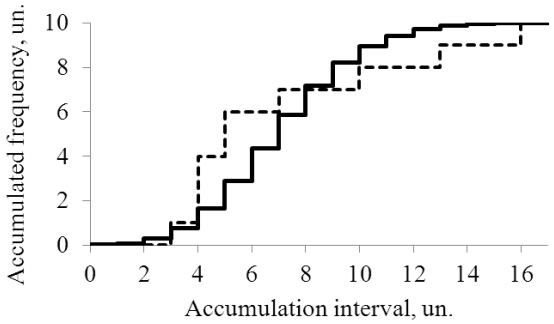

Fig. 2. Schedule of empirical and theoretical Poisson distribution function for the direction of transportation «Lviv-Zaporizhia»

Since, in any of 30 areas of transportation that participated in the experiment the maximum deviation between the empirical and theoretical poisson distribution functions did not exceed its critical value, the hypothesis concerning the appropriateness of the input stream of single orders for long-distance freight haulage to the poisson flow on the first stage of verification is not refuted.

Methodology for implementing the second phase of the pilot study is similar to the first one; however 10 values of the total daily intensity of single orders receipt from each of the areas of the country, not depending on the direction of cargo transportation, serve as the initial information for its implementation. The calculation results of the maximum value of deviation of the empirical poisson distribution function from the theoretical one are given in table 2.

Table 2 The maximum deviation between the empirical and theoretical poisson distribution function for regions of the country

Region	Maximum deviation value
Vinnitsa	0,139
Volyn	0,264
Dnipropetrovsk	0,321
Donetsk	0,276
Zhytomyr	0,200
Zakarpattia	0,157
Zaporizhia	0,334
Ivano-Frankivsk	0,288
Kyiv	0,175
Kirovohrad	0,258
Luhansk	0,160
Lviv	0,145
Mykolaiv	0,317

End of the table

Region	Maximum deviation value
Odessa	0,141
Poltava	0,155
Rivne	0,265
Sumy	0,198
Ternopil	0,271
Kharkiv	0,311
Kherson	0,243
Khmelnytskyi	0,380
Cherkasy	0,289
Chernihiv	0,291
Chernivtsi	0,244
Crimea	0,147

Graphic representation of simulation results of experimental investigation is provided for regions characterized by the medium and the largest deviation between the empirical and theoretical poisson distribution function in fig. 3 and 4.

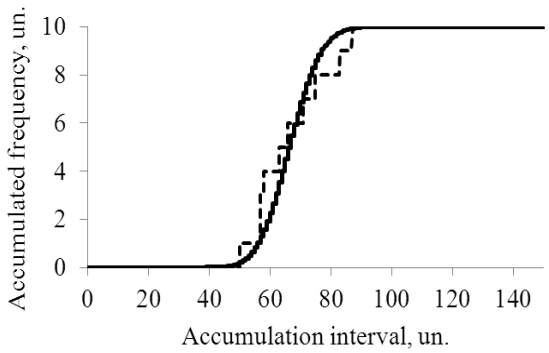

Fig. 3. Schedule of empirical and theoretical Poisson distribution function for Kherson region

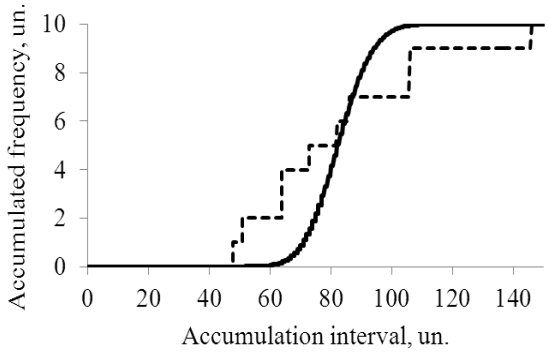

Fig. 4. Schedule of empirical and theoretical Poisson distribution function for Khmelnitskyi region

As a result of verification of the total daily flow of single orders for each of the regions of the country for their compliance with the Poisson flow, we can say that the hypothesis in question cannot be refuted, however none of the values of the maximum deviation between the empirical and theoretical distribution functions did not exceed its critical value.

Conclusions

Analysis of the literature that deals with the study of a random flow of events showed that the most common example of such flows is a simple Poisson flow, which is the sum of a large number of independent rare events, each of which to some extent affects the overall flow. Under these conditions, the probability that an incoming stream of single orders for long-distance trucking corresponds to the Poisson flow is high enough. However, a separate single order that is declared by a cargo owner to be performed during one day is a rare event, while the number of shippers who have the occasional need for cargo haulage during one day is significant. Accordingly, the flow of a large number of single orders from various shippers across the country during one day constitutes the total flow, which in terms of its origin corresponds to the simplest one, but this statement requires experimental confirmation or refutation.

As a result of two-step hypothesis testing of conformity of a flow of single orders with the Poisson flow it was revealed that according to the criteria of Kolmogorov the deviation between the empirical and theoretical distribution functions of random variables is not significant. The proof of this is the fact that in any series of experiments, the maximum deviation between the empirical and theoretical the Poisson distribution function did not exceed the critical value of the selected criteria of consent, and therefore we can say that the incoming flow of single orders for intercity cargo haulage meets the simplest Poisson flow.

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