THE DESIGN OF SOFTWARE SOLUTION FOR TRANSPORT CONTROL AND ORGANIZATION IN THE QUARRY USING PRINCIPLES OF LOGISTICS

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Abstract

The paper presents an example of the solution of transport management and organization in the quarry in terms of material flow requirements and machine efficiency. Raw material transport is a very important technological process in the quarry. Harmonization of material flow requirements and transport management are a significant logistical problem in quarries. The basis of this solution is to ensure the electronic collection of information in quarry and their subsequent use in ensuring the required material flow with minimizing downtime of machinery. Optimization of such transport management in the quarry is ensured by the developed software. The main objectives of this optimization were to minimize transport equipment downtime and maximize materials flow using available mechanisms. For the software solution was chosen as the method of computer simulation of individual alternatives with subsequent evaluation of optimal solutions in terms of minimum downtime respectively maximum transport performance. The transport management software was designed based on practical experience in the granodiorite quarry in Slovakia. However, with minor modifications, it is also applicable to other quarries with automotive raw materials transport. Finding a solution to this problem is the basis for economically sustainable quarrying.

Keywords: Material flow, optimizing software, simulation, transport, logistics

1. INTRODUCTION

Mining in the quarry represents a set of different connected technological processes. For effective functioning of these technological processes it is necessary to be assured logistics and established logistics system [1]. In quarry, the main tasks of logistics are the management, integration, regulation and control of all material, information and finance flows and related logistics activities - transport, storage, handling and packaging [2]. The established logistics system of the quarry thus ensures the control, assurance and realized of the flow of materials, information and finance [3]. The basic objective of activities in the stone quarry is to ensure a smooth material flow and an economically efficient supply of raw material as an input to the technological lines for the production of aggregates. This objective can only be achieved by optimizing the individual elements of the logistics system [4]. The issue of process optimization and overall logistics of the company needs to be given considerable attention, and many authors are dealing with this issue at present - (Zeng, 2019), (Ercelebi, 2009), (Straka, 2018), (Khouri, 2018). From the point of view of achieving the stated basic objective of activities in the quarry, transport can be considered as one of the key technological processes and elements of the logistics system [5]. Optimizing of transport process is therefore an important step towards increasing the efficiency of quarrying and ensuring the functioning of the logistics system [6]. This paper is focused on design of software solution for organization and management of quarry transport. This software has been designed and implemented in the quarry as an aid to the daily planning of mining in the quarry under varying input conditions to solutions minimizing mechanism downtime and ensuring maximum material flow to technological line for the production of aggregate [7].

2. THE MAIN OBJECTIVES OF OPTIMIZATION, INPUT CONDITIONS AND USED RELATIONS

Based on request of the mining company, key objectives of optimization were identified as follows:

- Minimize the downtimes of shovel excavators used to load disintegrated raw ore and dumpers used for transport,
- Maximize the transport output when using transport mechanisms available.

Both of these goals are related to the need for better allocation and management of mechanisms at individual workplaces. Therefore, it is the question of a classical optimization problem [8].

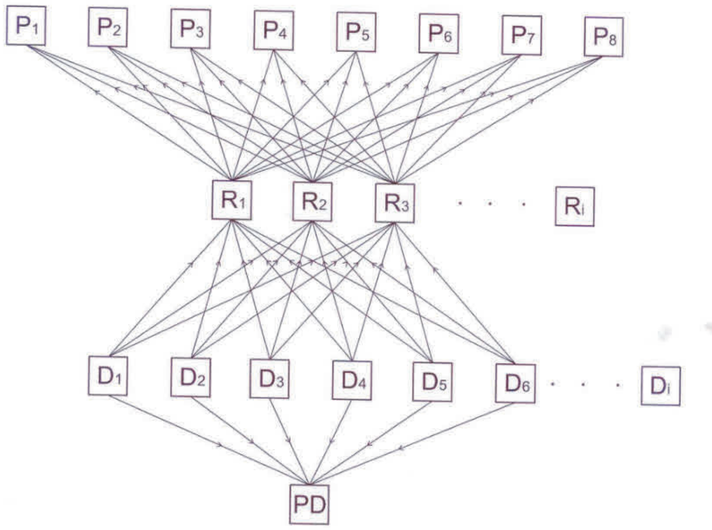

Figure 1 Scheme of the transport system in quarry [author]

Expected hour performance of a dumper:

$$Q_p = 3600 \frac{m_n . k_{pr}}{t_{c_p}} = 3600 \frac{G . k_{vn} . k_{pr_p}}{t_{c_p}} \tag{1}$$

where:

Q_p - expected hour performance of a dumper ($t.h^{-1}$),

m_n - average load weight (t),

t_{cp} - average duration of one dumper cycle (s),

G - carrying capacity of a dumper (t),

k_{vn} - dumper carrying capacity use coefficient,

k_{prp} - dumper downtime coefficient.

More precisely, the average cycle of dumper can be determined by analyzing data from GPS devices and using the arithmetic mean.

$$t_c = \frac{\sum_{i=1}^{n} t_{c_i}}{n} \tag{2}$$

where:

t_c - average time of one work cycle (s),

t_{ci} - duration of one work cycle (s),

n - amount of cycles (cycles).

Loader downtime per shift:

$$t_{pr_r} = t_e - t_{p_r} \tag{3}$$

where:

t_{prr} - downtime duration of loading device in one shift (s),

t_e - effective time in one work shift (s),

t_{pr} - actual work time of loading device in one shift (s).

$$t_{p_r} = \sum_{i=1}^{p} n_{c_{p_i}} . t_{n_{p_i}} \tag{4}$$

where:

t_{pr} - actual work time of loading device in one shift (s),

n_{cp} - amount of work cycles of loading device in one shift (cycles),

t_{np} - average time of dumper loading (s),

p - amount of dumpers assigned to loading device (pieces).

Dumper downtime per shift:

$$t_{pr_p} = t_e - t_{p_p} = t_{p_p} . (\frac{1}{k_{pr_p}} - 1) \tag{5}$$

where:

t_{prp} - downtime duration of dumper in one shift (s),

t_e - effective time in one work shift (s),

t_{pp} - actual work time of dumper in one shift (s),

k_{prp} - dumper downtime duration coefficient in one shift (-).

$$k_{pr_p} = \frac{t_{p_p}}{t_e} \tag{6}$$

where:

k_{prp} - dumper downtime duration coefficient in one shift (-),

t_{pp} - actual work time of dumper in one shift (s),

t_e - effective time in one work shift (s).

An important task was also to determine the basic criteria conditions. The first condition is related to performance of loading mechanism and transporters assigned to it.

$$t_e \geq \sum_{i=1}^{p} n_{c_{p_i}} . t_{n_{p_i}} \tag{7}$$

where:

t_e - effective time in one work shift (s),

n_{cp} - amount of dumper work cycles in one shift (cycles),

t_{np} - average time of dumper loading (s),

p - amount of dumpers assigned to loading device (pieces).

The second condition is related to transport performance and primary crusher as a primary element of treating line.

$$\sum_{i=1}^{p_c} Q_{p_i} \leq Q_d \tag{8}$$

where:

Q_p - hourly performance of dumper ($t.h^{-1}$),

p_c - total number of dumpers transporting the raw ore (pieces),

Q_d - hourly performance of primary crusher ($t.h^{-1}$).

3. OPTIMIZING SOFWARE

In terms of the selected methods, the method of computer simulation of individual alternatives with subsequent evaluation of optimum solutions in terms of minimum downtime and maximum transport output was adopted prospectively. The computer simulation is now used in various areas of process control, transportation and logistics [6].

Optimizing program has been created in Java programming language, the advantages of which are as follows: safety, ability of scaling, multiplatformity, robustness, etc. The program was proposed as desktop application based on priority requirements and shall meet the following requirements. simple graphical interface, possibility to adjust parameters of individual work mechanisms, work cycle duration time of mechanisms used, effective time of work our duration, primary crusher capacity, optima output into files of the .xls type of MS Excel application in the form of tables [6].

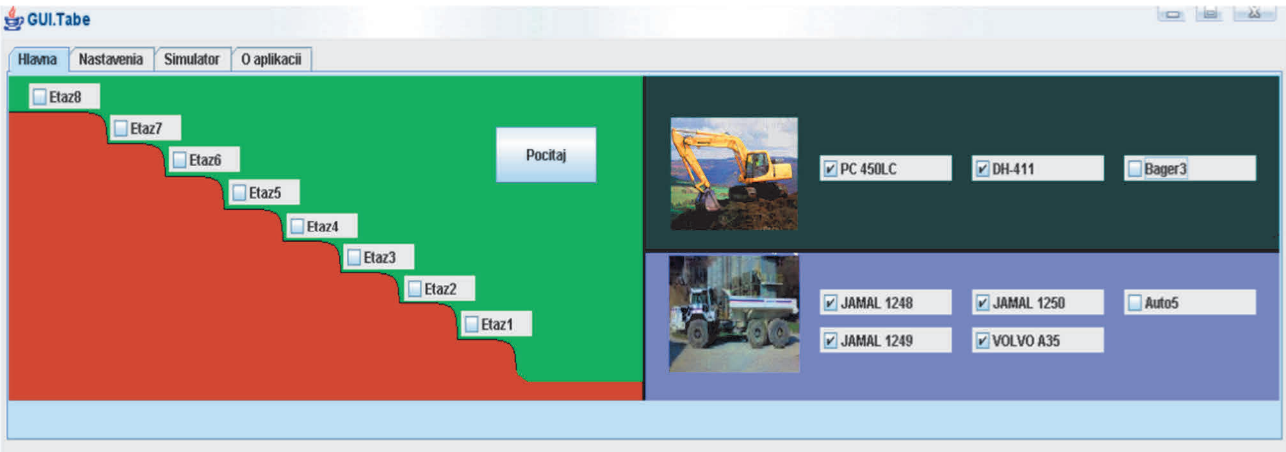

Figure 2 Sample of input parameters [author]

The main input data to be selected are accessible mining workplaces and types of loading devices and dumpers used.

Primary problem solved by the program is the division of dumpers and loading mechanisms on individual mining workplaces. Based on actual requirements stated by the user, the optimizing program should guarantee the optimum calculation in terms of minimum downtimes and simultaneously optimum with respect o maximum transported aggregates of stones from the loading place to the crusher.

Based on the selected mining sections, loading devices and dumpers, each variant of reallocation of mechanisms is simulated and the total downtime value and total transported quantity are determined. In the program, there is a possibility to simulate actual situation independent on results of the above mentioned optimum.

Maximum quantity transported for level 1 and 2				
Total downtime [min]	389	Total downtime [%]	16,64	
Total transported [t]	2700	Primary crusher [%]	118,68	
		Mobil crusher [t.hour^{-1}]	65	
Number of level	Combination of dumpers	Shovel	Downtime of shovel [min]	Downtime of shovel [%]
E1	JAMAL 1248 JAMAL 1249 JAMAL 1250	PC 450LC	177	45
E2	VOLVO A35	DH-411	208	53
Dumper	SHIFT [hour]	Number of cycles	Downtime of dumper[min]	Downtime of dumper [%]
JAMAL 1248	6,5	35	0	0
JAMAL 1249	6,5	35	0	0
JAMAL 1250	6,5	35	0	0
VOLVO A35	6,5	20	0	0

Figure 3 Sample output of optimization program for determining the maximum quantity transported [author]

4. CONCLUSION

The designed software to optimize the transport was applied in selected stone quarry in Slovakia. The application of this system simplified mining planning in this quarry. At the same time, transport costs have been reduced due to better transport management and organization. As part of the application of this software, the data collection method was gradually changed. The previous data collection system with PDA that required operator interaction has been replaced by an automatic GPS data collection system. This data is automatically downloaded, thus updating existing data and subsequently evaluating the data via pivot tables. The statistical processing of these data provides information on the performance and efficiency of the used mechanisms (e.g. number of dumper cycles performed, driving times, downtime of machines, etc.). The data thus obtained are also inputs to the designed optimization software. Based on them, it is possible to simulate of the current situation and find an optimal solution for dividing of available mechanisms into individual ready workplaces. Output data helps to manage and organize the transport system more efficiently, to control and regulate the material flow of the raw material and to plan further procedures for the extraction of the raw material in the deposit. The application of this software showed the need for further development in the field of optimization of logistics transport systems and their interconnection with information systems in quarries, which is also positively reflected in the economic indicators of the company.

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