Nikola Stanić Saša Stepanović*, Dejan Bugarin*, Miljan Gomilanović**

SELECTION THE RATIONAL MODEL OF TRANSPORT TRUCK BY THE SELECTIVE COAL MINING AT THE OPEN PIT GACKO**

Abstract

This paper gives the selection of the optimal model of trucks for transport of coal, and seam waste at the OP Gacko in terms of selective exploitation. Mining of coal and seam waste is carried out in two exploitation zones, the central and roof zone, and the coal and waste transport and disposal is carried out to the different crushing plants and landfills. Using the software package Talpak, the capacity of a truck for transport of coal, and seam waste was calculated for different transport routes and types of trucks. The analysis was done for three types of trucks: Belaz 7555, Belaz 75491 and Belaz 75135. The results analysis were used for evaluation, ranking and selection the optimal type of truck.

Keywords: truck transport, OP Gacko, transportation costs

INTRODUCTION

Works on coal mining at the open pit Gacko currently performed by the Main mining project of the open pit Gacko - Central field capacity of $2.3 \cdot 10^6$ t/year of run-of-mine coal. Mining takes place in two zones, the roof and central exploitation zone.

Excavation the overburden and inter-seam waste in the central zone of the open pit (the zone of exploitation the main and the first and the second floor of coal seam), is carried out within the second continuous BTO system and within the DTO the combined system. Overburden excavated by the bucket wheel excavator type ER 1250 17/1.5 within the first BTO system is transported by conveyor belts with a belt width of 1200 mm and disposed on the West outer

landfill by a spreader Ars 1200 (20 + 50) * 21. In the case of the second BTO system, the base of excavation equipment includes a bucket-wheel excavator ER 1250*16/1, which operates in tandem with a self-propelled transporter P of 1600*21/50. Disposal is done in the excavated space of the Field B. In addition to a continuous system in the excavation of overburden, the hydraulic shovel excavators Komatsu PC 2000, Terex RH 90C, D 475 bulldozer Komatsu in tandem with a loader Komatsu WA 700 and a combine Wirtgen 2500SM. Transport of overburden is carried out by trucks, capacity of 110 t (trucks BELAZ 75135) to the crusher SB are 1525 (DTO system).

* Mining and Metallurgy Institute Bor, e-mail: nikola.stanic@irmbor.co.rs

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TRANSPORTATION SYSTEMS OF COAL AND SEAM WASTE

Coal mining is done applying the technology of selective mining. The following hydraulic shower excavators are engaged on these activities are engaged: Komatsu PC 800, Hyundai R800, and CAT 385B. Removed quantities of coal are transported by truck 55 t (BELAZ 7555) to the primary crusher for coal SB 1315, and SB 1515 (DTD system).

Transportation of coal and waste excavated in the process of selective coal mining is divided into internal and external. Having in mind, the coal excavation and seam waste takes place in two spatially separate exploitation wholes, the central zone and roof zone. In each zone and for different periods of development work, there are the appropriate schemes of coal and seam waste transport, given in Figures 1 and 2.

Figure 1 Scheme of coal and waste transport in the central zone of exploitation

Figure 2 Scheme of coal and waste in the roof zone of exploitation

CALCULATION THE TRUCK TRANSPORT

Internal transport of coal is by trucks and takes place from the excavation site to the crushing plants for coal.

Internal transport of waste is by truck in the central zone of exploitation and takes place from the excavation site to the crushing plant for waste, or DTO crusher system. Transport of waste in the roof zone of exploitation is by truck from the excavation site to a place of disposal on the external landfill.

External transport of coal takes place from the crushing plants to the landfill of the power plant by belt conveyors, belt width 1200 mm. The external transport of waste from the central coal series takes place from the crushing plant for waste to the site of disposal in ther excavated area of the Field B. Disposal of waste tailings is carried out within a disposal of overburden from the central zone of the open pit, or by a combined system (DTO, crusher-conveyor belt-stacker). Disposal is done by a stacker type OS 1600.

Computer program Talpac was used for calculation the system excavator - truck used a computer program Talpac. Based on the input parameters, a hourly capacity of the truck was calculated for a particular relation.

Software package Talpak is a simulation of the loading and transport process at the open pits. The software optimizes the transport fleet budget, calculation the technical and economic parameters of equipment operation such as a cycle length, capacity, etc. In the present case, this program was used to determine the parameters in transport of various materials (coal and waste) and from different sites (the central zone and roof zone of exploitation). The calculation results are used as the base for the operating costs of transport.

The organization of work at the open pit Gacko is 365 days a year, 7 days a week in 3 shifts. Total effective time during the year amounted to 3,500. Based on these organizations, following the planned working time was used for calculation the loading and transport:

- Total possible number of shifts per year:	1,095 shift/year
- Duration of a shift:	8 h
- Operating hours per year:	8,760 hours
- Effective working hours per shift	5.5 h
- Effective working hours per year	3,500 hours

Presented planned and effective working hours at the open pit was used in the software Talpac for calculation the loading and transport system. Table 1 shows the input

parameters and loading mechanization used for calculation. Table 2 shows the input parameters for the transport mechanization required for calculation.

Table 1 Characteristics of loading machinery

Komatsu PC 800
Parameters			
	Shovel volume (m ³)	6	Motor power (kW)	363
	Speed (km/h)	4.2	No. of revolutions (rpm)	1800
	Excavation depth (m)	8.45	Weight (kg)	75200
	Medium ground pressure (N/cm ²)	12.2	Length of rig (mm)	7500
	Caterpillar width (mm)	610	Total length (mm)	14405
	Width of caterpillar base (mm)	4110	Height of branch	4690
	Length of caterpillar base (mm)	5810	Cabin height	3670
	Shovel width (mm)	2200	Total width	4110

Table 2 Characteristics of transport mechanization

Truck Belaz 7555-55 tons
Hopper capacity (m ³)	37.5
	Engine power (kW)	522
	Capacity (t)	55
	Max. speed (km / h)	55
	Dump angle (°)	47
	Weight (kg)	41000
	Total height (mm)	4610
	Total width (mm)	5240
	Total length (mm)	8890
	Price (KM)	800 000
Truck Belaz 75491-80 tons
Hopper capacity (m ³)	46
	Engine power (kW)	630
	Capacity (t)	80
	Max. speed (km / h)	50
	Dump angle (°)	46
	Weight (kg)	72500
	Total height (mm)	5350
	Total width (mm)	5420
	Total length (mm)	10300
	Price (KM)	1 300 000
Truck Belaz 75135-110 tons
Hopper capacity (m ³)	71.2
	Engine power (kW)	895
	Capacity (t)	110
	Max. speed (km / h)	50
	Dump angle (°)	47
	Weight (kg)	100100
	Total height (mm)	5900
	Total width (mm)	6400
	Total length (mm)	11500
	Price (KM)	1 800 000

Based on the entered data, the hourly capacities of the truck were calculated for the certain relation expressed in $\text{čm}^3/\text{h}$ when operating in conjunction with the loading equipment. Based on the amounts that should be transported into a specific route and hours of operation, for each zone of work implementation in the considered period of exploitation, the number of required trucks was calculated. Number of trucks needed in the corresponding period was calculated based on the total time required

for truck engagement for the amounts of coal and seam waste from the individual work sites, and for the specific transport lengths. Tables 3, 4 and 5 are give the parameters of loading and transport system, calculated in the software package Talpac. Calculations are made according to the annual periods for the three types of trucks (Belaz 7555, Belaz 75491, Belaz 55135), depending on the zone of exploitation (roof and central zone) and the type of materials (coal and seam waste).

Table 3 *Parameters of transport by the trucks type Belaz 7555*

Year	Place	Central Zone - Coal	Central Zone – seam waste	Roof zone - coal	Roof zone – seam waste	Required number of trucks	Reserve in capacity (%)
2017	Quantities (čm^3)	703,125	175,732	1,077,000	357,712	10	24.50%
	Capacity of transp. truck ($\text{čm}^3/\text{h}$)	98.8	89.4	69.9	47.8		
	Required time of engagement (h)	7,114	1,965	15,401	7,484		
2018	Quantities (čm^3)	703,125	155,418	1,077,000	521,436	11	19.64%
	Capacity of transp. truck ($\text{čm}^3/\text{h}$)	92.5	84.9	66.5	46.7		
	Required time of engagement (h)	7,601	1,831	16,203	11,156		
2019	Quantities (čm^3)	703,125	94,935	1,077,000	769,835	13	17.72%
	Capacity of transp. truck ($\text{čm}^3/\text{h}$)	78.3	68.4	55.54	46		
	Required time of engagement (h)	8,978	1,389	19,392	16,735		
2020	Quantities (cm^3)	703,125	208,438	1,077,000	589,884	14	21.51%
	Capacity of transp. truck ($\text{čm}^3/\text{h}$)	70.29	62.86	56.16	39.67		
	Required time of engagement (h)	10,003	3,316	19,177	14,870		

Table 4 *Parameters of transport by trucks type Belaz 75491*

Year	Place	Central Zone - Coal	Central Zone – seam waste	Roof zone - coal	Roof zone – seam waste	Required number of trucks	Reserve in capacity (%)
2017	Quantities (čm ³)	703,125	175,732	1,077,000	357,712	9	12.00%
	Capacity of transp. truck (čm ³ /h)	109.32	99.25	77.32	59.81		
	Required time of engagement (h)	6,430	1,771	13,929	5,981		
2018	Quantities (čm ³)	703,125	155,418	1,077,000	521,436	10	9.00%
	Capacity of transp. truck (čm ³ /h)	96.22	97.03	72.23	51.99		
	Required time of engagement (h)	7,309	1,602	14,912	10,030		
2019	Quantities (čm ³)	703,125	94,935	1,077,000	769,835	11	8.40%
	Capacity of transp. truck (čm ³ /h)	92.84	89.08	70.53	58.36		
	Required time of engagement (h)	7,572	1066	15,270	13,192		
2020	Quantities (cm ³)	703,125	208,438	1,077,000	589,884	12	7.80%
	Capacity of transp. truck (čm ³ /h)	77.5	58.08	70.34	49.37		
	Required time of engagement (h)	9,072	3,581	15,312	11,949		

Table 5 *Parameters of transport by trucks type Belaz 75135*

Year	Place	Central Zone - Coal	Central Zone – seam waste	Roof zone - coal	Roof zone – seam waste	Required number of trucks	Reserve in capacity (%)
2017	Quantities (čm ³)	703,125	175,732	1,077,000	357,712	6	21.25%
	Capacity of transp. truck (čm ³ /h)	120.3	142.3	120.1	96.1		
	Required time of engagement (h)	5,844	1,235	8,964	3,721		
2018	Quantities (čm ³)	703,125	155,418	1,077,000	521,436	7	27.48%
	Capacity of transp. truck (čm ³ /h)	120.3	109.8	120.2	93.8		
	Required time of engagement (h)	5,843	1,415	8,964	5,559		
2019	Quantities (čm ³)	703,125	94,935	1,077,000	769,835	7	16.16%
	Capacity of transp. truck (čm ³ /h)	120.2	109.1	119.9	90.4		
	Required time of engagement (h)	5,848	870	8,986	8,515		
2020	Quantities (cm ³)	703,125	208,438	1,077,000	589,884	7	18.52%
	Capacity of transp. truck (čm ³ /h)	120	108.9	118.9	86.3		
	Required time of engagement (h)	5,858	1,915	9,058	6,835		

Based on the determined parameters of transportation the masses of coal and waste, the costs of standardized material were calculated. The standardized materials included: fuel (kg/čm³), lubricant (kg/čm³), an oil (kg/čm³), tires (pcs.) and spare parts

(kg/čm³), Table 6 gives a summary of the standardized material costs per year for three types of trucks. Based on the calculated standardized costs, the calculation was made of the total operating costs, and they are shown in Table 7.

Table 6 Costs of standardized material per year

Type of truck	Years	Normative costs per year							
		Unit costs (KM/čm ³)	Unit costs (KM/t)	Unit costs (KM/čm ³)	Unit costs (KM/t)	Unit costs (KM/čm ³)	Unit costs (KM/t)	Unit costs (KM/čm ³)	Unit costs (KM/t)
		CZ-U*	CZ-U	CZ-SJ†	CZ-SJ	KZ-U‡	KZ-U	KZ-SJ§	KZ-SJ
Belaz 7555	2017	1.574	0.984	1.721	1.076	2.151	1.344	3.062	1.914
	2018	1.669	1.043	1.803	1.127	2.251	1.407	3.130	1.956
	2019	1.939	1.212	2.194	1.371	2.660	1.663	3.175	1.984
	2020	2.140	1.337	2.371	1.482	2.633	1.646	3.652	2.283
Belaz 75491	2017	1.685	1.053	1.838	1.148	2.308	1.442	2.931	1.832
	2018	1.890	1.181	1.875	1.172	2.458	1.536	3.344	2.090
	2019	1.952	1.220	2.027	1.267	2.513	1.570	2.999	1.874
	2020	2.303	1.439	3.013	1.883	2.519	1.574	3.512	2.195
Belaz 75135	2017	2.381	1.349	2.041	1.156	2.384	1.351	2.935	1.663
	2018	2.381	1.349	2.591	1.468	2.383	1.350	3.003	1.701
	2019	2.383	1.350	2.607	1.477	2.388	1.353	3.109	1.761
	2020	2.386	1.352	2.611	1.479	2.407	1.364	3.248	1.840

Table 7 Operating costs of the different types of trucks

			CZ-U	CZ-SJ	KZ-U	KZ-SJ
Truck Belaz 7555	2017	The required quantities (čm ³)	703,125	175,732	1,077,000	357,712
		Total (KM)	1,106,892	302,408	2,316,299	1,095,254
	2018	The required quantities (čm ³)	703,125	155,418	1,077,000	521,436
		Total (KM)	1,173,661	280,143	2,424,814	1,631,945
	2019	The required quantities (čm ³)	703,125	94,935	1,077,000	769,835
		Total (KM)	1,363,556	208,279	2,865,060	2,443,918
	2020	The required quantities (čm ³)	703,125	208,438	1,077,000	589,884
		Total (KM)	1,504,519	494,291	2,835,571	2,154,515
Truck Belaz 75491	2017	The required quantities (čm ³)	703,125	175,732	1,077,000	357,712
		Total (KM)	1,184,685	322,920	2,485,396	1,048,314
	2018	The required quantities (čm ³)	703,125	155,418	1,077,000	521,436
		Total (KM)	1,328,744	291,486	2,646,879	1,743,859
	2019	The required quantities (čm ³)	703,125	94,935	1,077,000	769,835
		Total (KM)	1,372,512	192,415	2,706,005	2,308,698
	2020	The required quantities (čm ³)	703,125	208,438	1,077,000	589,884
		Total (KM)	1,619,129	627,928	2,712,791	2,071,830
Truck Belaz 75135	2017	The required quantities (čm ³)	703,125	175,732	1,077,000	357,712
		Total (KM)	1,673,999	358,590	2,568,067	1,049,887
	2018	The required quantities (čm ³)	703,125	155,418	1,077,000	521,436
		Total (KM)	1,673,999	402,728	2,566,091	1,565,642
	2019	The required quantities (čm ³)	703,125	94,935	1,077,000	769,835
		Total (KM)	1,675,286	247,470	2,572,027	2,393,199
	2020	The required quantities (čm ³)	703,125	208,438	1,077,000	589,884
		Total (KM)	1,677,867	544,270	2,592,028	1,915,858

* Central Zone - coal,

† Central Zone – seam waste

‡ Roof zone - coal,

§ Roof zone – seam waste

CAPITAL AND OPERATING COSTS OF VARIANT SOLUTIONS

In order to gain a clearer status on the costs of variant solutions, the calculation of the capital costs was made. Capital expenditure (capex) were calculated as annuity loans for the purchase of a truck loan. The loan was calculated for the following conditions: the return period 10 years, interest rate

of 6%. The operating costs (opex) included the total standardized costs per year in the areas of exploitation. Table 8 gives the total values of capital and operating costs. Figure 3 and Figure 4 shows a graph of movement the capital and operating costs for three types of trucks.

Table 8 Capital and operating costs (KM)

Type of truck	costs	2017	2018	2019	2020	Σ
Belaz 7555	opex	4,820,853	5,510,564	6,880,814	6,988,895	24,201,126
	capex	1,280,000	1,360,000	1,563,200	1,628,800	5,832,000
Belaz 75491	opex	5,041,315	6,010,968	6,579,629	7,031,678	24,663,590
	capex	2,402,000	2,009,800	2,139,800	2,262,000	8,813,600
Belaz 75135	opex	5,650,541	6,208,460	6,887,982	6,730,024	25,477,007
	capex	1,728,000	1,951,200	1,875,600	2,008,000	7,562,800

Figure 3 Operating costs by type of truck

Figure 4 Capital costs by type of truck

TRANSPORT COSTS PER VARIANT SOLUTIONS

Specific costs of transport according to the variant embodiments given as a ratio of the total cost and weight needed to conduct necessary transported per year periods,

and the values are shown in the diagram in Figure 5. Cost unit quantity of material is provided in the HP/m^3 .

Figure 5 Specific transportation costs KM/m^3

Figure 6 shows the specific transport costs, expressed per meter of transport. These specific costs are given for the medium annual transport lengths. A medium

transport length per some years is calculated as a weighted mean of length of transport route by the amount of material that is transported.

Figure 6 Costs per meter of transport route

CONCLUSION

Based on the calculated values of the technical and economic parameters of transport, as the most type of truck is allocated a truck Belaz 7555 capacity 55 t. The optimal type of truck can be determined through the present procedure of analysis, which has to satisfy the relevant requirements.

The analysis was required on:

- specific ratio the amount of coal and seam waste in the deposit and defined level of selection in exploitation;
- specific physical and mechanical properties of coal and seam waste;
- specific transport lengths of coal and seam waste;
- specific site within the open pit, if there are more.

All listed parameters significantly affect the efficiency of operation the specific truck model, and a good knowledge of physical mechanical and structural characteristics of the work environment and technological characteristics of excavation equipment must be to make the final assessment on the best model of vehicle. When considering different models of trucks in addition to the technical operating parameters, such as the hourly capacity, capacity utilization factor, time utilization, etc. must be analyzed as well as the economic parameters of material transport for a specific model of truck that would cover both operating and capital costs.

In this case, the most favorable model truck is a truck Belaz 7555, which has the

smallest capacity and the volume of the crate. This conclusion can be drawn only for the period under consideration, or for consideration the weighted average duration of transport. The presented analysis shows that the increase of transport length, the parameters on the basis of which the assessment of the transportation economy change in favor of the vehicles with a higher load-carrying capacity and volume of crates. The limit of application in relation to the other model of vehicle, in this particular case is the model 7555 Belaz up to 6 kilometers, while in the longer distances better parameters can be expected in the application a truck Belaz 75135.

The question of selecting the optimal type of truck in selective exploitation must be solved through a complex analysis for each specific case. This derives from the specificity of transport in selective exploitation considering that the same type of truck is used for transport of waste and transport of useful minerals. Also, the analysis must include a longer period of time in order to take into account the changeable conditions of exploitation in the real space of the open pit and real-time of exploitation.

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