The International Journal of
TRANSPORT & LOGISTICS
Medzinárodný časopis
DOPRAVA A LOGISTIKA

ISSN 1451-107X

SOME RESEARCH TO DETERMINE THE CAPACITY OF TRUCK HAULAGE IN OPEN-PIT MINING

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Article history:
Received 25 January 2016
Accepted 1 April 2016
Available online 13 April 2016

Abstract: *This paper presents the results obtained from research on determining the capacity of the truck haulage in open-pit mines for extracting metals. As a case study in this paper is taken the truck haulage in the copper mine "Buchim"- Rep. of Macedonia, where the data is taken from the SkyLinks system for dispatching a truck haulage and all the data is statistically processed. Comparison is made between the technical and the exploitation hour capacity of trucks and also is proposed guidelines for increasing the exploitation capacity as a very important technical parameter.*

Key words: *truck, capacity, mineral resource, time utilization.*

1 INTRODUCTION

It should be borne in mind that the capacity of the truck haulage is a very important parameter not only in terms of cost-effectiveness in the operation but also in terms of planning the production capacity of the mine. In this paper is presented the general principles for determining the capacity of truck haulage, and also the types of transport capacities. Calculations are made for the technical capacity of truck haulage in the copper mine "Buchim", by determining the average weight transported in a work cycle based on statistical analysis of the data registered with SkyLinks system based on global positioning system (GPS). Exploitation capacity of truck haulage is determined based on the ratio of the real coefficient for time utilizing of trucks also registered with SkyLinks system. At the end of this paper is performed a comparative analysis of both capacities and also is given draft guidelines for increasing the coefficient of time utilization of trucks and therefore their exploitation operational capacity.

2 GENERAL PRINCIPLES FOR DETERMINING THE CAPACITY OF TRUCK HAULAGE

The capacity of the transportation equipment applied in open-pit mines for metal exploitation is very important parameter which affects the economics of the operation in the mining company. Capacity of trucks with cyclic action used in mines depends on the following factors:

- Mining-technical factors (capacity of the open-pit mine, properties of the load, bearing capacity of the ground, surfaces of the working platforms for loading and unloading);
- Structural features of roads (length, radius of curvature, gradient, quality of road construction);
- Excavating technology;
- Construction and technical properties of the selected mechanization;
- Organization of work;
- Transport schemes of the open-pit mine;
- Climate and subjective factors, etc.

The capacity of the truck is a product of the nominal payload capacity Q_t and the number of trips per unit time n_c ,[3]:

$$Q_h = Q_t \cdot n_c = \frac{60 \cdot Q_t}{T_c} = \frac{3600 \cdot Q_t}{T_c} \left[\frac{t}{h} \right] \tag{1}$$

The mass of transported loads of the truck or truck actual payload [2] is calculated according to the equation :

$$Q_t = V_s \cdot k_p \cdot \gamma_r [t] \tag{2}$$

The total cycle time of the truck (T_c) is the amount of time needed for: loading, actively driving the full and empty truck, time for maneuver and time of unloading the material, active drive of the full and empty truck or the length of the transport distance that varied by changing the position of excavation in the open-pit mine.

If in equation (1) we replace the value of Q_t given in the equation (2), the capacity of the truck will be:

$$Q_h = \frac{60 \cdot V_s \cdot k_p \cdot \gamma_r}{T_c} \left[\frac{t}{h} \right] \tag{3}$$

Where:

V_s - volume of dump box [m^3],

k_p - coefficient of filling the dump box of the truck,

γ_r - bulk ore in loose condition $\left[\frac{t}{m^3}\right]$,

T_c – total cycle time of the truck [min].

Equation (1) shows that the haulage capacity of the truck depends mainly from two parameters Q_t and T_c. That means it presents a function of two independent variables and if we replace: Q_h=Z; Q_t=X; T_c=Y, then we will get the function with two variables (independent variables):

$$Z = 60 \cdot \frac{X}{Y}\left[\frac{t}{h}\right] \tag{4}$$

in case the total cycle time of the truck (T_c) is expressed in minutes or

$$Z = 3600 \cdot \frac{X}{Y}\left[\frac{t}{h}\right] \tag{5}$$

in case the total cycle time of the truck (T_c) is expressed in seconds.

The graph of this two-parameter function Z = f(X, Y) is a curved surface that is presented in Fig.1.

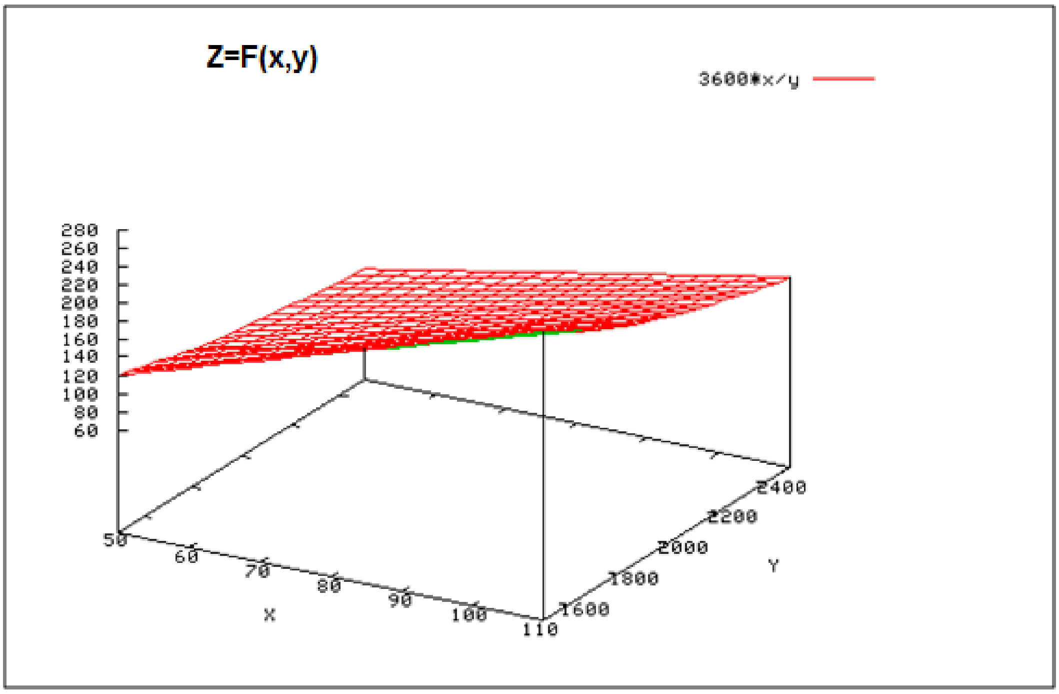

Fig.1 *Diagram of the dependence of the hour capacity of transported truck load and the total cycle time of the truck*

A number of factors affect the size of the hour capacity of the truck including: volumetric weight of the loose material, granulometric composition of the material, humidity of the material, conditions of the transport route and more. It is very difficult to calculate the exact hour transport capacity. The exact determination of the capacity is possible only through direct measurements of mass transported in one cycle and measuring the total time duration of the transport cycle including: the time for loading the material, time of actively driving the full and empty truck, time for unloading the material, time to maneuver and the waiting time for loading or unloading the material. In the mining practice, often the transport capacity is determined by adopting the constant value for transported mass in one cycle, while the values of the total time duration of the cycle change bearing in mind that mining exploitation is a dynamic system and the location of working site is often changing. In open-pit mines with truck haulage we distinguish three types of capacities[1]:

- Theoretical
- Technical and
- Exploitation capacity.

The theoretical (maximum or constructive) capacity is when the truck will work continuously (without retention, maneuvering and waiting) and the coefficient of full truck load is k_p=1. Often the data of theoretical capacity is used only in the choice of the trucks when it is carried out comparison of structural features of several models of trucks.

The technical capacity is accomplish in specific working conditions depending on the effective working time and other relevant factors. Technical capacity often serves as a basis for calculating the exploitation capacity, as well as comparative analysis of different schemes of transport, loading and unloading of material, etc. The technical capacity is calculated according to the equation (3).

The exploitation capacity is accomplish over the total working hours in specific working conditions, which is function of all relevant factors (factor of truck load, factor of time utilization, etc.). This capacity is calculated for intervals of one hour to one year. Equation for calculation the exploitation capacity is:

$$Q_h = \frac{60 \cdot Q_t \cdot K_{vi}}{T_c} \left[\frac{t}{h} \right] \tag{6}$$

Where K_{vi} represents the coefficient of hour time utilization and mainly depends on the conditions of exploitation.

For precise calculations of exploitation capacity it is very important to know exactly how much is the value of the time utilization coefficient. The values of this coefficient depending on the conditions of exploitation are shown in the table 1.

Tab.1 *Values of the coefficient of hours time utilization depending on the conditions of exploitation*

Terms of exploitation	**Koefficient, K_{vi}**	**Effective minutes per hour**
good	0,92	55
average	0,83	50
bad	0,67	40

3 DETERMINING THE CAPACITY OF TRUCK HAULAGE IN OPEN-PIT MINE FOR COPPER "BUCHIM"

The open-pit mine for exploitation of copper "Buchim" (Fig.2) is using discontinuous technology for loading and transporting ore from the excavation benches to the primary crusher. For loading the ore are used two electric excavators with volume of bucket of 7,65 m^3 and 11,47 m^3, type P&H 1900 AL and P&H 2100 BL, and also two hydraulic excavators with volume of bucket 8 m^3 and 10,4 m^3 type O&K RH 90 C and type O&K RH120 C. Mined ore and waste rock is transported with trucks, Caterpillar 785B with load capacity of 136 t, Wabco 120C with load capacity of 108 t, Terex with load capacity of 95 t.

Fig.2 *Open-pit mine for copper "Buchim"*

3.1. Statistical analysis of transported ore by the truck in one work cycle

In this paper it is analyzed a data generated by the SkyLinks system for transported ore from dumper with number 17 (CAT 785B), which is loaded with excavator PH-3. The ore is transported from the excavation benches: 645, 480, 495, 480, 495, 480, 495, 510 and 630 to the primary crusher with distance interval from 0,830 km to 1,829 km. In addition to the text are given the results of statistical analysis, where is determined the type of distribution the probability of occurrence on a random quantity - transported ore in a cycle.

Tab.2 *Summary of statistics for transported ore by dumper No.17 in t/cycle*

Count	1369
Average	95,4064
Medium	95,1
Mode	100,0
Geometric mean	95,334
Variance	13,285
Standard deviation	3,64485
Coeff. of variation	3,82034%
Standard error	0,0985096
Minimum	59,7
Maximum	109,2
Range	49,5
Lower quartile	93,1
Upper quartile	97,5
Interquartile ranger	4,4
Skewness	-1,02605
Stand. Skewness	-15,4987
Kurtosis	12,9926

Stand. Kurtosis	98,1281
Sum	130611
Sum of squares	1,2479E7

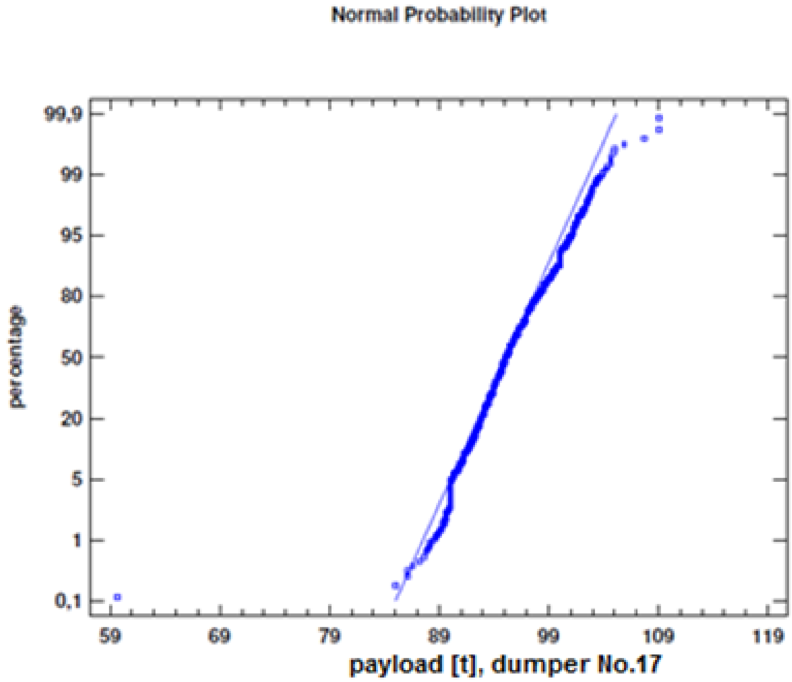

Fig.3 *Normal probabilities of transported ore by dumper No.17 in t/cycle*

From the graph of normal probabilities shown in Fig.3, we can conclude that the data form a straight line which is strong evidence that mass of transported ore by dumper No.17 in one cycle is a random value with normal distribution and density of probabilities shown in Fig. 4.

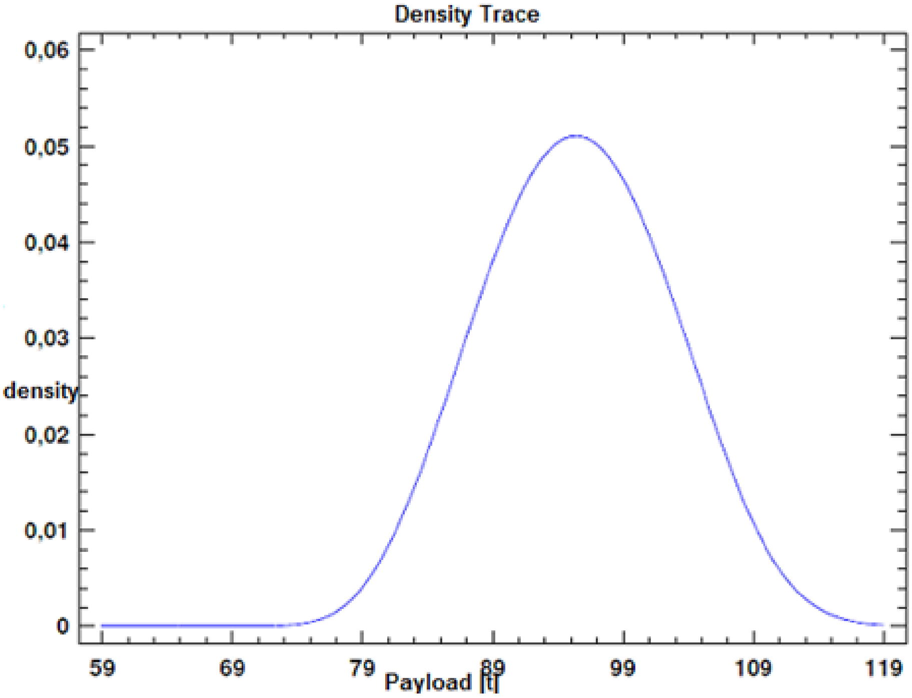

Fig.4 *Density trace of transported ore by dumper No.17*

3.2. Determination of technical transport capacity of truck

The average mass of transported ore allows us to calculate the technical hour capacity according to the equation (1) by setting the values for the total cycle time for the working conditions in the open-pit mine "Buchim". The total cycle time of the truck (T_c) was changed in the intervals from 500 to 2500 s/cycle with step of 250 seconds, taking into account the haulage distances for ore in the open-pit mine "Buchim",[5]. Table 3 shows the calculated values of technical transport capacity of dumper No. 17, and based on them is made a diagram which shows the change of hour capacity depending on the total cycle time.

Tab.3 *Technical capacity for damber No.17 for* $Q_{t,sr} = 95,4$ *t*

T_c (s/cikl)	500	750	1000	1250	1500	1750	2000	2250	2500
$Q_{h,techn.}$ (t/h)	686,88	457,92	343,44	274,75	228,96	196,25	171,72	152,64	137,38

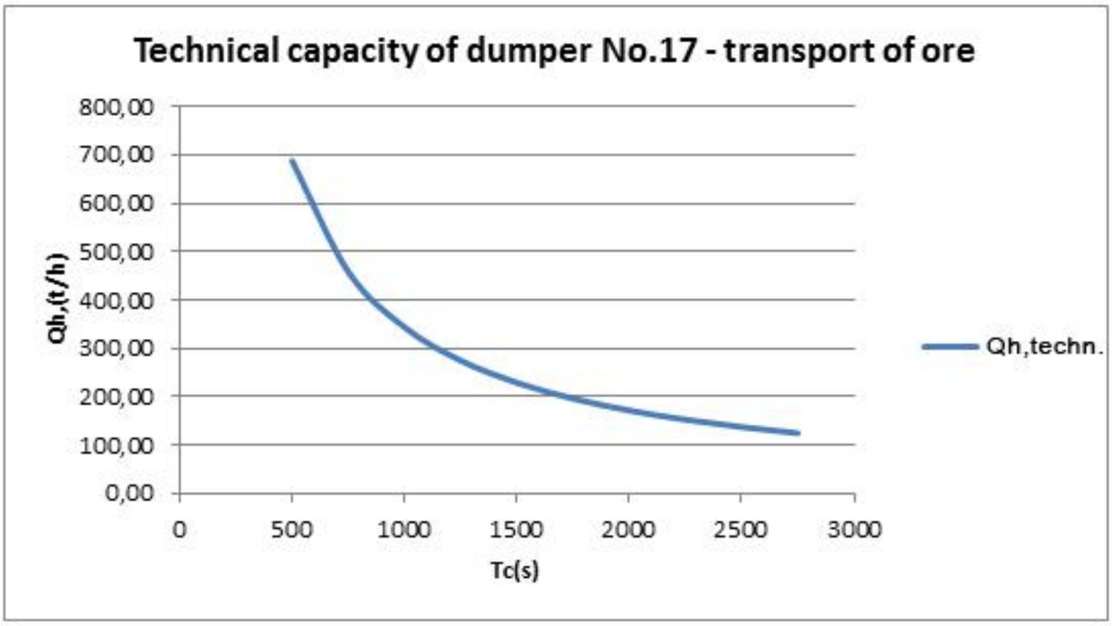

Fig.5 *Diagram of the dependence of the technical capacity of damper No. 17 from the total cycle time*

3.3. Determination of exploitation transport capacity

To avoid subjectivity in endorsing the value of the hour time coefficient of the dumper from which depends the value of the exploitation transport capacity of the dumper (equation 6), was used data from the SkyLinks system for recording the delays in the operation of the selected truck haulage in period of three months [5]. The distribution of recorded delays by categories of dumper No.17 are shown in Fig.6. The report on the number of working hours and time utilization for dumper No.17 are shown in Table 4.

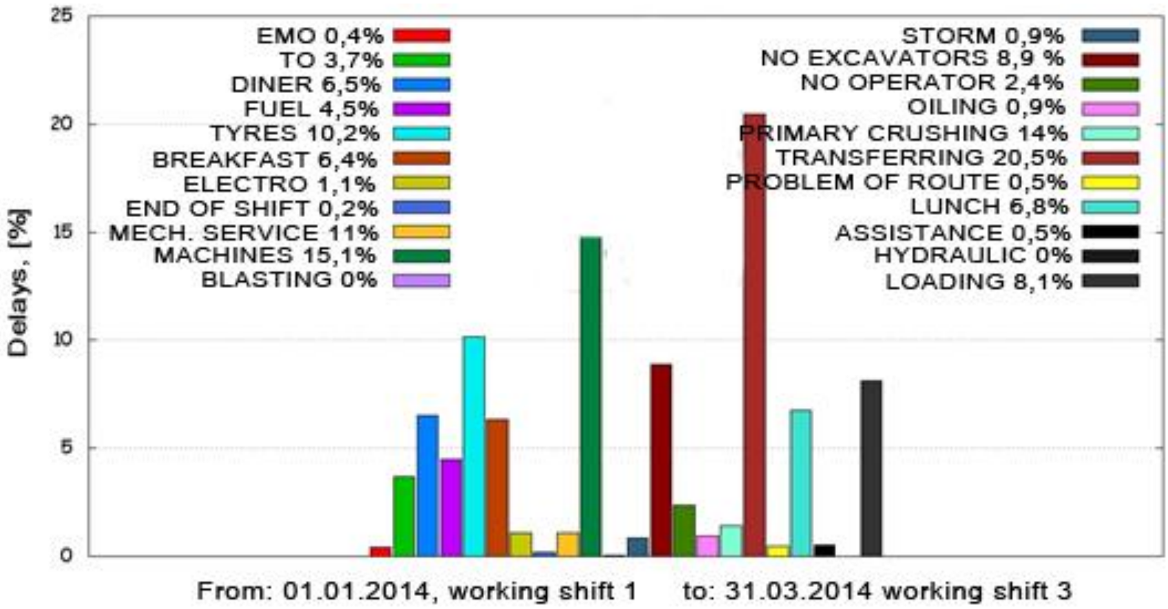

Fig.6 *Distribution of delays in categories for dumper No.17*

Tab.4 *Report on the number of working hours, delays and time utilization for dumper No.17*

Open- pit mine for copper "Buchim"					
Working hours for trucks					
From	01.01.2014	working shift 1			
To	31.03.2014	working shift 2			
Machine park:	D17				
Brigade:	All				
Released:	13:08	24.06.2014	1,4 sec.		
Prepared by:	Oleg	Zlatanov	Received by:		
Dumper	Working	Working hours	Delays	Work [%]	Delays [%]
17,Cat -785	2055	1410	644,9	68,6	31,4
Total	2055	1410	644,9	68,6	31,4
					SkyLinks 3.14

We calculated the exploitation capacity values for the dumper No.17 with hour time utilization of K_{vi} = 0,686 (according to equation 6).

With the help of Stat Graphics software for statistical data processing we determine mathematical dependencies of exploitation capacity in function of the total cycle time for the dumper (Fig.7) in the form:

$$Y = \frac{a}{x} \tag{7}$$

where the coefficient “a” is determine for different number of dumpers, and for different type of load. The functional dependence of the capacity of dumper No.17 is:

$$Q_{\exp,h} = \frac{229133}{T_C}\left[\frac{t}{h}\right] \tag{8}$$

In the previous equation the total cycle time of the dumper (T_c) is expressed in seconds.

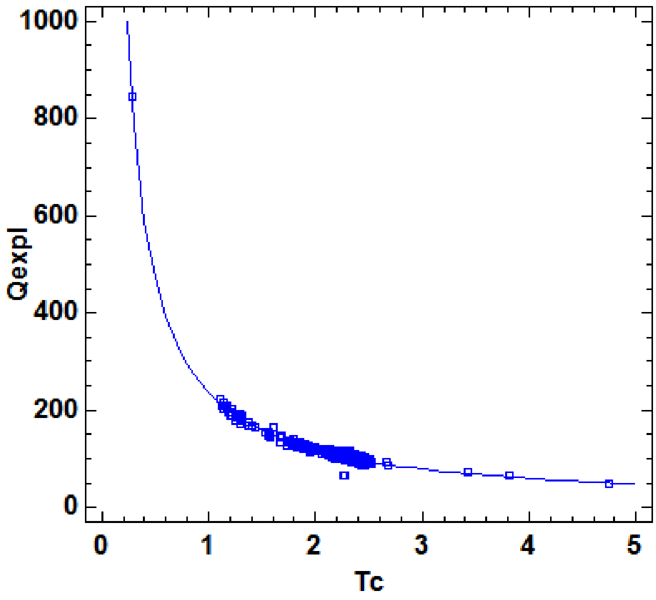

Fig.7 *Diagram for determining the reliability $Q_{expl.} = f(T_c)$ by nonlinear regression analysis*

4 COMPARISON BETWEEN TECHNICAL AND EXPLOITATION TRANSPORT CAPACITY

To make a comparison between the technical and exploitation capacity of the dumpers while transporting ore or waste rock, the first thing that is needed to be done is to calculate the parametars with the same value of working time for the cycle (T_c). We can make this comparison with equation (8), where we make arbitrary input values for T_c, in the range from 500 to 2500 seconds with a step of 250 seconds. In table 5 are shown the values for the technical and exploitation capacities and their differences.

Tab.5 *Capacities comparison for truck No.17 for $Q_{t,sr} = 95,4$ t*

T_c(s/cikl)	500	750	1000	1250	1500	1750	2000	2250	2500
$Q_{h,techn.}$ (t/h)	686,88	457,92	343,44	274,75	228,96	196,25	171,72	152,64	137,38
$Q_{h,expl.}$ (t/h)	458,27	305,51	229,13	183,31	152,76	130,93	114,57	101,84	91,65
Difference (t/h)	228,61	152,41	114,31	91,45	76,20	65,32	57,15	50,80	45,72
Difference (%)	33,2	33,2	33,2	33,2	33,2	33,2	33,2	33,2	33,2

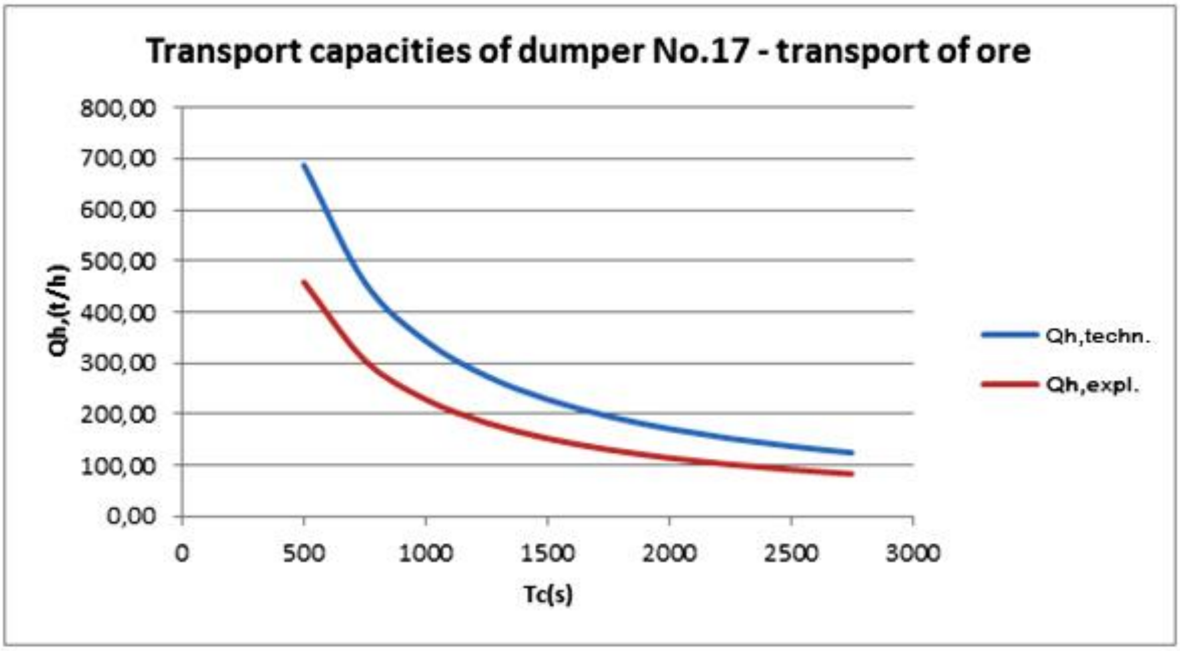

Fig.8 *Diagram for capacities comparison for truck No.17 (transport of ore)*

5 CONCLUSION

Exploitation capacity of truck haulage can be increased by applying the preventive maintenance of transport units. Large percentage of delays for truck haulage are related to other factors which include: waiting for loading, delays in primary crushing, delays due to mechanical defect of excavators, organizational delays and much more. Therefore, to increase the coefficient of time utilization of truck haulage we should improve the functioning of the entire production system in the open-pit mine.

References

[1] Borovic, R.: Kamionski transport na površinskim kopovima (monografija). (1995), RGF Beograd.
[2] Ignjatovic, D., Jovancic, P.: Mašine i uredzaji za površinsku eksploataciju I transport (zbirka zadataka). (2012), Univerzitet u Beogradu, RGF.
[3] Kennedy, B. A.: Surface Mining. Society for Mining, Metallurgy, and Exploration, (1990), USA
[4] Verma, K., Montu, A., Anand, V.K.: GPS based truck disptach system at West Bokaro collieries. (2001), Asian GPS Conference, New Delhi.
[5] Чекеровски, Т.: Оптимизација на диспечерски систем за управување на мобилна рударска опрема со GPS технологија (докторска дисертација -непублицирана). (2015) ФПТН- УГД Штип.