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in

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z mednarodno udeležbo/with international participation

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KAZALO / INDEX

Dear conference participants,

we are organizing again, the 19th scientific conference with the international participation "Waste Management - GzO'19 Urban Mining" together with the 14th scientific conference with international participation "at 46. Jump over the Leather Skin". Thus continuing the tradition of biennial meetings of domestic and foreign experts from the fields of Mining, Geotechnology, Environment and Waste Management. I would like the participants to take advantage of the both conferences primarily with a view to broader connecting, improvement of mutual cooperation and exchange of experiences different professions in such demanding interdisciplinary fields.

At both scientific conferences, after the paper selection of the scientific GzO'19 committee, 16 domestic and foreign lecturers, experts in the fields of Mining, Geotechnology, Environment and Waste Management will be presented their contributions. As in previous years, will be presented novelties, successful regional approaches to addressing the topics of conferences, examples of good practice, the results of research and development projects. For the exchange of ideas, opinions and experiences regarding the state and possibilities of further development, three technical sections will be held and the second day of the conference will be also organized professionally guided technical excursion to the Doline dimension stone quarry, of the company Marmor Sežana d.d. The Proceedings of the GzO'19 conference comprises 16 papers of these 8 papers from the world (Finland, Northern Macedonia, Germany, Poland and South Africa).

I would like to thank the University of Ljubljana, the Faculty of Natural Sciences and Engineering, the Department of Geotechnology, Mining and Environment and the Slovenian Mining Association - SRDIT and patrons the Ministry of Environment and Spatial Planning and the Ljubljana City Municipality for sponsoring over the 19th Scientific Conference with the international participation "Waste Management GzO'19 - Urban Mining". On behalf of the organizing committee, I would like to thank the long-term sponsors Marmor Sežana d.d., Geological Survey of Slovenia, Institute for Mining, Geotechnology and Environment - IRGO, Termit d.d., Moravče and Salonit Anhovo, Kamnolomi d.o.o., Deskle. For organizing and conducting a professionaly guided technical excursion in the Doline dimension stone quarry, I would like to thank the company Marmor Sežana d.d..

The organization and implementation of conference with international participation requires the demanding and teamwork of many individuals. I would like to thank the members of the organization and scientific GzO committee, which contributed to the successful performance of the GzO'19.

I also owe you the credit for a successful conference to all authors of the articles that you have prepared and will present your professional contributions and to all of you who will contribute with questions, opinions and comments in various expert discussions.

With mining Good luck!

Assist.prof.dr. Jože KORTNIK
Chairman of the Organization and
Scientific committee GzO

ID 16

Pristop k optimiranju kamionskega transporta pri površinskem izkoriščanju kovin z namenom zmanjševanja stroškov izkoriščanja

Approach towards optimising on truck transport during surface exploitation on metals in function of minimising the costs of exploitation

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Povzetek

V prispevku je podan pristop optimiranja kamionskega transporta rude in jalovine z namenom zmanjševanja skupnih stroškov izkoriščanja. Z glavnim rudarskim projektom se praviloma podajajo zunanje transportne poti in transportne ceste za vsako etažo posebej, tako za rudo kot za jalovino. Upoštevamo, da stroški transporta, v smislu skupnih stroškov za površinsko izkoriščanje kovinskih mineralnih surovin, presegajo 40%; razvoj optimiranja kamionskega transporta pa omogoča možnost povečanje dobička pri izkoriščanju.

Ključne besede: površinsko pridobivanje, optimizacija, kamionski transport, stroški izkoriščanja.

Abstract

This paper provides approach to optimizing the truck transport of ores and waste in function of minimize of total costs for exploitation. With the main mining project it is usual to give out external transport routes as well as the roads from each bench separately, both for ore and for waste. We take into account that transport costs in terms of total costs for surface exploitation of metallic mineral resources enter more than 40%, any approach to the development of optimization of truck transport will mean the opportunity to increase profits from exploitation.

Key words: surface mining, optimization, truck transport, cost for exploitation.

1. INTRODUCTION

Surface mining of metals, in other words, implies deeper surface mines with relatively larger transport distances for truck transport. Truck transport is optimal for transport distances to 1500 meters of medium transport distances. But today's research that include mining trucks with CNG, LNG, or hybrid-powered diesel-electric (trolley) powered provides an opportunity to increase transport routes.

Particularly interesting are the hybrid drives, where the movement of the excavations and internal non-capital roads is on a diesel drive, and on external capital roads, electrical installations are used and the plant is electrically driven (trolley). Recently, the use of LNG and, above all, CNG gas as an ecological fuel, takes up a larger share in the replacement of diesel as a fuel. However, knowing the fact that the total share of the cost of transport in surface exploitation enters most of the (in surface mining is even more than 40%), the need for exploring approaches to optimization transport in function of minimizing the costs.

Today, for mining trucks transporting we used already defined roads with alignment, length and route, possible interventions for their optimization would be:

- optimum choice of excavator (shovel) – mining trucks when is transporting ore or waste,
- minimizing the transport distances (at the level of the bench or working block),
- minimizing waiting times when the mining trucks are loading,
- minimizing the waiting time for unloading the ore at the crusher reception point,
- minimizing the waiting time during waste unloading of the dumping site, etc.

2. ANALYSIS EXCAVATION-MINING TRUCK

The analysis of the loading and transport time of various excavator or shovel and mining (dump) trucks will serve as a possible approach to the optimization of truck transport, in this dissertation. Namely, in order to minimize the costs of truck transport, it is necessary to maximize the utilization of loading and transport equipment, that is, to find a suitable shovel - truck system. To be specific, if the time of one mining - truck (dumper) cycle is t_{cd}, and the time of one shovel cycle is t_{cs}, and the shovel operates in conjunction with m shovel, therefore it can theoretically be accomplished with n shovels.

The question arises as to whether the shovel can always serve the n shovel and if so, with that degree of utilization. This is a stochastic process that includes the likelihood of servicing mining trucks from one shovel. The measurements of the use of m shovels with n mining truck are additionally given, in order to optimize the process of servicing. For this purpose, 2 types of shovels with bucket volume of 10.5 and 14 m^3 and 4 types of mining truck with a load of 100, 125 and 140 tons were analyzed. To be specific, the analysis was done on 5 shovels (Table 1) and 27 mining truck (Table 2).

Table 1.: Analyzed excavators.

No.	Tag	Shovel (m^3)	Type	Age (year)	No.	Tag	Shovel (m^3)	Type	Age (year)
1	I	10.5	1	10	4	IV	14	2	4
2	II	10.5	1	8	5	V	14	3	2
3	III	14.0	2	5					

Table 2.: Analyzed dump trucks.

No.	Tag	Load capacity (t)	Type	Age (year)	No.	Tag	Load capacity (t)	Type	Age (year)
1	A/1	100	A	10	15	C-1/15	140	C-1	4
2	A/2	100	A	10	16	C-1/16	140	C-1	4
3	A/3	100	A	10	17	C-1/17	140	C-1	4
4	A/4	100	A	10	18	C-1/18	140	C-1	4
5	A/5	100	A	10	19	C-1/19	140	C-1	4
6	B-1/6	125	B-1	8	20	C-1/20	140	C-1	4
7	B-1/7	125	B-1	8	21	C-1/21	140	C-1	4
8	B-1/8	125	B-1	8	22	C-1/22	140	C-1	4
9	B-1/9	125	B-1	8	23	C-1/23	140	C-1	4
10	B-2/10	125	B-2	5	24	C-2/24	140	C-2	2
11	B-2/11	125	B-2	5	25	C-2/25	140	C-2	2
12	B-2/12	125	B-2	5	26	C-2/26	140	C-2	2
13	B-2/13	125	B-2	5	27	C-2/27	140	C-2	2
14	C-1/14	140	C-1	4					

The analysis was done under the obtained data from metal mines in Macedonia. Some of the data is further modeled and calculated. Specifically, the full cycle time when loading of 5 levels (benches) is analyzed. One shovel operates on each of these levels. The full cycles of each dumper are analyzed separately, which comes to a specific shovel. An entry table is presented below.

Table 3.: Analyzed the mean time and capacity of the dump trucks.

Dump truck		Excavator								
		Tag	I	II	III	IV	II	III	IV	V
Tag	Tech. load	Distance (m)	1,350	1,550	1,950	2,300	1,550	1,950	2,300	2,750
		Distance (m)	1,550	1,750	2,150	2,500	1,750	2,150	2,500	2,950
			Dumper cycle time				Average dump truck capacity			
	t		min	min	min	min	t/h	t/h	t/h	t/h
A/1	100		26.2	28.8	34.2	37.9	208.55	175.38	158.47	139.15
A/2	100		26.4	28.8	34.3	38.3	208.28	175.05	156.76	138.35
A/3	100		26.4	29.0	34.6	38.2	206.93	173.30	157.10	138.55
A/4	100		26.9	28.6	34.4	37.7	210.09	174.25	159.01	137.28
A/5	100		26.1	28.7	34.7	38.2	208.80	173.15	157.16	136.53
B-1/6	125		26.1	28.8	34.4	38.0	260.77	218.18	197.12	174.62
B-1/7	125		26.2	28.1	34.5	38.4	266.88	217.68	195.54	174.81
B-1/8	125		25.9	28.9	34.7	37.4	259.76	215.85	200.50	175.33
B-1/9	125		26.5	28.9	34.3	37.8	259.56	218.95	198.52	178.49
B-2/10	125		26.0	28.0	34.3	38.0	267.68	218.43	197.60	175.07
B-2/11	125		25.6	28.7	34.8	37.7	261.10	215.37	199.18	178.36
B-2/12	125		25.8	28.5	34.3	37.7	263.29	218.68	198.87	178.28
B-2/13	125		26.0	28.3	34.1	38.1	264.89	219.99	197.08	177.04
C-1/14	140		25.7	28.1	34.1	38.8	299.11	246.68	216.63	188.05
C-1/15	140		25.7	28.3	34.2	37.4	297.06	245.26	224.65	198.90
C-1/16	140		26.0	28.9	34.1	37.9	290.73	246.14	221.45	199.45
C-1/17	140		25.5	28.5	33.9	37.6	294.58	247.51	223.28	196.40
C-1/18	140		26.3	27.9	33.8	37.1	300.55	248.45	226.40	199.99
C-1/19	140		26.0	28.6	34.1	37.5	293.84	246.15	223.77	200.88
C-1/20	140		25.8	28.4	34.1	38.0	296.14	246.44	221.18	198.25
C-1/21	140		25.6	28.6	34.2	37.3	293.61	245.69	224.95	197.93
C-1/22	140		26.3	28.2	33.9	37.2	298.27	248.01	225.76	197.49
C-1/23	140		25.9	28.3	34.6	37.6	296.95	243.04	223.36	197.60
C-2/24	140		25.1	28.2	34.4	36.9	297.37	244.00	227.88	199.80
C-2/25	140		25.5	28.6	34.5	37.7	294.14	243.18	223.06	201.27
C-2/26	140		25.6	28.6	34.1	37.7	293.20	246.52	222.54	200.36
C-2/27	140		25.8	28.6	33.8	37.4	293.58	248.36	224.49	198.55

On the basis of these time cycles, the following weighted values of the analyzed effective hourly capacities of the dumper trucks are calculated.

Table 4.: Average capacity of the dump trucks.

Dump truck			Excavator					
			Tag	I	II	III	IV	V
			Distance (m)	1,350	1,550	1,950	2,300	2,750
			Distance (m)	1,550	1,750	2,150	2,500	2,950
Tag	Number	Tech.load		Average capacity of the dump truck				
		t		t/h	t/h	t/h	t/h	t/h
A	5	100.00		229,21	208.55	175.38	158.47	139.15
B-1	4	125.00		287.57	260.77	218.18	197.12	174.62
B-2	4	125.00		288.88	267.68	218.43	197.60	175.07
C-1	10	140.00		328.95	294.58	247.51	223.28	196.40
C-2	4	140.00		334.25	297.37	244.00	227.88	199.80
Total/average	**27**	**128.15**		**299.20**	**270.07**	**224.98**	**204.28**	**179.92**

In order to obtain and analyze the ratio of the shovel – dumper truck, it is necessary to compare the analyzed data from realistic capture of the dumper cycles and to calculate the effective hourly capacities with a simulated value model.

3. MODEL OF TRUCK CYCLES AND EFECTIVE CLOSURE CAPACITIES

The model of the dumper cycles is defined by generating random moments of dumper cycles, which differ from the real ones according to the set times of minimum and maximum impulsion cycles. Random variables of the dumper cycles in the diode range from the shortest to the longest. In the analysis, the peak of extreme waiting cases were generally removed (for example, in the analysis, the time of those dumper cycles in which there were occasional stops greater than 15 minutes were not taken into account).

Table 5.: Model of medium periods of the dump cycle and dump capacity.

Dump truck			Excavator							
		Tag	I	II	III	IV	II	III	IV	V
		Distance (m)	1,350	1,550	1,950	2,300	1,550	1,950	2,300	2,750
Tag	Tech. load	Distance (m)	1,550	1,750	2,150	2,500	1,750	2,150	2,500	2,950
			Dumper cycle time				Average dump truck capacity			
	t		min	min	min	min	t/h	t/h	t/h	t/h
A/1	100		31.1	37.6	47.6	40.6	159.57	126.05	147.78	109.29
A/2	100		32.6	31.0	45.4	41.2	193.55	132.16	145.63	129.87
A/3	100		31.9	34.7	41.9	40.8	172.91	143.20	147.06	123.97
A/4	100		31.7	38.3	40.0	52.8	156.66	150.00	113.64	106.57
A/5	100		35.1	33.1	40.7	44.4	181.27	147.42	135.14	131.29
B-1/6	125		28.2	35.7	46.0	47.6	210.08	163.04	157.56	135.14
B-1/7	125		37.7	36.6	44.3	41.9	204.92	169.30	179.00	142.31
B-1/8	125		34.3	34.2	48.9	49.4	219.30	153.37	151.82	132.04
B-1/9	125		37.9	38.1	43.2	51.6	196.85	173.61	145.35	133.21
C-1/18	140		32.3	33.7	41.7	48.7	249.26	201.44	172.48	186.67
C-1/19	140		32.7	36.2	48.3	42.8	232.04	173.91	196.26	157.60
C-1/20	140		34.0	33.8	40.4	45.4	248.52	207.92	185.02	150.27
C-1/21	140		29.7	33.3	40.9	43.3	252.25	205.38	194.00	183.01
C-1/22	140		28.6	37.6	38.5	50.9	223.40	218.18	165.03	184.62
C-1/23	140		31.2	31.4	40.4	48.7	267.52	207.92	172.48	156.13
C-2/24	140		35.7	32.0	43.3	40.3	262.50	194.00	208.44	147.89
C-2/25	140		30.0	30.3	41.0	45.4	277.23	204.88	185.02	148.94
C-2/26	140		27.2	40.0	37.0	46.6	210.00	227.03	180.26	165.03
C-2/27	140		28.1	37.7	43.1	49.5	222.81	194.90	169.70	180.65

The analysis showed that from all recorded periods of the dumper cycle in their effective movement under normal operating conditions (without unforeseen breaks for rest, pause, defect, etc.) the longest cycles do not exceed 15 minutes. Therefore, time values are generated in an interval of additional 1 to 12 for shovel I and II, 1 to 14 for shovel III and 1 to 15 min for shovel IV and V. The model of the generated times of dumper cycles and their calculated capacities is given below.

Table 6.: Average dumper capacity at modeled values.

Dump truck			Excavator					
			Tag	I	II	III	IV	V
			Distance (m)	**1,350**	**1,550**	**1,950**	**2,300**	**2,750**
			Distance (m)	**1,550**	**1,750**	**2,150**	**2,500**	**2,950**
Tag	Number	**Tech.load**		**Average capacity of the dump truck**				
		t		**t/h**	**t/h**	**t/h**	**t/h**	**t/h**
A	5	100.00		185.06	172.79	139.77	137.85	120.20
B-1	4	125.00		220.36	207.79	147.16	139.80	125.37
B-2	4	125.00		221.07	208.82	154.59	146.48	127.86
C-1	10	140.00		265.53	245.27	199.90	179.69	166.42
C-2	4	140.00		280.76	243.13	161.35	153.77	134.80
Total/average	**27**	**128.15**		**239.61**	**220.58**	**168.53**	**157.27**	141.38

Again, on the basis of these time cycles, the following weighted values of the analyzed hourly effective capacities of the dumper at the modeled values were obtained.

4. ANALYSIS OF RESULTS

Based on the data from Table 7, a statistical analysis of the shovel-dumper truck ratio was made. The ratios of the average modeled hourly capacities of the trucks with actual ones in the production of various shovels were analyzed. The percentage utilization in this ratio is calculated. Minimum, maximum, medium usage, shovels and mining truck are also calculated. The interval of utilization of each dumper or shovel is also calculated. Outputs are given in Table 7. In Fig. 1 is a diagram showing the percentage of utilization in the shovel / dumper truck ratio. And, in Fig. 2 the possible zones to optimally use the shovel / dumper truck.

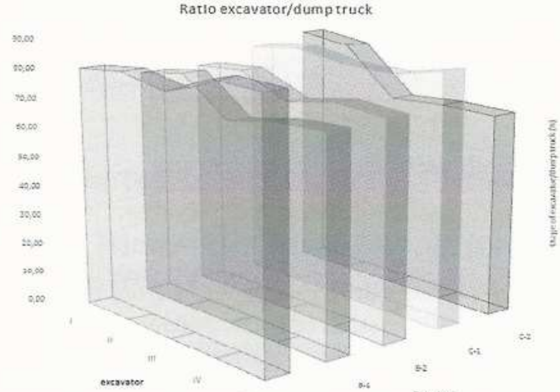

Figure 1.: Graph of excavator/dump truck ratio.

Table 7.: Analysis of the excavator/dump truck ratio.

Excavation/ Dump truck	I	II	III	IV	V	AVERAGE	MIN	MAX	INTERVAL
	Used%								
A	80.74	82.85	79.69	**86.99**	86.38	83.33	79.69	86.99	7.30
B-1	76.63	**79.68**	67.45	70.92	71.79	73.30	67.45	79.68	12.23
B-2	76.53	**78.01**	70.77	74.13	73.03	74.49	70.77	78.01	7.23
C-1	80.72	83.26	**80.76**	80.48	**84.73**	81.99	80.48	84.73	4.26
C-2	**84.00**	81.76	66.13	67.48	67.47	73.37	66.13	84.00	17.87
AVERAGE	79.72	81.11	72.96	76.00	76.68				
MIN	76.53	78.01	66.13	67.48	67.47		66.13		
MAX	84.00	83.26	80.76	86.99	86.38			86.99	
INTERVAL	7.47	5.25	14.64	19.51	18.91				

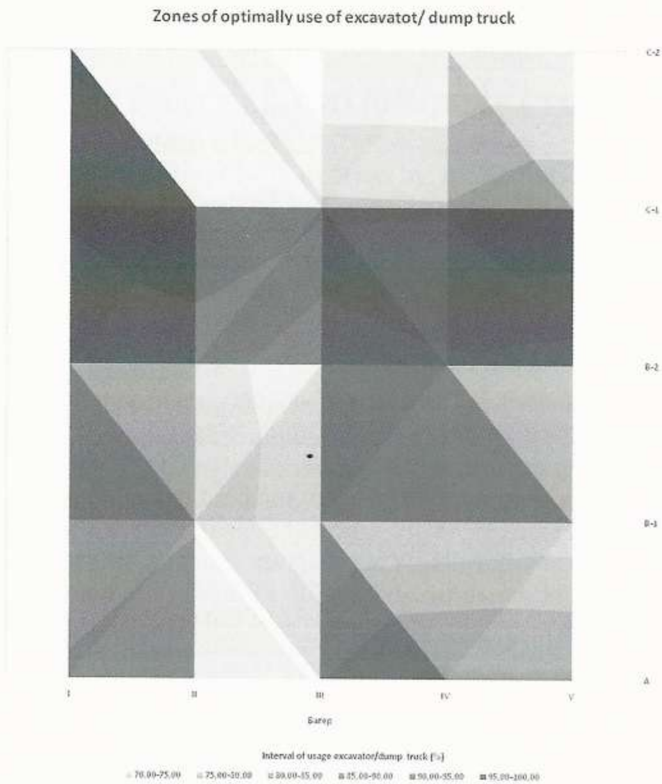

Figure 2.: Zones of optimally use of excavator/dump truck.

5. DISCUSSION

Based on the research carried out in this paper, ie from the analyzed results, there is a possible approach to the optimization of truck transport in the surface exploitation of metals. This approach is based on optimizing the utilization of the shovel - truck system. Namely, the smaller the time of the dump cycle, the less the waiting time for the charger to chargee it. Also in this approach, minimizing the waiting for empty mining truck before the filling site of a particular dumper is considered, if it is overloaded. Any increase in the use of the excavator (shovel) - mining trucks will mean minimizing transport costs but also minimizing the loading costs. Based on the analysis of the results, the following achieved effects of this approach can be ascertained. The dumper trucks have an average utilization of 67-87%.

Best results would be achieved if type A mining truck take priority over shovel IV, type B-1 dumper trucks are sent with priority to shovel II. With the same priority are the type B-2 dumper trucks, which are essentially the same as B-1, but from the newer generation. The most number dumper type C-1 are optimum to send to the shovel V and shovel III. And mining truck from C-2 to shovel I (Table 8).

6. CONCLUSIONS AND PROPOSAL

In this paper an attempt has been made to define the approach to optimizing the transport of trucks in the surface metal pits. In the paper are analyzes real data on the middle values of the dumper cycle as well as the calculation of their respective capacities. The development of a mathematical model was made by generating random variables, a model of values of the dumper cycles and their capacities.

Table 8.: Operator priorities of excavator/dump truck.

Priority	Dump truck	A	B-1	B-2	C-1	C-2
1	Excavator	IV	II	II	V	I
2		V	I	I	II	IV
3		I	III	IV	III	III
4		II	V	V	I	V
5		III	IV	III	IV	II

The analysis of the results of the modeling allows the definition of the approach to maximizing the efficiency of the utilization of the shovel-dump ratio. With the help of these results, the discussion also provides appropriate recommendations for the specific use and movement of the mining truck. So, the results of this paper can help in model research to improve the utilization of the operation of shovels and mining truck at the level of surface mining. This would certainly create conditions for minimizing transport costs. This research provides only one initial approach and it should initiate further research with the introduction of other parameters that would increase the reliability of the modeling.

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