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## Using a model to approach the process of loading and unloading of mining output at a quarry

### Introduction

Mineral commodities (reserves), even though increasingly expensive to extract, are still available so that new approaches to loading and unloading these commodities should be applied (Szamałek 2011). Modelling and model creation is one of the fundamental cybernetic approaches to investigation, analysis, planning, and systems designing. Modelling is the process of replacing a dynamic system by its model. The model represents a simplification of any object or process, and is created from a real object. The problem of modelling and model creation is solved by authors from a variety of spheres like process technology, transport, handling, etc. (Malindžák 2009; Malindžák et al. 2010; Andrejiova et al. 2012, 2013; Berežny Grinčova 2009; Marasova et al. 2008).

This paper describes a model of loading and transportation of mineral resources from the point of loading to the point of unloading, considering specific conditions. This process is a typical technological process for surface quarry plants affecting the operation of other technological units (e.g. crushing line). The model provides, for example, a system for optimizing the day-to-day flow of raw material to be exploited – especially when the need exists to extract resources from multiple locations. Fulfilment of this daily capacity depends on the specific conditions of extraction, material quantity, the performance of the loading and transport equipment, transportation distance, organization of work, shift duration, and other

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factors. The modelling of the process can be used as a basis for choosing a transportation system, or for rationalizing or optimizing an existing system, having a significant impact on performance evaluation of the transport system or even the whole company (Rosová and Balog 2012). This matter is also related to one of the major objectives of EU energy policy; it addresses the security of energy supplies and the creation and maintenance of a functional internal market. Of course, this does not limit the rights of Member States to determine the conditions for exploiting their energy resources, the choice between different energy sources, and the general structure of energy supply (Škvareková and Kozáková 2012).

## 1. Model creation and algorithm for material unloading

The modelling of loading and transportation of mineral resources can be divided into 2 basic parts. The first one – advance workings – includes calculating the parameters for modelling. The second one is the model’s creation in graphical form for a monitored period based on an algorithm. The number of loaded trucks can be determined from the model as well as the quantity of material transported from the place of loading. In case of several loading sites, the modelling should be adapted for all sites and transportation lines. The model is prepared in the form of a table from the values found with the appropriate combination of loading sites, and will be used as a basis for raw material unloading from different loading sites based on the selected criteria.

### 1.1. Defining the process and calculation of values needed for modelling

Before proceeding to create a model, it is necessary to characterize the process and calculate the parameters for modelling.

The loading and transportation process of mineral resources is shown in Fig. 1, which represents a formalized scheme of individual parts of the processes of loading, transportation, and unloading the mineral resources.

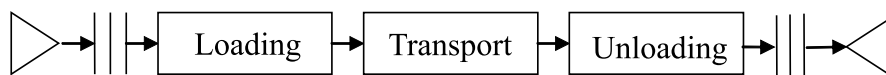


Fig. 1. Formalized scheme of the process

Rys. 1. Sformalizowany schemat procesu

The “Input” to all blocks on the scheme is a type of mineral resource with its characteristic properties (physical and chemical) that is exploited by primary or secondary rock blasting in a surface mine on one or more sites.

The “Loading” features the loading of a transport means by handling equipment like wheel loaders. The parameters of this process include loader bucket capacity (m<sup>3</sup>, tons),

work cycle period of the loader which determines the performance, and ratio of loader bucket capacity to the truck bed. The loading process can be covered by one or more loaders.

The “Transport” features material transportation from the loading site to the unloading site by a mining truck characterized by its capacity ( $m^3$ , tons) and performance depending on transport routes. That process can be covered by one or more transport means with the same or various capacities and on multiple transport lines.

The “Unloading” features the unloading of the mining truck (by dumping-out its bed) into the crusher’s feeding hopper or a dumping site.

The background for modelling these processes is the loader’s performance capacity calculation for truck transportation.

### 1.1.1. Performance calculations of a wheel loader

Performance calculation of the loader can be made by the following methods: mathematically – calculations according to known relationships; or empirically – based on the observation time of the equipment’s work. The performance should also be examined by a combination of the abovementioned methods. Effective performance per hour of a wheel loader is one of the most important parameters for this modelling.

The effective hour’s performance of a wheel loader  $Q_E$  shall be determined by calculation based on the mathematical formula (Marasová and Šaderová 2001):

$$Q_E = \frac{3600}{t_{CN}} \cdot q_N \cdot \rho \cdot k_p \cdot \eta_\varepsilon \text{ [Mg}\cdot\text{hour}^{-1}] \quad (1)$$

- ↪  $q_N$  – bucket capacity of a wheel loader [ $m^3$ ],
- $\rho$  – bulk density of material [ $Mg\cdot m^{-3}$ ],
- $k_p$  – coefficient of bucket utilization,
- $\eta_\varepsilon$  – coefficient of time utilization,
- $t_{CN}$  – wheel loader operating cycle [s].

There are two ways to obtain an operation cycle of a wheel loader  $t_{CN}$  – from technical documentation for a loader or by monitoring of the loader under real conditions. The monitoring is carried out for the whole operational cycle of the wheel loader, and separately for each work operation of the operation cycle:

- 1) time for scooping of the loader’s bucket,
- 2) time of lift and rotation of the full bucket over the transport means (mining truck),
- 3) dumping the material from the loader’s bucket into truck’s bed,
- 4) time for bucket rotation and time for preparation for next bucket filling,
- 5) dead time.

### 1.1.2. Capacity calculations of a quarry's truck transportation

When modelling the transport process, it is necessary to determine a “capacity calculation of truck transport”, which includes calculations of the following parameters (Marasová and Šaderová 2001):

- a) hourly performance of a mining truck,
- b) number of truck turns per hour on each transport route,
- c) number of trucks to be required in order to meet loader performance.

**a) The hourly performance of a mining truck can be solved by the formula**

$$Q_A = M_n \frac{60}{T_c} \text{ [Mg}\cdot\text{h}^{-1}] \quad (2)$$

- ↪  $M_n$  – the truck capacity [Mg],  
 $T_c$  – one transport cycle time [min].

Transport cycle time is expressed as a sum of partial times following the formula

$$T_c = t_n + t_v + t_z + t_j \text{ [min]} \quad (3)$$

- ↪  $t_n$  – time for loading a truck [min],  
 $t_v$  – time for unloading a truck [min],  
 $t_z$  – dead time [min],  
 $t_j$  – truck driving time [min].

Time for loading a truck is calculated by the formula

$$t_n = \frac{M_n}{Q_e} \cdot 60 \text{ [min]} \quad (4)$$

- ↪  $Q_E$  – effective hour loader performance [Mg·h<sup>-1</sup>] (from formula no. 1).

The time required for unloading a truck (backwards or sideways) can be obtained from the manufacturer's documentation, and depends on the type of mechanism of the truck to be unloaded. The unloading time can also be obtained by monitoring under real conditions, and is about 60–90 seconds.

Dead time, depending on the level of work organization, should be close to zero. The truck's driving time in 1 transport cycle can be calculated following the formula

$$t_j = 120 \frac{L}{v_s} \text{ [min]} \quad (5)$$

- ↻  $L$  – transportation distance [km],  
 $v_s$  – average speed of the truck [ $\text{km}\cdot\text{h}^{-1}$ ].

Transport cycle time  $T_c$  for each operational condition is obtained by monitoring.

**b) The number of truck turns per hour on each transport route is calculated by the formula**

$$p_o = \frac{60}{T_c} \quad (6)$$

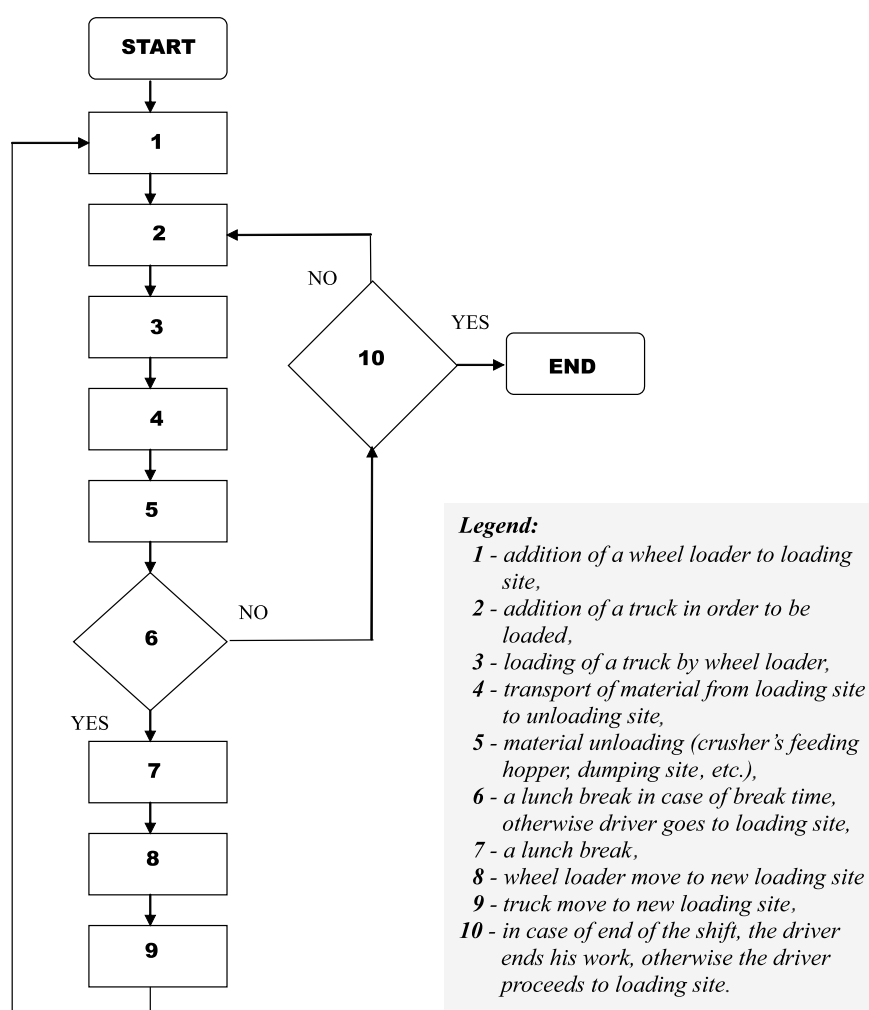


Fig. 2. Algorithm for material unloading modelling process

Rys. 2. Algorytm modelowania procesu rozładunku materiału

**c) The number of trucks to be required in order to meet the loader performance is determined by**

$$P_A = \frac{Q_E}{Q_A} \quad (7)$$

The time of loading and time of all non-transport operations is constant for the example concrete quarry plant. The truck driving time grows linearly with distance. To reach the same performance while increasing the distance, it is necessary to increase the bed capacity of the trucks or add more trucks – proportionally with the distance.

### 1.2. Algorithm for material unloading modelling process

The modelling is performed based on the algorithm in Fig. 2. The algorithm is designed according to the requirements of material transport from 2 loading sites so that a change of loading site is performed after the lunch break. There is only 1 wheel loader.

## 2. Modelling of material loading and unloading under specific operational conditions

The specified model will adequately determine the method of material supply for the smooth operation of technological lines assuring material treatment in case there is only 1 wheel loader and the transport is provided from two different loading sites.

Table 1. Operational conditions for modelling of the process

Tabela 1. Warunki operacyjne modelowania procesu

Volume to be required for transport on a daily basis	3800 t
Number of loading sites	5 ( $N_1 \dots N_5$ )
Bulk density of a material	1.697 Mg·m <sup>-3</sup>
Number of wheel loaders	1
Wheel loader's bucket capacity	6.2 m <sup>3</sup>
Operation cycle time of a wheel loader	30 seconds
Coefficient of bucket utilization	0.85
Number of mining trucks	3
Mining truck capacity	40 Mg
Coefficient of time utilization	0.67
Length of the shift (including breaks and dead times)	10 hours

Firstly, it is necessary to establish the distances between loading and unloading sites, to perform a calculation for the loader performance, and to perform capacitive calculations of transport when creating a model by the formulas (1 to 7). Operational conditions and parameters for the model's design are given in Table 1.

### 2.1. Wheel loader performance calculations

Wheel loader performance under selected conditions was established from observing the loader's operational cycle for each loading site. An operation cycle consists of the following activities:

- ◆ material scoop,
- ◆ driving time with the loader's bucket full,
- ◆ dumping the material from the loader's bucket into a truck's bed,
- ◆ driving time with empty loader's bucket and preparations for scooping.

There is an arithmetic average of 30 seconds established from the operation's cycle measurement in order to calculate wheel loader performance. As shown in Table 1, there is only 1 type of material to be loaded at various loading sites.

The loader's effective hourly performance of  $Q_E = 720$  tons per hour is calculated from input parameters based on equation 1. It is the equivalent of 7,200 tons during the 10-hour shift. This type of loader is thus able to satisfy the requirement for a load of 3,800 tons of raw material per day, provided that there is enough material at the loading sites (not always the case).

The weight of the raw material in the loader's bucket for a bucket utilization coefficient of 85% has an average of 9 tons. Four buckets are necessary to fill in the mining truck to reach 36 tons, with the truck's capacity at 90%. To meet the requirement of 3,800 tons, the wheel loader needs more than 106 trucks at that capacity during one shift.

### 2.2. Capacity calculations of transport for loading sites

Mining truck performance was established according to the calculations in chapter 1.1.2. The transport cycle time is established from observations under real conditions. Table 2 shows the arithmetic average of the measured values of the transport cycle time for all loading sites as well as distances from loading sites to unloading sites ( $L_{1-5}$ ). Also calculated are the values  $Q_{DP}$ ,  $p_o$  and  $p_A$ .

The maximum distance of 1,800 m to the unloading site is from loading site  $N_3$ . The minimum distance of 1,000 m to the unloading site is from loading site  $N_1$ . Consequently, the measured parameters are used for calculations of hourly truck performance, the number of turns, and the number of trucks necessary to match loader performance for all loading sites.

The mining truck which transports material from loading site  $N_1$  ( $Q_A = 216$  [Mg/h]) shows the highest performance, while the lowest performance is shown by the truck transporting material from loading site  $N_3$  ( $Q_A = 144$  [Mg/h]).

Table 2. Capacity calculations results

Tabela 2. Rezultaty wyliczeń zdolności

Loading site	Measured parameters		Calculated parameters		
	$L$ [m]	$T_c$ [min]	$Q_A$ [Mg/h]	$p_O$ [h <sup>-1</sup> ]	$p_A$
$N_1$	1 000	10	216	6.0	3.33
$N_2$	1 100	11	196	5.4	3.67
$N_3$	1 800	15	144	4.0	5.0
$N_4$	1 450	12	180	5.0	4.0
$N_5$	1 700	14	154	4.3	4.67

Table 3. Volume of unloaded material from different loading sites

Tabela 3. Ilość rozładowanego materiału z różnych miejsc załadunku

Loading site	Number of truck turns per shift		$Q_{AS}$ [Mg/shift]		Required volume [Mg]
	One A	Three A	One A	Three A	
$N_1$	48	144	1 728	5 184	3 800
$N_2$	43	129	1 548	4 644	3 800
$N_3$	32	96	1 152	3 456	3 800
$N_4$	40	120	1 440	4 320	3 800
$N_5$	34	102	1 224	3 672	3 800

Table 2 shows that there should be on average 4 mining trucks in operation for each loading site. As shown in Table 1, there is only 1 wheel loader for 5 loading sites and 3 mining trucks. The volume of material transported from different loading sites by 1 or 3 trucks (36 ton each) is shown in Table 3.

All values were calculated using the number of turns of mining trucks per shift assuming a shift of 8 hours.

Table 3 shows that 3 mining trucks are quite enough to handle transport of 3,800 ton of material in one shift from loading sites  $N_1$ ,  $N_2$ , and  $N_4$ . However, 3 mining trucks alone can't handle 3,800 tons of material from sites  $N_3$  and  $N_5$ .

Thus, transport from loading sites  $N_3$  and  $N_5$  is considered to be a bottleneck. It is advisable to consider other transport combinations while transporting from  $N_3$  and  $N_5$ .

The model can be useful if we need to find suitable transport combinations of loading sites  $N_3$  and  $N_5$  with sites  $N_1$ ,  $N_2$ , and  $N_4$ .



### 2.3. Modelling of unloading material under specific conditions from two loading sites

The loading should be carried out at two loading sites by one wheel loader, thus it is necessary to establish the time needed to move the loader over the loading sites. Transfer times identified by observation under real conditions are shown in Table 4, which also provides a distance matrix for the loading sites. For example, the shortest distance is between the loading sites  $N_1 - N_2$ , and the longest distance is between the sites  $N_1 - N_4$ .

Table 4. Transfer times of the wheel loader between the loading sites

Tabela 4. Czas przemieszczania się ładowarki kołowej pomiędzy miejscami załadunku

Loading site	Distance [m]	Transfer time [min]	Loading site	Distance [m]	Transfer time [min]
$N_1 - N_2$	450	2.25	$N_2 - N_4$	850	4.25
$N_1 - N_3$	1 100	5.5	$N_2 - N_5$	750	3.75
$N_1 - N_4$	1 000	5.0	$N_3 - N_4$	700	3.5
$N_1 - N_5$	800	4.0	$N_3 - N_5$	650	3.25
$N_2 - N_3$	1 000	5.0	$N_4 - N_5$	550	2.75

Table 4 shows that the movement of the loader takes about 5–6 minutes, and it is moving before or during a lunch break as shown in the algorithm in Figure 2.

Modelling of material transport can be performed for various periods of time (estimated hours of work before and after the lunch break) for each loading site. Subsequently, graphical models will be transformed into tabular form. Appropriate combinations of loading sites are established.

Models of transportation and loading of raw material were created for different variants of work shifts:

- ◆ Variant I: 240 + 240 minutes (1/2 shift).
- ◆ Variant II: 220 + 260 minutes (220 minutes – period of time until lunch break; and 260 minutes – period of time until pause).
- ◆ Variant III: 260 + 220 minutes (260 minutes – period of time until lunch break; and 220 minutes – period of time until pause).

Figures 3 and 4 show models developed in graphical form for each loading site considering the use of three cars for established periods of time. The red color features the loading of the mining truck; blue, the transport cycle (transport, unloading, and driving back to the wheel loader); and yellow, the dead time of trucks at the beginning of a shift. Green is the time to completion of the transport cycle of transport at the time of the break or the end of the shift. Table 5 shows the values obtained from graphical models for given periods of time.

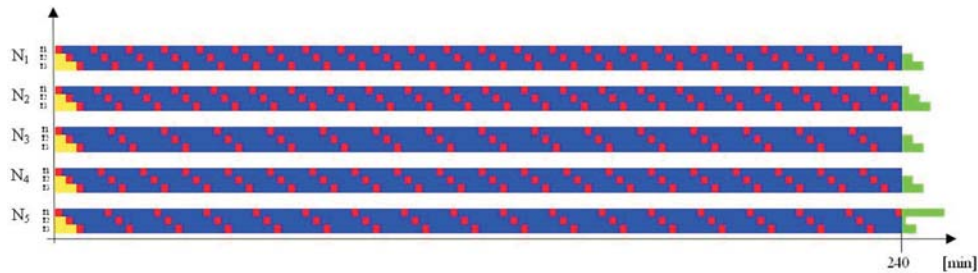


Fig. 3. Graphical model for time period of 240 minutes (1/2 shift)

Rys. 3. Graficzny model dla 240 minut (1/2 zmiany)

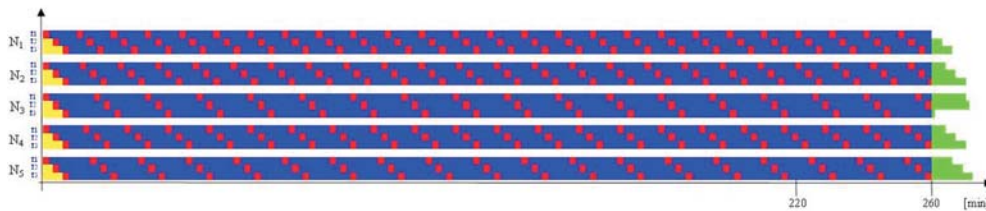


Fig. 4. Graphical model for time periods 220 and 260 minutes (1/2 shift)

Rys. 4. Graficzny model dla 220 i 260 minut (1/2 zmiany)

Table 5. Numbers of trucks to be loaded for different time periods

Tabela 5. Ilość wozideł do załadunku dla różnych przedziałów czasu

	$N_1$	$N_2$	$N_3$	$N_4$	$N_5$
220 minutes	66	60	45	55	48
240 minutes	72	66	48	60	51
260 minutes	78	71	53	66	57

Depending on the requirements, each loading site would load 53 mining trucks over a period of 240 minutes (1/2 shift). Loading sites that do not meet this requirement are marked in colour, e.g. sites  $N_3$  and  $N_5$ .

The next step is to create pairs of loading sites by combination of the bottleneck sites  $N_3$  and  $N_5$  with loading sites  $N_1$ ,  $N_2$ , and  $N_4$ . We do not consider transport combinations within the loading sites  $N_1$ ,  $N_2$ , and  $N_4$  because these sites comply with the capacity requirements.

Transport combinations for Variant I are shown in Table 6. Table 6 shows that combinations of loading sites  $N_3$  and  $N_5$  do not comply with the demand for 106 loaded trucks for a total volume of 3,800 tons; therefore, they are excluded from the solution. Other combinations meet the given requirements with a reserve in most cases.

Table 6. Number of trucks to be loaded considering combinations of loading sites – Variant I

Tabela 6. Liczba woźdźel do załadunku przy założeniu kombinacji miejsc załadunku – Wariant I

Variant I	2 × 240 minut		
Loading site	Number of trucks	Loading sites	Number of trucks
$N_1 - N_3$ $N_3 - N_1$	120	$N_3 - N_4$ $N_4 - N_3$	108
$N_1 - N_5$ $N_5 - N_1$	123	$N_3 - N_5$ $N_5 - N_3$	99
$N_2 - N_3$ $N_3 - N_2$	114	$N_4 - N_5$ $N_5 - N_4$	111
$N_2 - N_5$ $N_5 - N_2$	117		

Table 7. Number of trucks to be loaded considering combinations of loading sites – Variants II and III

Tabela 7. Liczba woźdźel do załadunku przy założeniu kombinacji miejsc załadunku – Wariant II i III

Variant II	220 minutes (time period until lunch break) and 260 minutes (time period until pause)		
Loading site	Number of trucks	Loading sites	Number of trucks
$N_1 - N_3$	119	$N_3 - N_5$	102
$N_1 - N_5$	123	$N_4 - N_3$	108
$N_2 - N_3$	113	$N_4 - N_5$	112
$N_2 - N_5$	117	$N_5 - N_1$	126
$N_3 - N_1$	123	$N_5 - N_2$	119
$N_3 - N_2$	116	$N_5 - N_3$	101
$N_3 - N_3$	98	$N_5 - N_4$	114
$N_3 - N_4$	111	$N_5 - N_5$	105
Variant III	260 minut (time period until lunch break) and 220 minutes (time period until pause)		
$N_1 - N_3$	123	$N_3 - N_5$	101
$N_1 - N_5$	126	$N_4 - N_3$	111
$N_2 - N_3$	116	$N_4 - N_5$	114
$N_2 - N_5$	119	$N_5 - N_1$	123
$N_3 - N_1$	119	$N_5 - N_2$	117
$N_3 - N_2$	113	$N_5 - N_3$	102
$N_3 - N_3$	98	$N_5 - N_4$	112
$N_3 - N_4$	108	$N_5 - N_5$	105

Similarly to Variant I in Table 6, results are shown for Variants II and III in Table 7. Table 7 shows that the combination of loading sites  $N_3$  and  $N_5$  do not comply with the demand for 106 loaded trucks for a total volume of 3,800 tons; they are therefore excluded from the solution.

#### 2.4. Matrix model – proposals for unloading the material from two loading sites

Tables 8 to 10, based on graphical models and calculations, feature the models of material processing (loading, transport, unloading) for each variant. Any combinations of load points for Variants II and III which are oversized for the specified conditions are excluded from the solution. When creating the matrix model, the following rules was considered:

- ◆ use of all loading sites,
- ◆ uniform utilization of mining trucks during each time period,
- ◆ determining the minimum number of loaded trucks at loading sites.

The model indicates a recommended number of trucks to be loaded for each loading site in order to meet the requirements of 106 cars.

Figure 5 shows a map of loading site combinations applicable for all 3 alternatives. This map can be used for the rapid selection of an alternative. The model provides the information required for decision making and can serve as a tool to manage the transport of raw materials in quarry plants.

Table 8. Unloading options – Variant I

Tabela 8. Opcje rozładunku – Wariant I

Variant I		$N_1$		$N_2$		$N_3$		$N_4$		$N_5$	
		7 <sup>00</sup> –11 <sup>00</sup>	11 <sup>30</sup> –15 <sup>30</sup>	7 <sup>00</sup> –11 <sup>00</sup>	11 <sup>30</sup> –15 <sup>30</sup>	7 <sup>00</sup> –11 <sup>00</sup>	11 <sup>30</sup> –15 <sup>30</sup>	7 <sup>00</sup> –11 <sup>00</sup>	11 <sup>30</sup> –15 <sup>30</sup>	7 <sup>00</sup> –11 <sup>00</sup>	11 <sup>30</sup> –15 <sup>30</sup>
1	A	60					46				
	B		60			46					
2	A	56									50
	B		56							50	
3	A			60			46				
	B				60	46					
4	A			56							50
	B				56					50	
5	A					60			46		
	B						60	46			
6	A							56			50
	B								56	50	

Table 9. Unloading options – Variant II (220 + 260)

Tabela 9. Opcje rozładunku – Wariant II (220 + 260)

Variant II	$N_1$		$N_2$		$N_3$		$N_4$		$N_5$	
	700–1040	1110–1530	700–1040	1110–1530	700–1040	1110–1530	700–1040	1110–1530	700–1040	1110–1530
1	60					46				
2			56			50				
3			56							54
4				63	43					
5					43			63		
6							52			54
7				62					44	
8								62	44	

Table 10. Unloading options – Variant III (260 – 220)

Tabela 10. Opcje rozładunku – Wariant III (260 – 220)

Variant III	$N_1$		$N_2$		$N_3$		$N_4$		$N_5$	
	700–1120	1150–1530	700–1120	1150–1530	700–1120	1150–1530	700–1120	1150–1530	700–1120	1150–1530
1			61			45				
2			62							44
3		60			46					
4				56	50					
5					53			53		
6						42	64			
7							62			44
8								52	54	

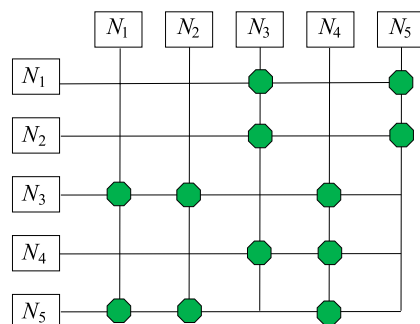


Fig. 5. Map of alternatives

Rys. 5. Mapa alternatyw

## Conclusion

The modelling approach applied in this article made it possible to optimize the raw material unloading from different loading sites for 3 organizational variants. A suitable unloading model was determined for real operating conditions, taking into account the existing or potential bottlenecks in the system. This model should ensure optimal, regular unloading of material from all loading sites. The approach represents one of the most effective ways of solving that type of problem, although other methods exist such as the simulations conducted by various authors like Marasová D., Husáková N., Gurecka J. (2012) or certain software programs (Šofranko et al. 2012).

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#### UŽYTIÉ MODELU PODEJŠCIA DO PROCESU ZAŁADUNKU I ROZŁADUNKU UROBKU W KAMIENIOŁOMIE

##### Słowa kluczowe

modelowanie, kamieniołom, model macierzowy, optymalizacja,  
surowce mineralne, załadunek, rozładunek

##### Streszczenie

Praca opisuje modelowe podejście do zagadnienia załadunku i transportu urobku z punktu załadunku do punktu rozładunku, przy założeniu wielu lokalizacji. Modelowanie i stworzenie modelu jest jednym z fundamentalnych podejść do badania, analizy, planowania i projektowania systemu. Model prezentowany w tym artykule został przygotowany na podstawie algorytmu zaprojektowanego zgodnie z wymaganiami transportu materiałów z dwóch punktów załadunku z użyciem tylko jednej ładowarki kołowej. Przy takich warunkach niezbędne było ustalenie czasu koniecznego do przemieszczenia ładowarki pomiędzy punktami załadunku. Finalnie model określa ilość wozideł do załadunku w każdym punkcie załadunku celem zapewnienia regularnego rozładunku materiału pochodzącego ze wszystkich punktów załadunku.

Po utworzeniu modelu macierzowego założono takie parametry, jak użytkowanie każdego punktu załadunkowego, jednorodne użytkowania wozideł technologicznych w każdym przedziale czasu, czy określenie minimalnej ilości załadowanych wozideł w punktach załadunku. Wykorzystanie dziennych zdolności przewozowych zależy od specyficznych warunków wydobycia, ilości urobku, pracy maszyn załadunkowych i transportowych, odległości transportowych, organizacji pracy, czasu trwania zmiany i innych czynników. Modelowanie procesu może być pomocne w wyborze systemu transportu lub też pewnej racjonalizacji czy optymalizacji systemu istniejącego. Modelowe podejście jest jednym z najlepszych sposobów rozwiązania tego problemu, choć istnieją też inne metody jak symulacje czy odpowiednie programy komputerowe.

**USING A MODEL TO APPROACH THE PROCESS OF LOADING  
AND UNLOADING OF MINING OUTPUT AT A QUARRY**

Key words

modelling, quarry plant, matrix model, optimization, mineral commodities, loading, unloading

Abstract

This paper describes a model approach to addressing the loading and transportation of mining output from the point of loading to the point of unloading, considering multiple locations. Modelling and model creation is one of the fundamental approaches to investigation, analysis, planning, and systems designing. The model in this article is prepared based on an algorithm that is designed according to the requirements of material transport from two loading sites with one wheel loader only. Given these conditions, it is necessary to establish the time necessary to move the loader between the loading sites. Finally the model identifies the number of trucks to be loaded for each loading site in order to ensure regular unloading of material from all loading sites.

When creating the matrix model, the rules like the use of all loading sites, uniform utilization of mining trucks during each time period, or determining the minimum number of loaded trucks at loading sites were considered. Fulfilment of daily capacity depends on the specific conditions of extraction, material quantity, the performance of the loading and transport equipment, transportation distance, organization of work, shift duration, and other factors. The modelling of the process can be used as a basis for choosing a transportation system, or for some rationalization or optimization of an existing system. The model approach is one of the best ways of solving this type of problem, although other methods exist such as simulation or software programs.