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INVESTIGATION OF THE FUNCTIONING OF THE TRANSPORT AND PRODUCTION SYSTEM OF A METALLURGICAL ENTERPRISE QUARRY

Timing of the time parameters of the technological routes of the transport and technological system of the quarry of the metallurgical enterprise was carried out. The statistical characteristics and laws of distribution of the above-mentioned parameters are determined.

In order to identify the correlations between the parameters of transport service indicators of technological routes and to identify the statistical characteristics of these parameters, the timing of the operation of rolling stock on the technological routes of the transport and production system of the quarry of the metallurgical enterprise was carried out.

The study presents the results of timing of two technological routes of the section of the transport and production system of the quarry. Timing was carried out during four working days in two shifts (from 08.00 to 20.00 and from 20.00 to 08.00).

Timing was carried out according to the following values: loading time, unloading time, driving time with a load, driving time without a load, technological and physiological idle time, number of drives.

The study was conducted using the Wialon software package.

Analyzing the obtained results, it is possible to conclude that idle vehicles before loading (unloading) cargo can occur on any shift during a work shift. This is due to the fact that during the time the car is traveling on the route, the value of the time parameters may be such that the conditions of vehicle downtime arise. In this regard, it can be concluded that the occurrence of idling vehicles on technological routes is of a probabilistic nature.

Key words: timing, distribution law, loading time, unloading time, technological downtime, technological routes, rolling stock, carrying capacity

INTRODUCTION

Quarry dump trucks are an important element of the transport and technological system of quarries of mining enterprises. In this regard, the task of solving the problem of increasing the efficiency of the system as a whole by choosing a rational fleet of rolling stock, taking into account the change in transportation conditions and the random nature of the time parameters of the transport process. Solving the given task requires obtaining the characteristics of the time parameters of the transportation process for further performance of the given task.

ANALYSIS OF LITERATURE DATA AND FORMULATION OF THE PROBLEM

The transport network in the quarry is a complex system consisting of a large number of active elements - dump trucks and excavators of individual types. This system is characterized by a relatively rapid change in traffic flow parameters in space and time, as well as by random values of the time of individual processes, such as vehicle maneuvering, loading and unloading, movement along the route. Optimum operational planning and management of quarry transport can increase its productivity by more than 20% due to reduction of idle time and queues. [1] As a result, the process of transporting technological raw materials by dump trucks in the conditions of mining and extractive production does not meet the requirements of the modern transportation process due to the inefficiency of the existing methods of managing fleets of heavy-duty dump trucks, which are not sufficiently adapted to the conditions of operation in the technological cycles of metallurgical and mining production. [2]

The analysis of works [3-12] devoted to the aspects of selection and approaches to the selection of rolling stock shows that the issues of selection, formation, calculation, economic feasibility of using one or another type of rolling stock on the technological routes of industrial enterprises were sufficiently studied. Thus, in the paper [3] it is stated that when choosing vehicles, a comprehensive approach is necessary, the essence of which is, first of all, that the issues of transportation, unloading, loading and storage should be considered simultaneously and in relation to other issues of technology and organization production The choice of vehicles is based on the generally accepted method of assessing the economic efficiency of new equipment and capital investments. The initial data necessary for the selection of the most economical means of transport include: the characteristics of the goods being transported; route information; data on the volume of cargo transportation by the consumer, etc. The existing approaches to the definition and understanding of the term "rolling stock selection" in transport logistics are considered in the paper [4]. In work [5-6] issues regarding the existing and modern methods of calculating the rolling stock fleet and their shortcomings are highlighted.

THE PURPOSE OF THE WORK PURPOSE AND OBJECTIVES OF THE STUDY

To identify the relationship between the parameters of transport service indicators of technological routes and to determine the statistical characteristics of these parameters by timing the operation of moving vehicles of the transport and production system of the career of a metallurgical enterprise.

RESEARCH RESULT

In order to identify the correlations between the parameters of transport service indicators of technological routes and to identify the statistical characteristics of these parameters, the timing of the operation of rolling stock on the technological routes of the transport and production system of the quarry of the metallurgical enterprise was carried out.

The rolling stock of the transport and production system of the quarry is represented by BeLAZ dump trucks with a load capacity of 30 and 42 tons. On some dump trucks, the load capacity was increased to 36 and 30 tons. The road transport division serves the technological routes of sections of the transport and production system and carries out the transportation of technological waste and products of their processing to ensure the continuous production process of the main production of the metallurgical enterprise.

The study presents the results of timing of two technological routes of the section of the transport and production system of the quarry. Timing was carried out during four working days in two shifts (from 08.00 to 20.00 and from 20.00 to 08.00).

Timing was carried out according to the following values:

-loading time, min.;
-unloading time, min.;
-the time of the trip with the cargo, min.;
-the time of the trip without the cargo, min.;
-downtime of a technological and physiological nature, min.;
-the number of rides.

The study was conducted using the Wialon software package.

The results of statistical data processing are presented in Table 1.

Table 1 – The main statistical characteristics of the time parameters of the technological routes of the transport and production system of the quarry

Parameter, min.	Mean, min.	Variance	Standard Error	Minimum, min.	Maximum, min.
1	**2**	**3**	**4**	**5**	**6**
Route A					
Loading time	5,515	3,026	0,107	3,32	11,12
Unloading time	12,787	2,619	0,099	9,25	19,38
The time of the trip with the cargo	2,273	0,809	0,055	1,250	5,920
The time of the trip without the cargo	11,131	3,205	0,110	8,500	18,100
Route B					
Loading time	3,199	2,469	0,091	1,430	10,50
Unloading time	3,086	2,989	0,099	1,270	10,70
The time of the trip with the cargo	5,927	1,671	0,075	2,4	12,1
The time of the trip without the cargo	2,070	0,395	0,036	1,2	5,19
Waiting time in the queue	5,971	34,479	0,338	0	24,52
Downtime per shift	30,813	319,983	3,322	2,04	77,86

Values - loading time, unloading time, the time of the trip with the cargo, the time of the trip without the cargo, waiting time in the queue were obtained for 650 rides. The values - downtime per shift, the number of rides are obtained for 27 shifts, and the value in the last line is the total idle time during one shift.

As a result of the statistical analysis, the laws of random values of the time parameters of the technological routes of the transport and production system of the quarry were established.

The results of the analysis are shown in Table 2.

As a result of the statistical analysis, it was found that the number of trips of each car during the shift is not a constant value, the average value of which is equal to 20.41 min.

Table 2 – Results of the statistical analysis of the time parameters of the technological routes of the transport and production system of the quarry of the metallurgical enterprise

Parameter, min	Technological routes	
	The law of distribution	Distribution function
Route A		
Loading time	Lognormal	$f(x) = (\frac{1}{\sqrt{0,107}})e^{-\frac{(lnx-5,15)^2}{2(0,107)^2}}$
Unloading time	Lognormal	$f(x) = (\frac{1}{\sqrt{x0,099^2}})e^{-\frac{(lnx-12.787)^2}{2(0,099)^2}}$
The time of the trip with the cargo	Normal	$f(x) = \frac{1}{0,055\sqrt{2\pi}}e^{-\frac{(x-2,273)^2}{2(0,055)^2}}$
The time of the trip without the cargo	Lognormal	$f(x) = (\frac{1}{\sqrt{x0,110^2}})e^{-\frac{(lnx-11,131)^2}{2(0,110)^2}}$
Route B		
Loading time	Lognormal	$f(x) = (\frac{1}{\sqrt{x0,091^2}})e^{-\frac{(lnx-3,198)^2}{2(0,091)^2}}$
Unloading time	Lognormal	$f(x) = (\frac{1}{\sqrt{x0,099^2}})e^{-\frac{(lnx-3,086)^2}{2(0,099)^2}}$
The time of the trip with the cargo	Normal	$f(x) = \frac{1}{0,075\sqrt{2\pi}}e^{-\frac{(x-5,927)^2}{2(0,075)^2}}$
The time of the trip without the cargo	Lognormal	$f(x) = (\frac{1}{\sqrt{x0,395^2}})e^{-\frac{(lnx-3,086)^2}{2(0,395)^2}}$
Waiting time in the queue	Exponential	$f(x) = 0,167e^{-0,167x}$
Downtime per shift	Normal	$f(x) = \frac{1}{3,322\sqrt{2\pi}}e^{-\frac{(x-30,813)^2}{2(3,332)^2}}$

DISCUSSION OF THE STUDY RESULTS

Figure 1 presents a histogram of the distribution of idle time on routes. This time parameter belongs to the normal distribution law and is difficult to analyze compared to other researched parameters. For the most part, it is quite difficult to analyze the situation of downtime on the routes, which may arise as a result of poor-quality ongoing repairs of rolling stock, installation of poor-quality spare parts, unsatisfactory physical and psychological condition of drivers, and unsatisfactory condition of the road surface.

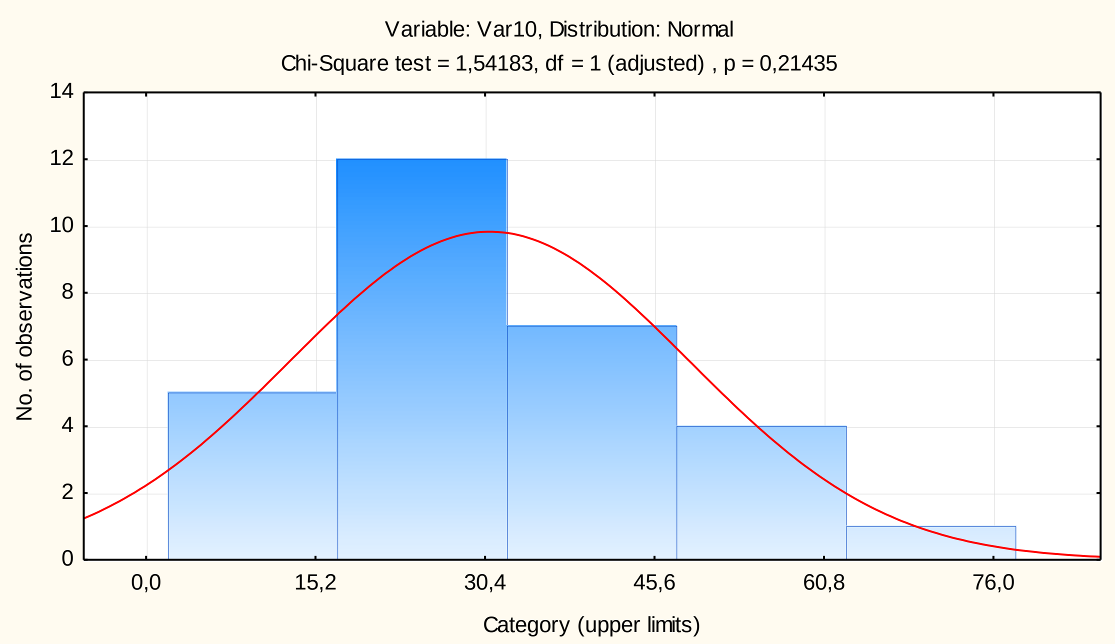

Figure 1 – Graphic representation of the empirical distribution law for the parameter downtime of a technological and physiological nature for technological routes

According to the obtained data, the loading time on the routes is presented in Figures 2, 3. Using the Chi-Square test, the hypothesis that the obtained samples belong to the logarithmic-normal distribution was tested. At the significance level of 0.95, the loading time obeys the logarithmic-normal distribution law with the parameters for route A - $\bar{x} = 5{,}515$; $\sigma = 0{,}107$, for route B - $\bar{x} = 3{,}199$; $\sigma = 0{,}091$.

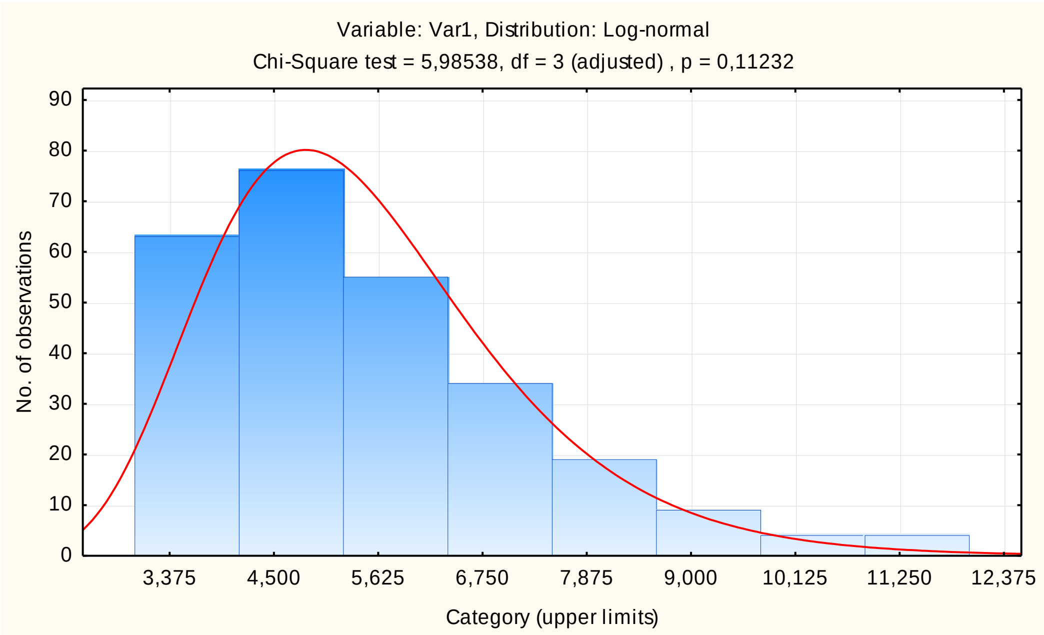

Figure 2 – Graphic representation of the empirical distribution law for the parameter loading time for technological route A

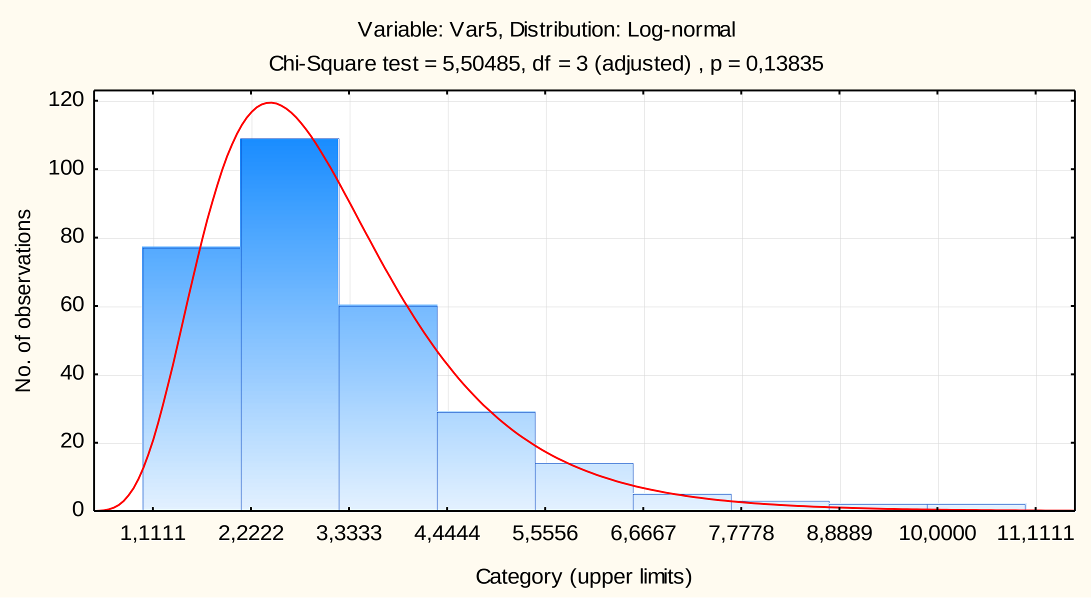

Figure 3 – Graphic representation of the empirical distribution law for the parameter loading time for technological route B

The unloading time, the distribution histograms of which are presented in Figures 4, 5, are also subject to the logarithmic-normal distribution law with parameters for the route A - $\bar{x} = 12{,}787$; $\sigma = 0{,}099$, для маршруту B - $\bar{x} = 3{,}086$; $\sigma = 0{,}099$.

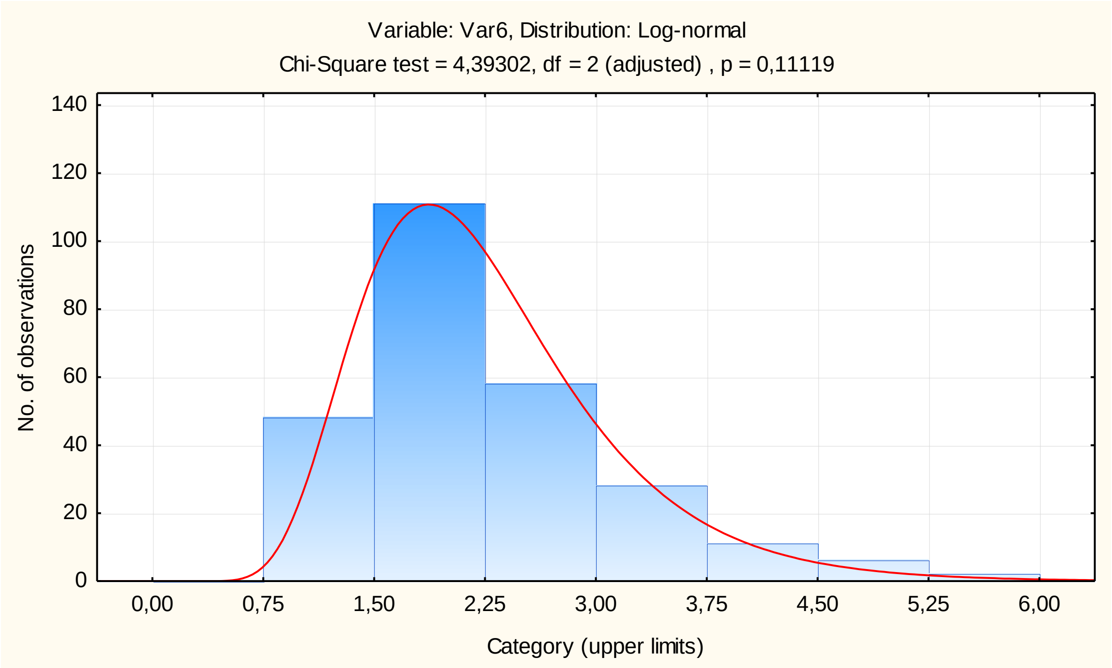

Figure 4 – Graphic representation of the empirical distribution law for the parameter for technological route A

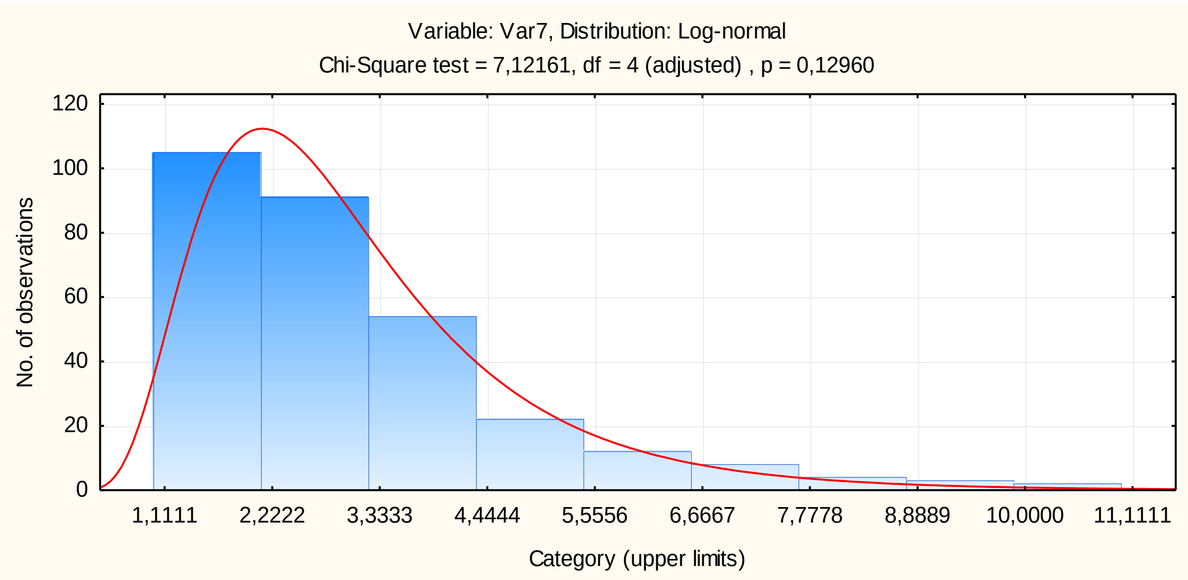

Figure 5 – Graphic representation of the empirical distribution law for the parameter for technological route B

Figures 6, 7 present histograms of the time distribution of the trip with cargo. Using the Chi-Square test, the hypothesis that the obtained samples belonged to the normal distribution law with parameters for the route was tested A - $\bar{x} = 2{,}273; \sigma = 0{,}055$, for the route was tested B - $\bar{x} = 5{,}927; \sigma = 0{,}075$.

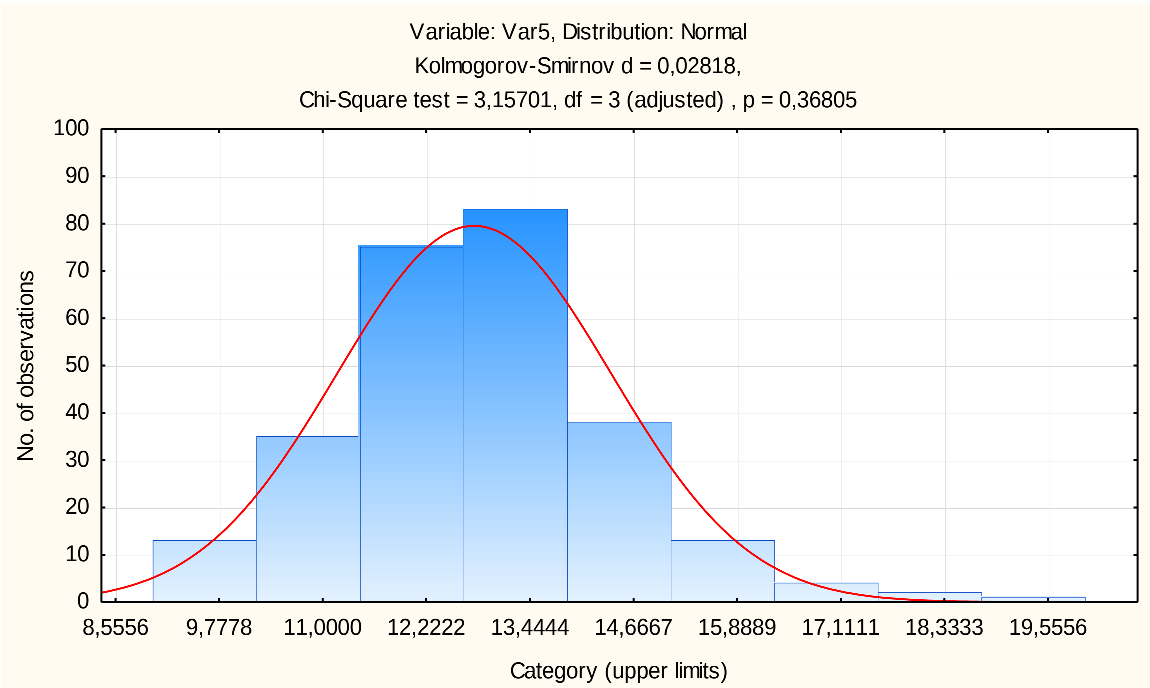

Figure 6 – Graphic representation of the empirical distribution law of the parameter the time of the trip with the cargo for technological route A

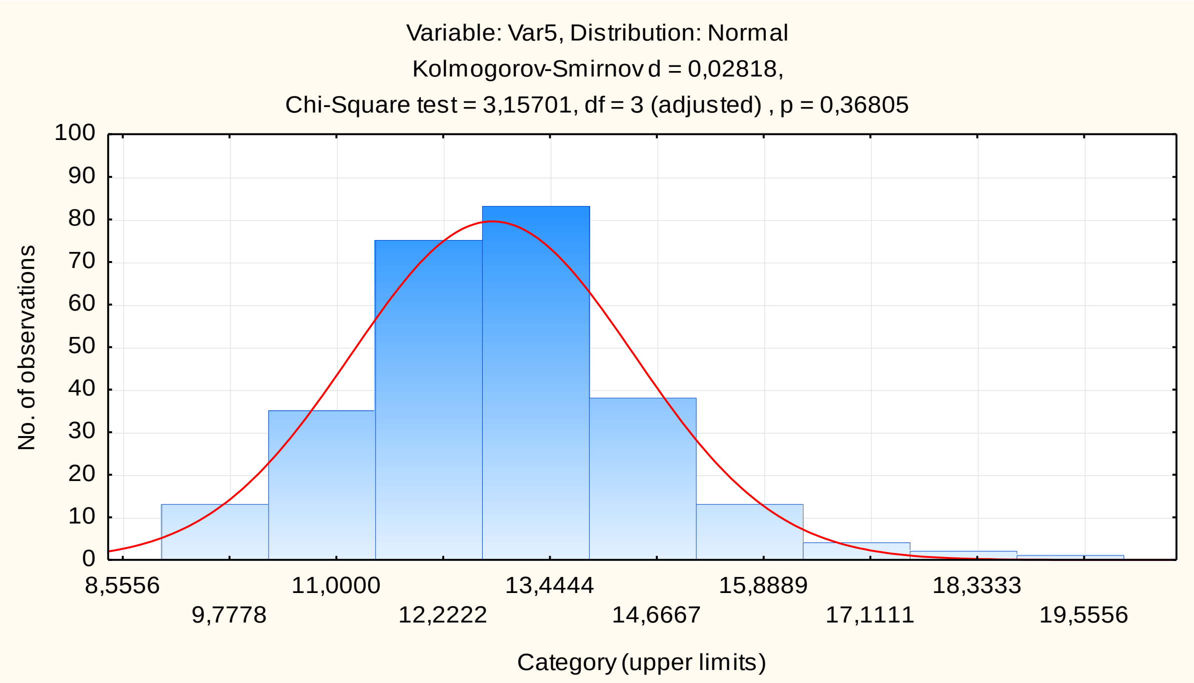

Figure 7 – Graphic representation of the empirical distribution law of the parameter the time of the trip with the cargo for technological route B

The travel time without cargo, the distribution histograms of which are presented in Figures 8, 9, are also subject to the log-normal distribution law with parameters for the route A - $\bar{x} = 11{,}131$; $\sigma = 0{,}110$, with parameters for the route B - $\bar{x} = 3{,}086$; $\sigma = 0{,}395$.

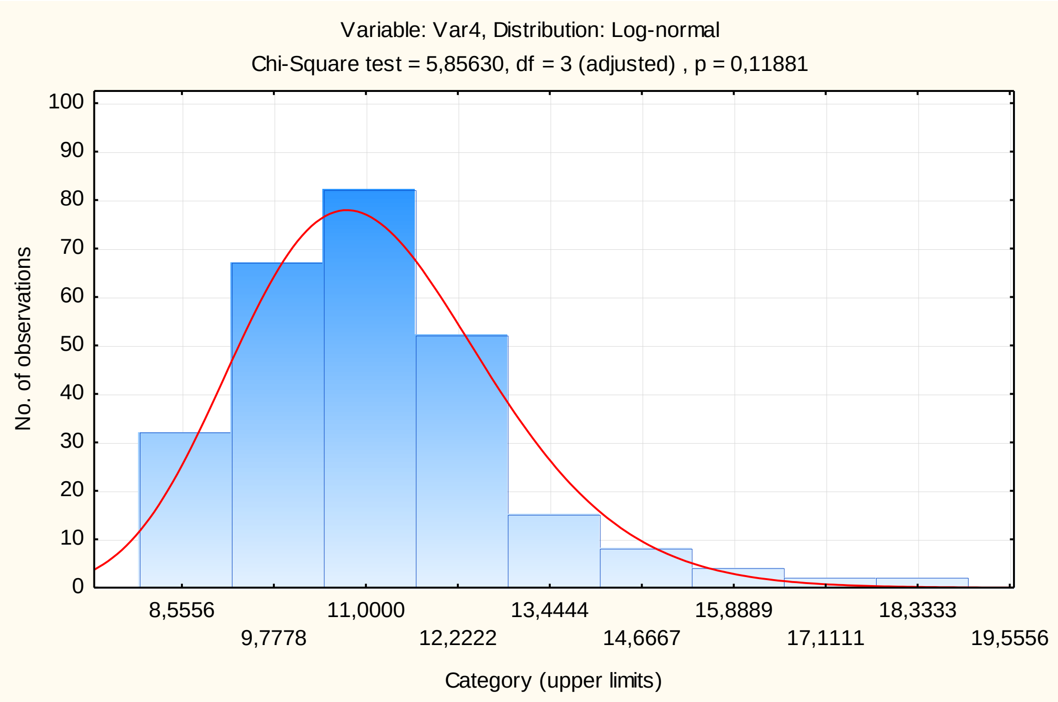

Figure 8 – Graphic representation of the empirical distribution law for the parameter the time of the trip without the cargo for technological route A

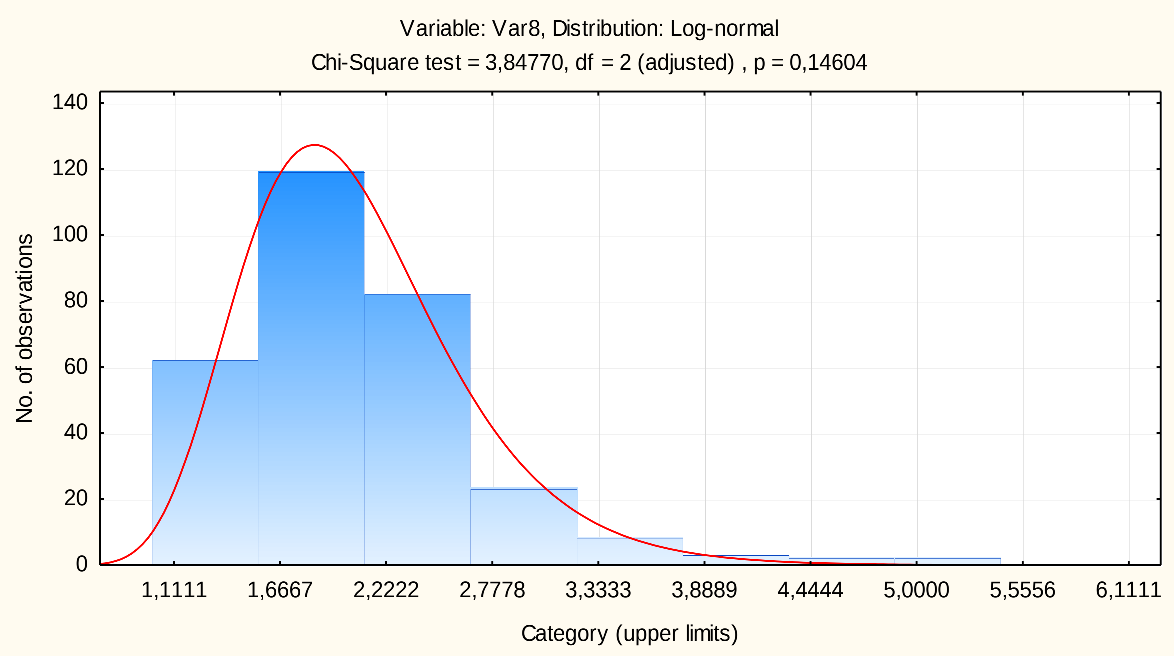

Figure 9 – Graphic representation of the empirical distribution law for the parameter the time of the trip without the cargo for technological route B

The histogram presented in Figure 10 describes the waiting time in the queue for reordering by unloading to the crushing and sorting complex and is subject to the exponential law of distribution with the parameter $\gamma = 0{,}167$.

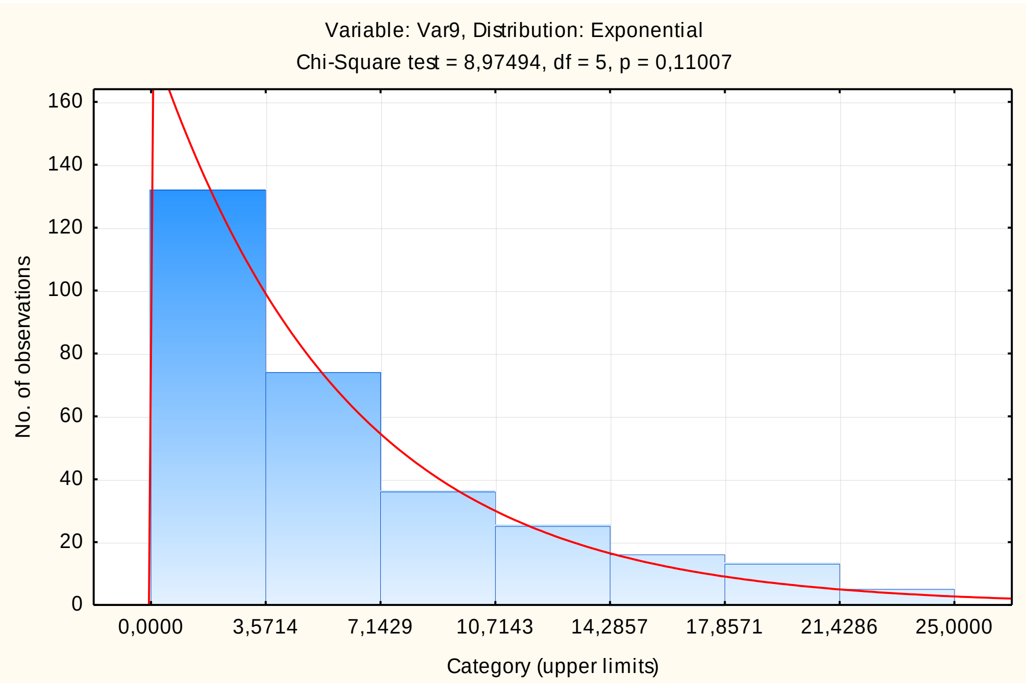

Figure 10 – Graphic representation of the empirical distribution law for the parameter waiting time in the queue for technological route B

CONCLUSIONS

1. Timing was carried out and the main statistical characteristics of the time parameters of the transport service cycle of technological routes were determined.

2. A statistical analysis of time parameters of technological routes was carried out. The obtained distribution laws of random variables.

Analyzing the obtained results, it is possible to conclude that idle vehicles before loading (unloading) cargo can occur on any shift during a work shift. This is due to the fact that during the time the car is traveling on the route, the value of the time parameters may be such that the conditions of vehicle downtime arise. In this regard, it can be concluded that the occurrence of idling vehicles on technological routes is of a probabilistic nature.

REFERENCES

1. Levykyn V. M., Shevchenko Y. V., Muzychenko S. E. (2005) Funktsyonalno-ynformatsyonnaia struktura ymytatsyonnoi modely protsessa operatyvnoho upravlenyia karernыm avtotransportom [*Functional-informational structure of the simulation model of the process of operational management of career vehicles*] Novi tekhnolohii - *New technologies*, 1-2, 123-129.

2. Hubenko V. K., Pomazkov M. V. (2010) Resursosberehaiushchaia tekhnolohyia marshrutyzatsyy avtosamosvalov na metallurhycheskom predpryiatyy [*Resource-saving technology for routing dump trucks at a metallurgical enterprise*] Visnyk Pryazovskoho derzhavnoho tekhnichnoho universytetu Seriia: tekhnichni nauky - *Bulletin of the Azov State Technical University Series: Technical Sciences,* 21, 113-120.

3. Maksymov Y. M., Perfyleva A. Y. (2014) Orhanyzatsyia vnutryzavodskoho transportnoho khoziaistva y puty eho sovershenstvovanyia [*Organization of intra-factory transport facilities and ways to improve it*] Lohystycheskye systemы v hlobalnoi эkonomyke - *Logistics systems in the global economy,* 4, 164-168.

4. Mochalyn S.M., Zarudnev D.Y. (2008) Analyz problemu vubora podvyzhnoho sostava v transportnoi lohystyke *[Analysis of the problem of choice of rolling stock in transport logistics*] Vestnyk SybADY - *Vestnik SibADI,* 8, 66-69.

5. Naumov V.S. (2006) Sushchestvuiushchye metodyky rascheta strukturы avtoparka y ykh nedostatky [*Existing methods for calculating the structure of the fleet and their shortcomings*] Visnyk KDPU - *Bulletin of KDPU, 2(37), 114-119.*

6. Roslavtsev D.M., Burma V.A. (2011) Formuvannia struktury avtoparku funktsionalnoho pidrozdilu pidpryiemstva [*Formation of the structure of the vehicles fleet of the functional support of the enterprise*] Vostochno-Evropeiskyi zhurnal peredovykh tekhnolohyi - *Eastern European Journal of Advanced Technologies*, 1(3), 30-32.

7. Halkyn A.S. (2013) Analyz alternatyvnykh proektov pry opredelenyy kolychestva y marky avtotransportnykh sredstv [*Analysis of alternative projects in determining the number and brand of vehicles*] Эkonomyka predpryiatyia - *Enterprise economy,* 3(11), 43-45.

8. Zarudnev D.Y., Bykova O.V. (2015) Sovremennoe sostoianye voprosa vыbora avtotransportnыkh sredstv pry dostavke hruzov [*The current state of the issue of choosing vehicles for the delivery of goods*] Sovershenstvovanye orhanyzatsyy dorozhnoho dvyzhenyia y perevozok passazhyrov y hruzov - *Improving the organization of traffic and transportation of passengers and goods,* 1, 83-87.

9. Barylnykova E.P., Kulakov A.T., Talypova Y.P. (2017) Model vybora podvyzhnoho sostava dlia perevozky hruzov avtomobylnym transportom [*The model for choosing rolling stock for the carriage of goods by road*] Yntellekt. Ynnovatsyy. Ynvestytsyy - *Intelligence. Innovation. Investments*, 12, 102-106.

10. Horiaynov A.N., Osokyna O.D. (2009) Struktura transportnoho parka y kharakterystyky transportnoi y lohystycheskoi system [*The structure of the transport fleet and the characteristics of the transport and logistics systems*] Vostochno-Evropeiskyi zhurnal peredovykh tekhnolohyi - *Eastern European Journal of Advanced Technologies*, 1(37), 28-31.

11. Balhabekov T.K. (2017) Vlyianye vozrastnoi strukturы avtoparka na эffektyvnost avtotransportnoho predpryiatyia [*Influence of the age structure of the fleet on the efficiency of the motor transport enterprise*] Trudy BHTU - *Proceedings of BSTU,* 2, 225-231.

12. Vueikova O.N. (2013) Teoreticheskoe obosnovanie vliyaniya strukturyi parka avtosamosvalov na prostoi avtomobilno-ekskavatornyih kompleksov otkryityih gornorudnyih karerov [*Theoretical drainage of the structure of the park of auto-dispensing on the mast of automobile-exasked complexes of open horned cars*] Sovremennyie problemyi transportnogo kompleksa Rossii - *Moving problems of the transport complex of Russia,* 3, 192-198.

Середа Б.П., Муковська Д.Я., Середа Д.Б. **Дослідження функціонування транспортно-виробничої системи кар'єру металургійного підприємства**

З метою виявлення співвідношень між параметрами показників транспортного обслуговування технологічних маршрутів та виявлення статистичних характеристик цих параметрів було проведено хронометрування роботи рухомого транспорту на технологічних маршрутах ТВС К МП металургійного підприємства. Рухомий склад ТВС К МП представлений самоскидами марки БеЛАЗ вантажопідйомністю 30 й 42 т. На деяких самоскидах вантажопідйомність була збільшена до 36 т. 30 т б. Автотранспортний підрозділ обслуговує технологічні маршрути ділянок ДПМШ та здійснює перевезення технологічних відходів та продуктів переробки основного виробництва для забезпечення неперервного виробничого процесу основного виробництва металургійного підприємства.

Дослідження проводилось на шести технологічних маршрутах ДПМШ ЦШП цеху шлакопереробки. Хронометраж проводився протягом чотирьох робочих діб у дві зміни (з 08.00 до 20.00 та з 20.00 до 08.00).

Хронометраж здійснювався за наступними величинами: час завантаження, час розвантаження, час їздки з вантажем, час їздки без вантажу, час на простої технологічного та фізіологічного характеру, кількість їздок.

Дослідження проводилось за допомогою програмного пакету Wialon.

Аналізуючи отримані результати, можна зробити висновок, що простої автотранспорту перед навантаженням (розвантаженням) вантажу можуть відбуватися в будь-яку зміну протягом робочої зміни. Це пов'язано з тим, що за час руху автомобіля по маршруту значення параметрів часу можуть бути такими, що виникають умови простою автомобіля. У зв'язку з цим можна зробити висновок, що поява простою автотранспорту на технологічних маршрутах носить імовірнісний характер.

Ключові слова: хронометраж, закон розподілу, час навантаження, час розвантаження, технологічний простій, технологічні маршрути, рухомий склад, вантажопідйомність.

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