Optimizing internal transport in terms of technical parameters in a mining company

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Abstract: The research scientific article summarizes the arguments within the scientific discussion on the issue of internal transport and machine park in mining companies. The machine park in mining companies is base of efective mining processes and optimal results of mining. The machine park in the mining company introduces a combination of stagnant and active equipment in the process of mining. The goal of this article is to reflect the innovative approach in the creation of internal transport by machine park in the mining company with the aim of increasing the reliability, safety, failures, and efficiency of mining equipment. The entity of the investigation was the selected mining company in Slovakia focused on limestone mining. Approach of research were focused on using comparative analysis of the technical parameters of mining machines and their technical performance. The relevance of the decision of this scientific research was connected with the innovation of a mining machine park focused on mobile machines with a combination of stationary machines. The article presents the results pointing to significant improvements in the machine park of the mining company. In this paper we suggest two alternatives (two models that monitor the factors as quality, costs, safety, reliability, and optimization of company resources, which are important for the optimal arrangement of equipments) of the composition of the machine park for a selected mining company with Mobil crusher Sandvik QJ341+, Mobile sorter McCloskey S130, Wheel loader CAT 972 M, and tracked excavator CAT 336F and second alternative Mobil crusher Hartl 12/65J, Mobile sorter Anaconda SR514, Wheel loader CAT 966 M and tracked excavator CAT 329E. The results of two alternatives of the machine park in a mining company can be recommendations for other mining companies in the area of building the machine park for mining processes and its optimization.

1 Introduction

The basic pillars of the "Sustainability" of mining processes are innovative approaches to the mining equipment, machines, technologies, and optimal application of the mining area in the synergy of the operation of the machine park for the internal transport of each mining company. The production cycle of limestone mining and processing is based on the efficient use of production equipment in the individual processes of the mining life cycle (Figure 1). The mining company has realized production equipment for some main processes and the research was focused on helpful equipment used in the main mining processes. The main goal of this article is to point out the innovative approach in the creation of the machine park in the mining company with the aim of increasing the reliability, safety, failures, and efficiency of mining equipments.
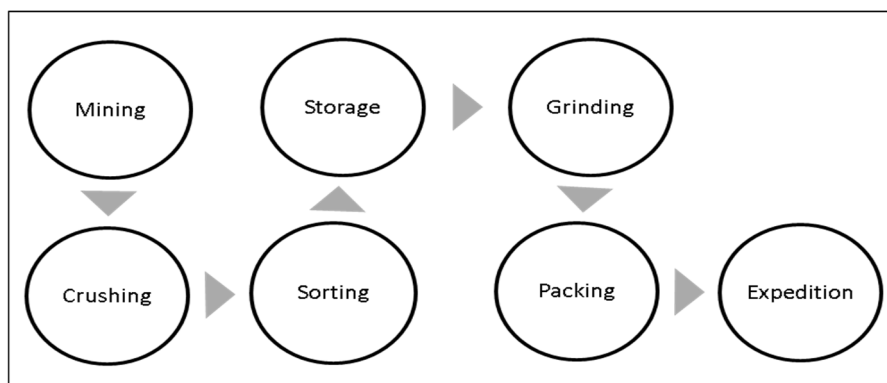

Figure 1 Main processes of limestone Mining (own source)

2   Literature review

Ambriško [1] and Grzegorzewka, Stasiak-Betlejewska [2] comment that the production potential creates indicators such as the number of machines, number of products, number of services, value of the gross value added, the price of buildings, the number and price of assets, the average level of employment, productivity growth, the value of the machine, the efficiency, profit, technical parameters, repairing, maintenance, modernization and others. Those indicators create a base for the value chain and for performance management in various enterprises in various processess [2]. Changing market requirements, pressure to minimize production costs, competition, but also legislative restrictions have an impact on mining processes and technical area of machine park in the mining companies [3,4]. Operational costs are very important part of the ň management of the machines and their performance. The main goal of mining company is minimize the operational costs. The one part of machine park is transport infrastructure and internal transport in mining company. This area create 20% costs of general costs of mining company and than is very important to solve transport and costs of machines park. Andrejiova, Kimaková [5] they indicated in the final study in their research that the transport infrastructure and the development thereof significantly affect performance of companies.The development of the transport segment is currently an essential process which affects industrial companies. The transport infrastructure and the services provided in this sector influence economic growth, the efforts aimed at increasing competitiveness, as well as prosperity of the society [5].

Machinery management (Figure 2) in mining companies is a major process focused on an efficient maintenance system.
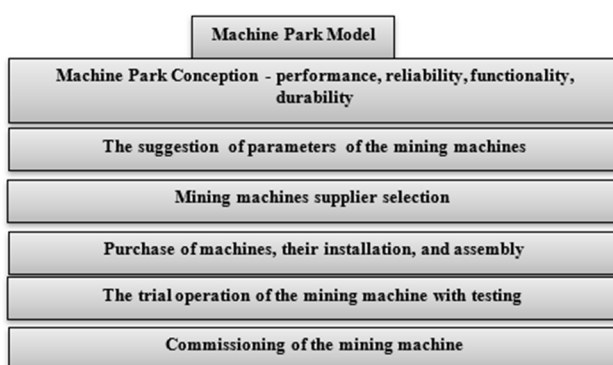

Figure 2 Machine Park model in mining company (own source)

The level of fleet maintenance has a significant impact on the performance of mining processes that are check by performance indicators as index of efficiency, coeficient of function and other index of performance of technical state of machines [3]. The maintenance process according to the ISO 13306 standard is one part of process management and it is a prerequisite for performing technical, management, and administrative activities during the life cycle of objects - machines and production equipment to fulfill the required function [1,6].

Process management can be provided by managerial instruments which are focused on special areas as maintenance. The most frequently implemented management approaches include: Supply chain management which is an important managerial tool determinant all conditions significant for suppliers and their use in praxis by the buying of machines in mining companies [7]. Maintenance management is focused on reliability, safety, functionality, reliability, quality, time, environment, and company costs [3,6]. Building a machine park in mining companies is the basis for the success of the mining process and very important part for financial page of the company. The Machinery park in a mining company stands on the financial plan which is creating one part of financial management. Financial management content is focused on the perception of the most important key factors of its sustainable effectiveness and performance in the context of its social, technological, and process aspects such as maintenance efficiency [8].

3   Methodology

In the scientific research of the mining company, we progressed based on the algorithm of steps (Figure 3), which was the principled tool for leading complex research in the mining company in area of machines. The subject of research was the machine park in the mining company for limestone mining. Many methods were used in solving the research, such as analytical, economical, graphical, and other.
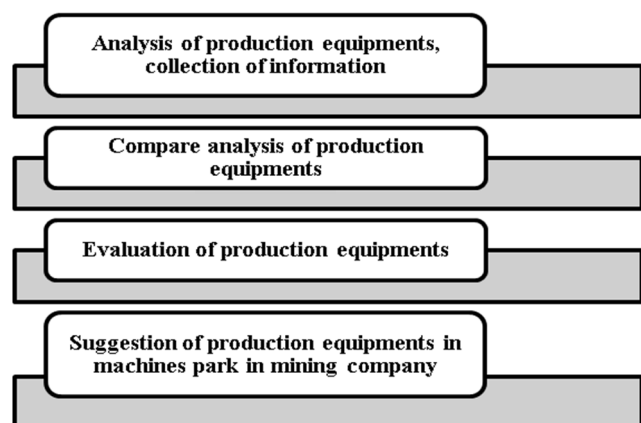

Figure 3 Algorithm of research in mining company (own source)

In this research, we dealt with the life cycle of production equipment in the phase of effective use in the mining process. By comparing analysis we watched the technical parameters of production equipment. The economic life cycle of production equipment in the phase of using means for the modernization, repair of production equipment, or buying new production equipment. The results of the research were the suggestion of production

equipment for a machine park in a mining company. Analysis of production equipment, collection of information - this step of the research was realized by a personal visit to the mining company. Comparing analysis of production equipment - consists of comparing original (past) and new equipment. Evaluation of production equipment - it consists of selecting the optimal production equipment for the machinery park in a mining company. The suggestion of production equipment in machine parks in mining companies - creates a model of using production equipment in machines parks for the life cycle of mining and its sustainability.

4 Results

Mining companies in the frame of innovation are using mobile machines with a combination of stationary machines. Mobile machines are bringing advantages for increasing demands of customers, for increasing volume of production-mining, for flexible reaction to market changes, and for an easier process of production [4]. The company's decision depended on increasing sales and insufficient production capacity in the process of crushing and sorting. The innovation process for the mining company meant buying new machines. The mining company bought a new mobile crusher (Figure 4). The significance of mobile machines is connecting to transport extracted raw material. In this way, the mining company is able to bring a mobile crusher, a mobile sorter directly to the excavated rock.

Crusher Hartl Powercrusher 12/65J

Crusher Sandvik QJ341+

Figure 4 Mobile crusher in Machine Park in mining company (own source)

Based on a comparison (Table 1) of the performance of the original Hartl 12/65J mobile crusher and the new Sandvik QJ 341+ mobile crusher, we can conclude that the Sandvik mobile crusher is more powerful to 50t/h for fraction 0-63 mm and 80 ton/h for fraction 0-100 mm. The mining company is able to use both crushers at the same time and thus produce more fractions of extracted raw

material. In the event of a failure of one device, the device will be replaced by another device without cessation of the crushing process. This machine is capacity reserve in Machine Park. This machine is capacity reserve in Machine Park. The capacity reserve in Machine Park in mining company is instrument for to block the mining process of reason no functionality of machine [9].

Table 1 Analysis of technical parameters of mobile crushers

Original machine		New machine	
Mobile crusher	Hartl 12/65J	**Mobil cusher**	Sandvik QJ341+
Machine performance			
fraction 0 – 63 mm	150 ton/h	**fraction 0-63 mm**	200 t/h
fraction 0 – 100 mm	250 ton/h	**fraction 0 –100 mm**	330 t/h

Source: (own source – research)

The mining company bought a new mobile sorter (Figure 5). As part of the mining company's machinery, it was also necessary to purchase mobile sorters as part of the following post-crushing process. Anaconda SR514 and McCloskey S130 mobile sorters sort the crushed raw

material into 0-10mm fractions, 10-32mm fractions, 32-80mm fractions and an oversized 80-130mm fraction. The introduction of new mobile sorters has increased the flexibility of processing the extracted raw material.

Sorter McCloskey S130   Sorter Anaconda SR514

Figure 5 Mobile sorter in Machine Park in mining company (own source)

The flexibility of handling mobile devices significantly facilitates the transfer of equipment and preparation for the processing process (crushing and sorting), which significantly increases overall productivity. Other equipment that is used in the mining process is wheel loaders (Figure 6). Due to the mobile crushers and screens, it was necessary to add more powerful wheel loaders. The function of wheel loaders is to load trucks and fill hoppers that feed the raw material into mobile crushers.

Wheel loader CAT 972M   Wheel loader CAT 966M

Figure 6 Wheel loader in Machine Park in mining company (own source)

With the help of new wheel loaders (Table 2) with a larger spoon volume, the loading time of cars will be significantly reduced, thus speeding up the actual shipment and the continuity of the crushing and sorting process. The Dosan DL250 and Volvo L120E wheel loaders have lower technical parameters than the new CAT 966M and CAT 972M wheel loaders. Operating weight is higher on 9200 kg for CAT 966M in comparing with Dosan DL 250and 5900kg for CAT972M with comparing with Volvo L120E.

Table 2 Analysis of technical parameters of wheel loader

Original machine		New machine	
Wheel loader	Dosan DL 250	**Wheel loader**	CAT 966M
Operating weight	14 000kg	**Operating weight**	23 200kg
Spoon volume	2.5m^3	**Spoon volume**	4.4m^3
Wheel loader	Volvo L 120E	**Wheel loader**	CAT 972M
Operating weight	19 000kg	**Operating weight**	24 900kg
Spoon volume	3.3m^3	**Spoon volume**	4.8m^3

Source: (own source – research)

Spoon volume is higer on 1.9 m³ for CAT 966M in comparing with Dosan DL250 and Spoon volume is higer on 1.5 m³ for CAT972M with comparing with Volvo L120E.More powerful wheel loaders had to be evaluated based on the volume of the bucket and the number of lorry. The following facts were found when comparing old and new wheel loaders (Table 3).

Table 3 Analysis of wheel loader

Wheel loader	Spoon volume	Number of lorry (24 ton)
Dosan DL 250	4.00	**6.00**
Volvo L 120E	5.28	**4.55**
CAT 966M	7.04	**3.41**
CAT 972M	7.68	**3.13**

Source: (own source – research)

The results of the wheel loader optimization show that the new CAT972M wheel loader is able to load a truck almost twice as fast as the Dosan DL 250 wheel loader, as the volume of its bucket is almost twice as large. As part of the optimization of the machinery in the mining company, it was necessary to purchase more powerful tracked excavators (Figure 7) with greater weight and the associated possibility of a larger volume of bucket used, which allows you to use the capacity of production facilities to the maximum and reduce the time required to ship processed raw materials.

Figure 7 Tracked excavator in Machine Park in mining company (own source)

The function of the tracked excavator is to load the excavated rock into a mobile crusher. We analyse the technical parameters (Table 4) of tracked excavators in a mining company. We can see a comparison of original and new crawler excavators. More powerful crawler excavators will ensure continuous production due to the constant utilization of crushers and shorten the interval of moving blasted rock from the floor to the crushing site.

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Table 4 Analysis technical parameters of tracked excavator (own source – research)

Original machine		New machine	
Tracked excavator	Dosan DX 225	**Tracked excavator**	CAT 329E
Operating weight	23 600kg	**Operating weight**	30 500kg
Spoon volume	1.7m^3	**Spoon volume**	1.8m^3
Tracked excavator	Volvo EC290CNL	**Tracked excavator**	CAT 336F
Operating weight	31 000kg	**Operating weight**	27 200kg
Spoon volume	1.7m^3	**Spoon volume**	2.2m^3
Original machine		New machine	
Tracked excavator	Dosan DX 225	**Tracked excavator**	CAT 329E
Operating weight	23 600kg	**Operating weight**	30 500kg
Spoon volume	1.7m^3	**Spoon volume**	1.8m^3
Tracked excavator	Volvo EC290CNL	**Tracked excavator**	CAT 336F
Operating weight	31 000kg	**Operating weight**	27 200kg
Spoon volume	1.7m^3	**Spoon volume**	2.2m^3

Source: (own source – research)

The technical parameters of the new tracked excavators are reflected in the operating weight and spoon volume. Operating weight for CAT 329E is higher on 6900kg to Dosan DX225 and Spoon volume is bigger 0,1 m^3 for CAT 329E. Operating weight for CAT 336F is lower on 3800kg to Volvo EC290CNL and Spoon volume is bigger 0,5 m^3 for CAT 336F.

5 Discussion

The framework of the mining machine park and assess the technical level of the machines used affects the dynamics of volume of the extraction [10]. Very important part of the machine park is the technological safety of mining equipment. Dogan, Derya (2021) comment the technical and economical style makes it possible to determine the optimal structure of the mining equipments park, as well as to modernize the technology of the production process of extraction and to form appropriate mobile sets of machines for the extraction [11]. Mining organizations need to use different kinds of techniques and tools in order to fulfill their foundation goals of the mining process. In this aspect, using machine learning (ML) could be very helpful for dealing with challenges in mining. The parts of this machine learning technics created i.e., clustering, classification, regression, correlation, algorithms - i.e., support vector machine, neural network, learning types i.e., ensemble learning, deep learning, and performance metrics i.e., accuracy, mean absolute error which are connected with risk management [11].

Risk management in mining companies is an important part of quality management orientated to maintenance and creates the view for the use of lean management in the area of the machines park [12]. Recent developments in smart mining technology have enabled the production, collection, and sharing of a large amount of data in real time. Therefore, research employing machine learning (ML) is very efecive . Among the ML models, support vector machine was utilized the most, followed by deep learning models. The ML models were evaluated mostly in terms of their root mean square error and coefficient of determination [11,13]. In mining machine park is important to use new technologies. Currently, the global mining industry is seeing a growing interest in battery-powered electric machines, which are replacing solutions powered by internal combustion engines. Both machines were specially designed to substitute diesel machines in the conditions of an ore mine. They are the lowest underground battery-powered drilling and bolting rigs with onboard chargers. The machines can also be charged by external fast battery chargers [14]. Modern theories that make up the paradigm of sustainable development, and the best practices derived from them, are based on the consistency of individual and public needs, factors of economic growth and ecosystem protection [15]. Green economy expansion is moving from a challenge facing modern society to the dominant area of scientific thinking, which is increasingly focused on solving the problems of reducing the anthropogenic impact on the environment consist by mining activities. It is very important fact for mining companies to create machine park with machines focus on environmental sustainability [16]. The need to optimize the machinery in the selected mining company and the purchase of new equipment arose due to an increase in demand from the steel and construction industries to cover all orders from customers.
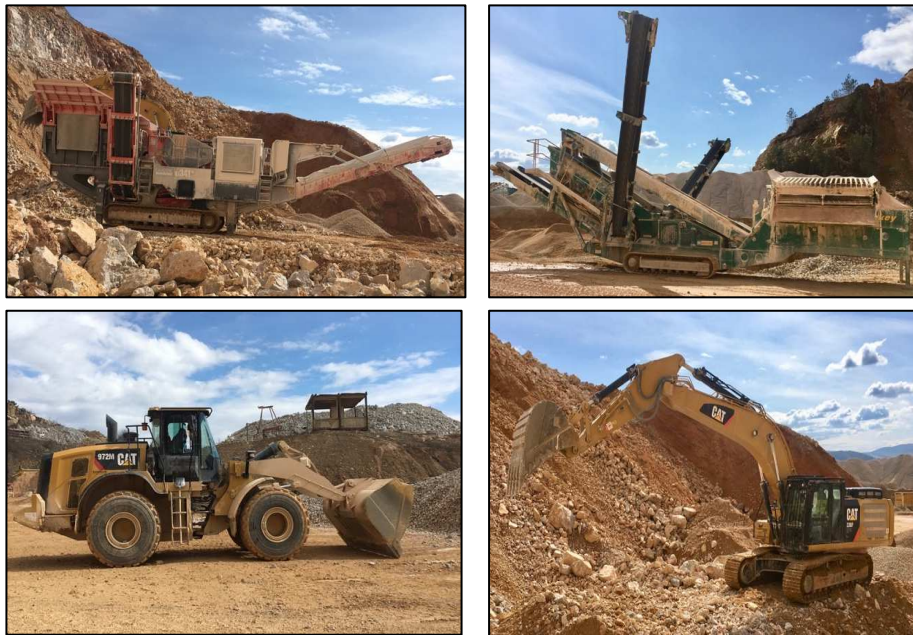
Figure 8 New Machine Park in mining company (own source)

The first step in the optimization process was the decision to combine stationary and mobile equipment in the mining process. Mobile equipment with the ability to move in the mining area will save time and power for the processes of crushing the raw material and its sorting. Mobile crushers and screens purchased by the mining company for flexibility and simplification of the production process are used and bring benefits to the crushing and sorting processes. The mobile crusher and mobile sorter is able to deliver directly to the excavated rock, which represents flexibility and operability. As part of the optimization of the machine park, wheel loaders and tracked excavators with better technical parameters were also replaced, which was reflected in the productivity of the mining process. The first alternative (Figure 8) for machine park in mining company is combination of machines: Mobil crusher Sandvik QJ341+, Mobile sorter McCloskey S130, Wheel loader CAT 972 M and tracked excavator CAT 336F. The second alternative (Figure 9) for machine park in mining company is combination of machines: Mobil crusher Hartl 12/65J, Mobile sorter Anaconda SR514, Wheel loader CAT 966 M and tracked excavator CAT 329E.
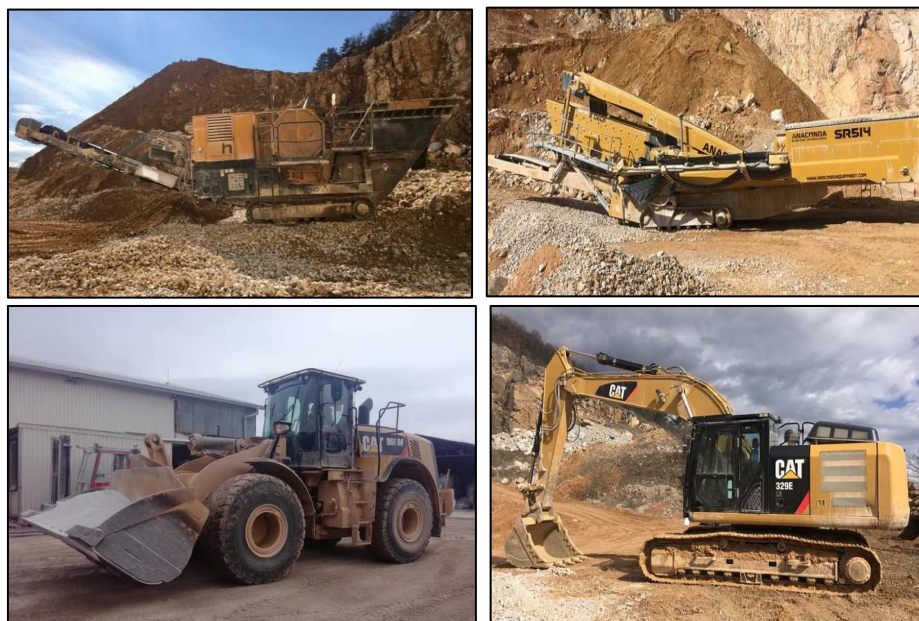

Figure 9 New Machine Park in mining company (own source)

The flexibility of handling mobile devices significantly facilitates the transfer of equipment and preparation for the processing process (crushing and sorting), which significantly increases the overall productivity. The property of flexibility is very important for a company in today's competitive market, the company needs to be able to respond quickly to market demands and produce a sufficient quantity of the required quality [17].

6   Conclusions

The necessary to optimize the machinery in the mining company and the purchase of new equipment arose due to an increase in demand from the steel and construction industries to cover all orders from customers. The first step in the optimization process was the decision to combine immobile and active equipments in the mining process that can be substituation in the mining space and in the mining processes. The main goal of this research and article was to point out the innovative approach in the creation of machine park in the mining company with the aim of increasing the reliability, safety, failures, and efficiency of mining equipment. The paper presents the results point to significant improvements in the machine park of mining equpments. Results of analysis were suggesting two alternatives of composition of machine park for selected mining company with Mobil crusher Sandvik QJ341+, Mobile sorter McCloskey S130, Wheel loader CAT 972 M and tracked excavator CAT 336F and second alternative Mobil crusher Hartl 12/65J, Mobile sorter Anaconda SR514, Wheel loader CAT 966 M and tracked excavator CAT 329E. Mobile crushers and screens purchased by the mining company for flexibility and simplification of the production process are used and bring benefits to the crushing and sorting processes. As part of the optimization of the Machine Park, wheel loaders and tracked excavators with better technical parameters were also replaced, which was reflected in the productivity of the mining process. The results of two alternative of machine park of mining equipments in mining company is the strategy of machine park for the future for many other mining companies.

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