GeoScience Engineering

FACTORS INFLUENCING THE ECONOMIC RESULTS OF QUARRIES

Jakub PITŘÍK

VSB – Technical University of Ostrava, Faculty of Mining and Geology,
Department of Economics and Control Systems, Ostrava, Czech Republic
E-mail: jakub.pitrik@vsb.cz

ABSTRACT

Human prosperity is closely linked to the availability of raw material resources, among other things. Despite enormous technological progress, we cannot dispense with mineral extraction. Since the mining industry still represents a key sector for society, striving for keeping abreast of the best practices, technologies, and knowledge available in the field is crucial. Benchmarking can serve this purpose, as it is already widely used in other industries. However, the question arises of what specific benchmarks are key for this field. The aim of this paper is, therefore, to highlight critical benchmarks relevant to monitoring and evaluating mining capacities. These have been identified by analysing the financial performance of specific mining operations.

Keywords: Benchmarking; Discriminant analysis, Financial result; Quarrying.

1 INTRODUCTION

Despite a number of specifics typical for mining activities, mineral extraction represents a classic business process. In terms of the definition of the entrepreneurial process, some characteristics link entrepreneurship to the pursuit of positive change in the world around us [1]. However, the vast majority of interpretations are associated with economic gain [2,3]. Definitions also include concepts such as value creation, wealth, return, reward, and profit related to the production of goods or services in particular projects. The financial evaluation of projects focuses on the commercial environment in which the objective is to invest in a project in such a way that, when completed, it will produce values that return the investment made and also produce resources that can be used to develop the firm further [4]. One of the methods that can help a company in its development is benchmarking. Benchmarking is understood to be a tool that has been successfully used since the 1970s. Since then, this method has spread not only to the field of product design and production, computer technology, and electronics but also to the field of industry or services offered, and nowadays, it is one of the key instruments of the top and middle management of many companies in almost all sectors [5].

However, when benchmarking mining companies, it is necessary to consider mineral extraction is a complicated and broad issue.

The management of mining companies cannot influence the natural conditions of the deposit that can significantly affect their profits [6]. We also encounter many other variables when comparing different sites. Currently, the number of mining companies operating in the Czech Republic amounts to 206 (2020). In total, more than 12 types of minerals are mined domestically. These are, in particular, construction raw materials, limestone, kaolin, gypsum, oil, natural gas, hard coal, lignite, etc. [7]. Each deposit is specific in its own way and is characterized by unique geological conditions or stockpiles. This logically defines the extraction methods and technologies used, which may also be different. In addition, the mineral resource mined within a given deposit determines how profitable the deposit will be. Political decisions, environmental protection, the state of the economy, and other external factors also affect the extraction and sales of raw materials. These can have a real impact on the quantity of production and the price of the mineral on the market. For example, although mineral extraction is crucial for the energy sector, it must meet the requirements of the free market [8]. Another fact making it difficult to compare mining companies with each other is their size. There are deposits whose mining rights are owned by multi-national concerns but also by private individuals. Although Hakim and Naelufar [9], in their five-year study on the enterprise size effect on company profits, concluded that company size does not always have a decisive influence on profits, individual mining sites can be affected by this factor. Particularly in the case of large concerns, the portfolio may include loss-making sites which they, nevertheless, want to keep (the reason for subsidising a loss-making site may be, for example, the desire to produce a certain range or quality, the strategic importance of the raw material for the future, etc.). A number of sites, therefore, operate with negative financial results for a long time. Its pros and cons are discussed by Gardner [10] who points out that deficit management is quite common within national governments, for example, and in some cases, we can see this phenomenon even in very successful companies. Thus, these facts may also affect the comparison of individual deposits and their profits. It can, subsequently, be concluded that the issue of benchmarking mining companies against each other is made particularly difficult by the great diversity of mining options, methods, and technology. Hence, in the context of benchmarking mining companies, it is crucial to identify which specific benchmarks among the vast number of variables are suitable for comprehensive monitoring and comparison and which would determine whether a given mining capacity will generate profit or loss. Financial performance is particularly useful to track and compare because it has a direct impact on the survival of the company [11].

2 ANALYSIS PROCEDURE

1. Firstly, it is necessary to define hypotheses. The first hypothesis: There are some factors suitable for complex monitoring and comparison of mining companies. The second hypothesis: These factors are statistically verifiable.
2. Secondly, a database of 52 quarries with uniformly stated accounting for the period of 2017–2019 was created (this period was chosen due to stable economic conditions). Euro was used as a currency unit in all monitored operations.
3. The results of operations, determined as the difference between all revenues and expenses in each operation, were ranked in ascending order. They were then sorted into 4 quartiles. The bottom quartile Q1 contained financial results ranging from EUR 3 347/year to EUR 31 943/year. The upper quartile Q4 contained results ranging from EUR 226 069/year to EUR 1 337 687/year.
4. The reported indicators were taken from the accounting and statistical data of the individual quarries, from which the average values were then calculated for comparison of the two quartiles, both in absolute and relative terms. The profit and loss and the change in inventories were compared in absolute terms, while the individual indicators in the field of revenue and costs were measured in relative terms, as absolute values are not meaningful here, given the different production of the individual quarries.
5. The next step in the procedure was to determine the statistically significant differences between the values of indicators of the quartiles Q1 and Q4 shown in Table 1, by testing the statistical significance of the differences in the average values of Q1 and Q4 contained in Table 1. The proportions of raw materials extracted in the Q1 and Q4 quarry mix and the prices of each raw material are shown in Graphs 1 to 4.

Table 1. *Average indicator values in quartiles Q1 and Q4*

Indicator	Q1	Q4
Financial performance (EUR)	9 757	724 634
Mining (t)	91 202	534 865
Revenue per product (EUR/tonne)	6.09	6.26
Total sales (EUR/tonne)	7.00	7.12
Change in inventories (EUR)	3 546	–23 574
Drilling and blasting (EUR/t)	0.85	0.62
Diesel, lubricants, oils (EUR/tonne)	0.34	0.25
Electricity (EUR/tonne)	0.17	0.29

Repairs (EUR/tonne)	0.40	0.56
Subcontractor cost (EUR/tonne)	0.27	0.90
Labour cost (EUR/tonne)	0.91	0.62
Wages (EUR/tonne)	0,21	0.14
Services (EUR/tonne)	0.51	0.26
Overhead (EUR/tonne)	0.40	0.36
Machinery cost (EUR/tonne)	0.60	1.85
Property cost (EUR/tonne)	0.11	0.21
Other costs (EUR/tonne)	0.06	0.10
Overburden (EUR/t)	0.05	0.00
Winter repair fund (EUR/tonne)	0.01	–0.02
Deposit variable (EUR/tonne)	0.01	0.10
Insurance, taxes (EUR/tonne)	0.06	0.13
Material tests (EUR/t)	0.10	0.06
Reclamation fund (EUR/tonne)	–0.01	0.03
Deposit fixed (EUR/tonne)	0.01	0.10
Share of product sales in total sales	0.905	0.922

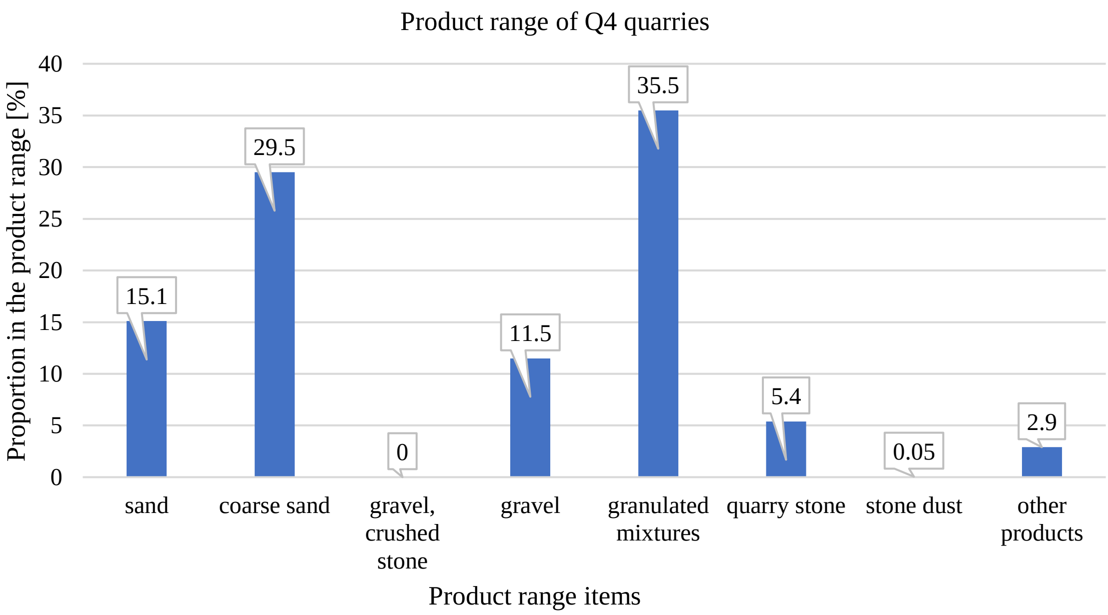

Figure 1. *Product range of Q4 quarries*

Vol. 69 (2023), No. 1
pp. 46–55, ISSN 1802-5420
DOI 10.35180/gse-2023-0088

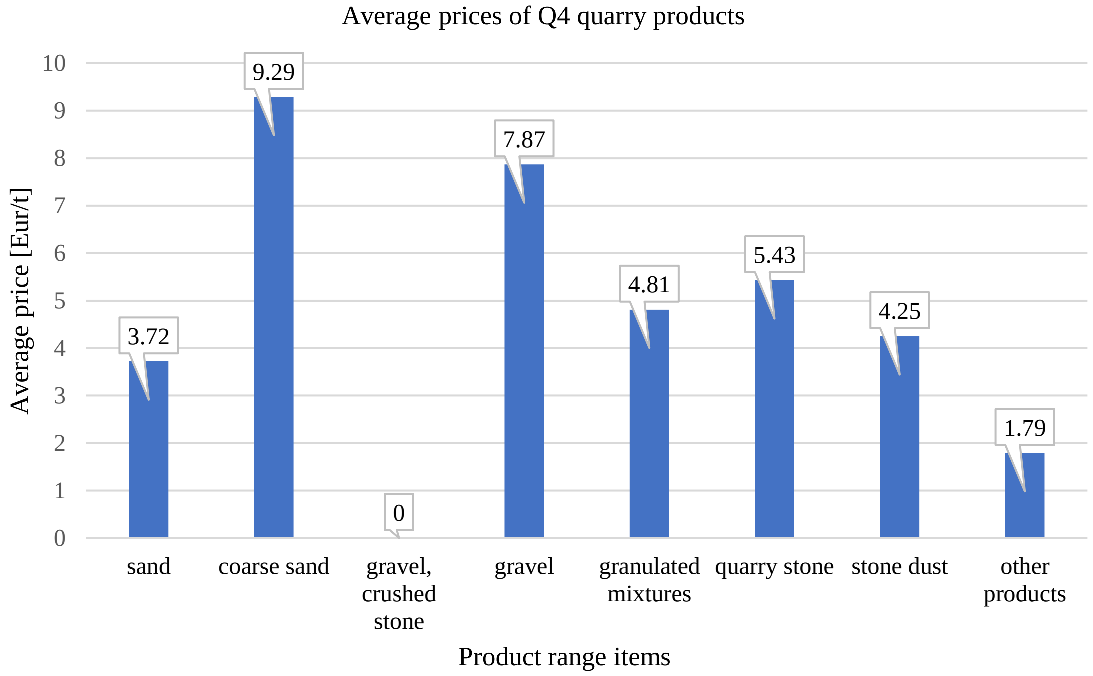

Figure 2. *Average prices of Q4 products*

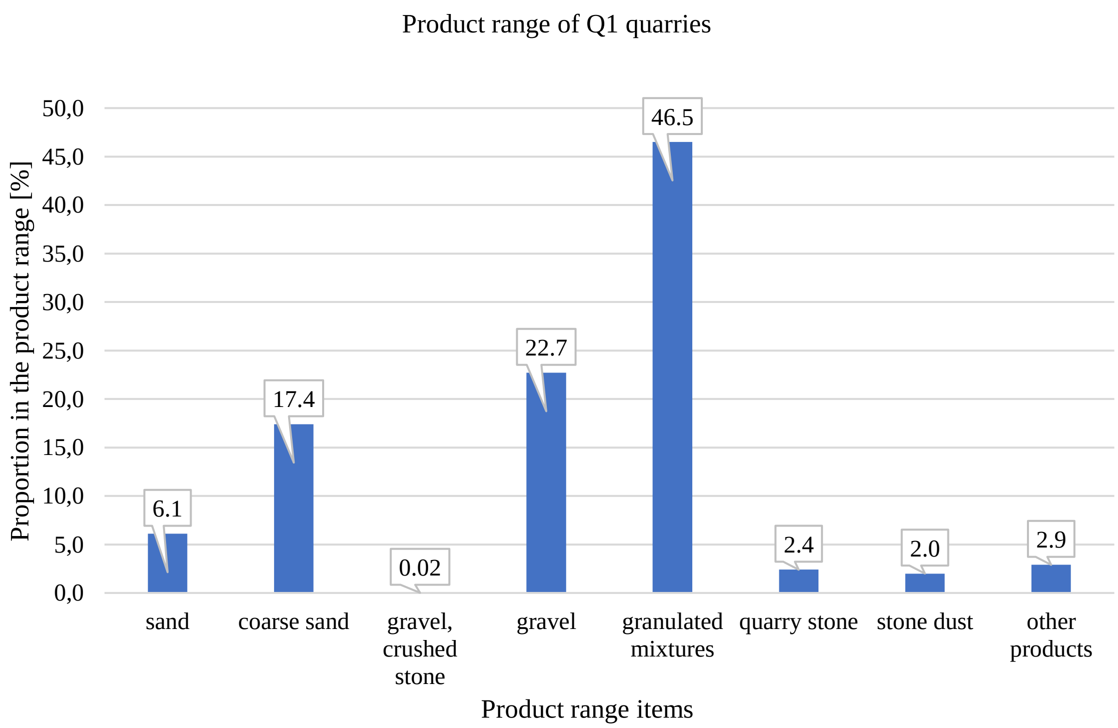

Figure 3. *Product range of Q1 quarries*

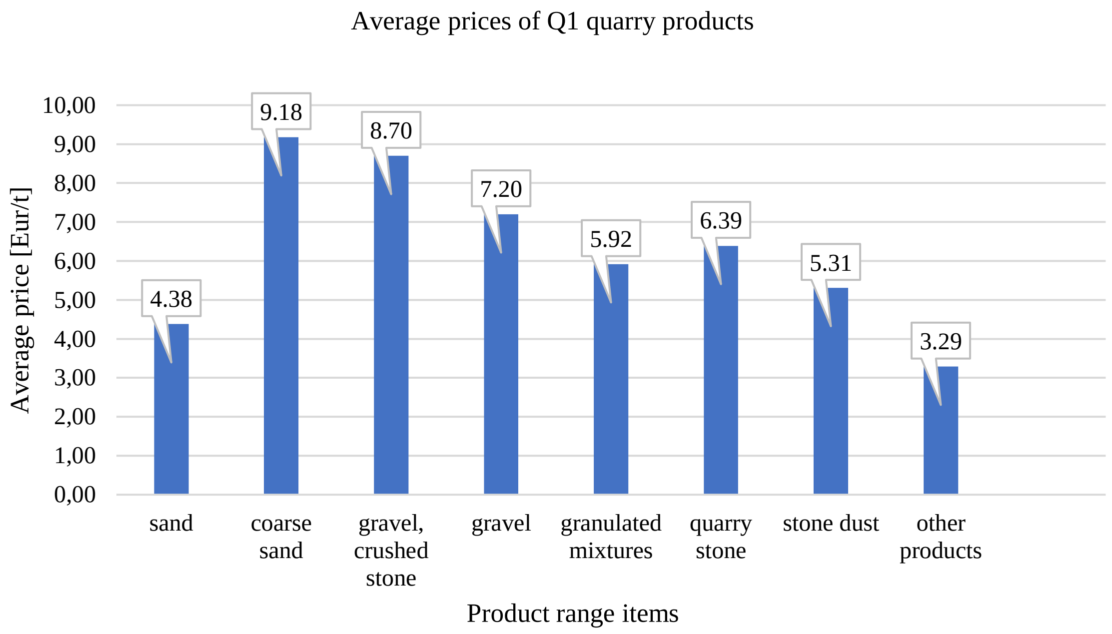

Figure 3. *Average prices of Q1 quarry products*

In conclusion, the following items can be considered as indicators showing statistically significant differences between the quarries included in quartiles Q1 and Q4:

1. sales of granulated mixtures per 1 tonne of production
2. machinery cost per 1 tonne of production
3. drilling and blasting costs per 1 tonne of production
4. subcontractor cost per 1 tonne of production
5. electricity cost per 1 tonne of production
6. cost of diesel, lubricants, and oils per 1 tonne of production

Unit costs and unit prices are included in Table 2 below.

Table 2. *Average values in Q1 and Q4 source*

Indicator	**Average value in Q1**	**Average value in Q4**
price of granulated mixture/t	5.92	4.81
machinery cost/t	1.72	0.60
drilling and blasting/t	0.84	0.63
subcontractor cost/t	0.25	0.83
electricity cost/t	0.15	0.29
cost of diesel, lubricants, and oils/t	0.33	0.24

Based on these indicators, the quarries were divided into two groups, namely quarries with poor and strong financial performance. For this purpose, a discriminant analysis was applied. The procedure for conducting the discriminant analysis is given by Hindls [12]. Ramayah [13] also provides an illustrated procedure on this issue.

A linear discriminant analysis was applied to the set of quarries in order to divide them into two groups according to the result of the financial performance. Each quarry was characterized using the ratios from Table 3. The different classes were denoted as Q1 and Q4, whereby:

- Class Q1: quarries with a financial result less than or equal to the lower quartile.
- Class Q4: quarries with a financial result greater than or equal to the upper quartile.

In order to divide these groups, it was necessary to find a linear discriminant function by which the fractures could be sorted.

The classification of individual fractures into groups Q4 and Q1 is based on the value of the linear discriminant function of the particular fracture. If this value is greater than C, the fracture can be assigned to group Q4. If the value of the linear discriminant function is less than C, the fracture is assigned to group Q1.

In the case of the analysed company, there were 13 quarries in each Q1 and Q4 class. The value of the optimum threshold point was determined as C=–5.322.

Considering the value of the optimal threshold point, the value of the linear discriminant function must be greater than –5.322 for a particular quarry to be classified in class Q4 (i.e., with the highest values of the financial performance). For this level to be transformed, considering specific coefficients, the linear discriminant function must be:

- as low as possible:
  - values of drilling and blasting costs per tonne,
  - machinery cost per tonne,
  - subcontractor cost per tonne,
  - cost of diesel, lubricants, and oils per tonne.

Since the coefficients of the linear discriminant function for these ratios are negative and reduce the value of the discriminant function, to be classified as Q4 they must also be:

- as high as possible:
  - price values per tonne of granulated mixtures,
  - values of electricity cost per tonne as the coefficients of the linear discriminant function for these ratios are positive and increase the value of the linear discriminant function.

However, this consideration was purely mathematical.

2.1 Discriminant analysis results

The set of quarries showing the best financial results (Q4) and, at the same time, the quarries with the worst (but positive) results (Q1) was combined and divided into two groups according to the amount of financial performance. These groups were again labelled Q1 and Q4. The variables mentioned above were used as proportional indicators characterising the individual quarries, i.e., discriminators:

- X_1 – average drilling and blasting costs per tonne of production,
- X_2 – average machinery cost per tonne of production,
- X_3 – average price of 1 tonne of granulated mixtures,
- X_4 – average subcontractor cost per tonne of production,
- X_5 – average cost of electricity per tonne of production,
- X_6 – average cost of diesel, lubricants, and oils per tonne of production.

The result comparison of the quarries division and the original two sets led to the following outcomes in terms of inclusion success:

Table 3. *Successful and failed classification*

Group of quarries	Successful classification	Failed classification
Q1	84.62 %	15.38 %
Q4	92.31 %	7.69 %

Vol. 69 (2023), No. 1
pp. 46–55, ISSN 1802-5420
DOI 10.35180/gse-2023-0088

Table 3 shows that the success rate of the quarries classification in terms of the achieved financial outcomes ranged from approximately 85 to 92 %. It can therefore be concluded that the six discriminators can be used to classify quarries regarding the accomplished financial result values. Based on this fact, it can be concluded that the first and second hypotheses can be verified.

2.2 Quarry sorting parameters

The analysed company owns a number of quarries which are classified based on their financial performance, production capacity, equipment, and real production levels into categories 1, 2, 3, and 4. The quarries in category 1 are considered the 'carrier' quarries of the mining company, category 2 performs worse, and category 3 shows the worst financial performance and is also the least important for the analysed company. Category 4 comprises temporarily idle quarries.

Category 1 includes the largest quarries with sufficient reserves, no conflicts of interest to be resolved, quarries with quality extracted rock in terms of technological parameters and usability, and a stationary technology powered by electricity. They are not located close to settlements that would limit the extent of blasting or lead to the need for dust disposal and have accessible transport infrastructure. In many cases, they have the advantage of close proximity to large-scale developments (e.g., transport infrastructure), which stabilises larger supplies of mined material for longer periods.

Category 3 contains small quarries with lower production, employing usually obsolete portable diesel-powered production lines. They are closer to population centres, which limits both the scale of blasting and the transportation options determined by the EIA (Environmental Impact Assessment). The sales do not cover the full range of the product portfolio, are directed to shorter distances, and do not have the advantage of large developments in close proximity. It often produces granular mixtures of 0–63 mm, where the quality requirements are not high, and which large quarries dispose of even at below cost in order to free up stock areas and not to have to store them.

In this context, the question arises as to why the analysed company holds category 3 quarries in its portfolio:

- With the current attitude of the public, activists, and environmental authorities, it is extremely difficult to expand mining capacity, let alone open a completely new mining operation that could be included in a more profitable category and be more cost-effective, easier, and more profitable to operate.

Classification is not permanent and, in some respects, a change in external conditions may cause a quarry to be reclassified, depending on the narrow profiles of the quarry. The bottlenecks that limit the size of the quarry, its production, and sales can be categorised as follows:

- Mining: inventory, quality, storage, the volume of the overburden
- Production: type of process line, its age, location (position)
- Sales: demand in proximity, presence of large buildings
- Economic: selling prices, costs

The respective limitation then determines the size of sales, production, and financial performance. In many cases, the bottleneck results from natural conditions and is invariable. Sales and financial factors may change over time and thus contribute to a shift to category 1 (e.g., higher sales when a major construction project is started in proximity to the quarry), but also vice versa (lower sales due to the completion of a major construction project, lower sales due to lower production caused by a lack of inventory of the extracted raw material).

From this point of view, we can then evaluate the ratios (discriminants) which showed statistically significant differences in their mean values in the Q1 and Q4 groups:

Average drilling and blasting costs per tonne: smaller quarries (Q1 category) report higher fixed costs associated with the transport and installation of drilling and blasting equipment, as these activities have to be carried out more frequently due to the permitted extent of blasting (proximity to the village). Secondary disconnection often has to be implemented. The lower production then increases the proportion of fixed costs per tonne of production.

Average cost of machinery per tonne: this is mainly depreciation in the form of internal leases for machinery and an interest rate of half the cost of the machine over the depreciation calculation period. These are therefore fixed costs which, when divided by the low production volume, lead to higher quarry values in the Q1 category compared to the Q4 group.

Average price per 1 tonne of granulated mixtures: product portfolio includes:

- fine aggregates: the most suitable product, includes the 4/8 fraction (aggregate grains from 4 to 8 mm), the 8/11; 8/16; 2/4; 11/22;11/16 fractions, up to 4 mm so-called sand, above 4 mm coarse sand. Fine aggregates require the most stringent quality measures.
- aggregate mixtures: comprise grains from 0 to a certain limit, e.g., 32 or 63 mm, used as material for road bodies, embankments, etc. Granulated mixtures 0/63 present lower quality requirements, produced by quarries in category Q1.
- railway sands and gravels: these are fractions 16/32 and 32/63 with higher quality requirements
- other products: e.g., quarry stone for strengthening riverbeds, building gabion walls, etc.

Granular mixes are often produced from overburden by quarries in the Q4 group, usually in large volumes. They take up storage space, and quarries try to sell them at or even below cost to gain access to the higher-quality parts of the deposit. They do not pose such a problem for the smaller quarries in the Q4 group, thus achieving higher prices.

Average cost per subcontractor: this is the cost of elementary technological transport and quarry cleaning. Costs associated with drilling and blasting are shown separately. Some of the subcontractor costs are fixed (transport, overheads).

Average electricity costs per tonne: linked to the propulsion of the stationary process lines that are installed at the quarries in the Q4 group.

Average cost of diesel, lubricants, and oils per tonne: related to the propulsion of the portable process lines installed at the quarries in the Q1 group.

2.3 Discriminant analysis conclusion

Benchmarking should basically show what goal a particular company should accomplish to move from its position toward the best in the industry. In this case, the question can be asked what result a specific quarry should achieve to move from the Q1 to the Q4 group. From a purely mathematical point of view, placing a quarry in a higher group requires raising the value of the discriminant function above the optimal threshold. With respect to the linear discriminant function equation, this means that the discriminator values of the coefficients with a positive sign should be maximized and the discriminator values of the coefficients with a negative sign minimized to increase the value of the linear discriminant function of a particular mining operation. This means that to transfer the quarry from Q1 upwards, the values of the discriminators should be changed as follows:

- Reduce:
    - Unit drilling and blasting costs
    - Unit machinery cost
    - Unit subcontractor cost
    - Unit costs of diesel, lubricants, and oils
- Increase:
    - Price per unit of granulated mixtures
    - Unit electricity cost

Approaching this material requirement from a substantive point of view, we can state:

- The unit drilling and blasting costs can be reduced by increased production to dissolve the fixed costs associated with drilling and blasting.
- The unit machinery cost can only be decreased by a production add-on to dissolve these fixed costs.
- The unit subcontractor cost can be cut down by increased production to dissolve fixed cost items.

- In general, the costs of diesel, lubricants, and oils cannot be reduced as they present variable costs associated with portable process lines. Converting to stationary electrically driven process lines would increase the cost of machinery dramatically.
- It is very difficult to increase the prices of granulated mixtures because it is an oversupplied and not very high-quality product.
- The unit electricity cost also cannot be substantially reduced, as it is not possible to replace the diesel-powered portable lines with the stationary electricity lines that are at the Q4 quarries.

From a substantive point of view, the quarries in the Q1 group have a narrow sales profile – an increase in demand and a corresponding increase in production. However, a quarry can barely influence this external factor. The quarry can rather monitor construction intentions around a particular site and ensure a supply that will lead to an increase in production. Nevertheless, one must also assume that the constraints of the EIA (Environmental Impact Assessment) and local government will be resolved. The mix of very successful, average, and unsuccessful quarries will therefore remain in the future, although possible shifts between groups and categories can be envisaged.

CONCLUSION

The paper identifies benchmarks that are suitable for the comprehensive monitoring and evaluation of mining companies with respect to their financial performance. For this purpose, a discriminant analysis (using data provided by an anonymised mining company) was conducted and evaluated. The analysis shows that the key benchmarks for this field comprise unit drilling and blasting costs, unit machinery cost, unit subcontractor cost, unit costs of diesel, lubricants, and oils, unit costs of granulated mixtures, and unit electricity costs. At the same time, it was found that the mining operations that performed better had lower unit drilling and blasting costs, unit machinery cost, unit subcontractor cost, unit costs of diesel, lubricants, and oils, and, conversely, higher unit costs of granulated mixtures and unit electricity costs. Thus, the study shows that a quarry with strong financial performance exhibits the following features. Given the complexity of the issue of benchmarking mining companies, it is not possible to derive a single recommendation that can ensure quarry success, as many factors cannot be controlled. These are mainly the natural parameters of the deposit, the market price of the extracted raw material, the inventory size, transport infrastructure, etc. It is also impossible to define exactly what value should be given to the benchmark specified in the analysis as crucial, because each quarry is different, their comparison is too complicated, and any recommended value would, therefore, only be suitable for an extremely small group of quarries with exactly same conditions (which is unthinkable in practice). Nevertheless, it is feasible to determine whether to increase or decrease the aforementioned benchmarks.

REFERENCES

[1] VILLACI, J. What is the Definition of Entrepreneurship? *Babson Thought & Action* [online]. Norfolk MA, Babson College, August 29, 2019 [acc. 2022-3-3]. Available at: https://entrepreneurship.babson.edu/entrepreneurship-definition

[2] Definition of Entrepreneurship by Different Authors. *Expertpreviews* [online]. [acc. 2022-1-4]. Available at: http://expertpreviews.com/definition-of-entrepreneurship-by-different-authors/

[3] Entepreneurship. In: *UK English Dictionary* [online]. [acc. 2022-2-3]. Available at: https://www.lexico.com/definition/entrepreneurship

[4] RYBÁR, P., M. CEHLÁR and M. TRÉGER. *Oceňovanie ložísk nerastných surovín [Valuation of Mineral Deposits]*. Košice: Štroffek, 2000. ISBN 80-88896-46-0.

[5] NENADÁL, J., D. VYKYDAL and P. HALFAROVÁ. *Benchmarking: mýty a skutečnost [Benchmarking: Myths and Reality]*. Praha: Management Press, 2011. ISBN 978-80-7261-224-6.

[6] ALBAVERA, F.S., G. ORTIZ and N. MOUSSA. Chapter V. Factors underlying the performance of investments in the mining industry. In: *Mining in Latin America in the Late 1990s.* Santiago de Chile: CEPAL/ECLAC, 2001, pp. 43–58. Serie 1: Recursos naturales e infraestructura. ISBN 92-1-121302-9. Available at: https://repositorio.cepal.org/bitstream/handle/11362/6385/1/S0150381_en.pdf

[7] STARÝ, J. et al. *Surovinové zdroje České republiky*. *Nerostné suroviny 2021 [Mineral Commodity Summaries of the Czech Republic 2021]*. Praha: Česká geologická služba, 2021. Available at: http://www.geology.cz/extranet/publikace/online/surovinove-zdroje/surovinove-zdroje-ceske-republiky-2021.pdf

[8] MARUSZEWSKA, E.W., M. VANĚK and Š. VILAMOVÁ. Economic situation of hard coal mining industry in Upper Silesian Coal Basin. *Acta Montanistica Slovaca*. 2014, vol. 19(2), pp. 70–78. ISSN 1335-1788. Available at: http://hdl.handle.net/10084/106685

[9] HAKIM, M.Z. and Y. NAELUFAR. Analysis of profit growth, profitability, capital structure, liquidity and company size of profit quality. *Jurnal Akademi Akuntansi*. 2020, vol. 3(1), pp. 12–35. ISSN 2654-8321. DOI: 10.22219/jaa.v3i1.10348

[10] GARDNER, K. Pros and Cons of a Budget Deficit. *Bizfluent* [online]. 21 Nov 2018 [acc. 2022-1-4]. Available at: https://bizfluent.com/info-7742308-pros-cons-budget-deficit.html

[11] LACY, D. 11 Reasons Why Profit is Essential. *Dynasty Business Growth Coaching and Consulting* [online]. [acc. 2022-6-4]. Available at: https://dynastybusinessconsulting.com/11-reasons-why-profit-is-essential/

[12] HINDLS, R., S. HRONOVÁ and J. SEGER. *Statistika pro ekonomy [Statistics for Economists]*. Praha: Professional Publishing, 2002. ISBN 80-86419-26-6.

[13] RAMAYAH, T., N.H. AHMAD, H.A. HALIM, S.R.M. ZAINAL and M.-C. LO. Discriminant analysis: An illustrated example. *African Journal of Business Management*. 2010, vol. 4(9), pp. 1654–1667. ISSN 1993-8233. Available at: https://academicjournals.org/journal/AJBM/article-full-text-pdf/1BF418E31373

For the purpose of the article, the author processed the internal data of a company that wants to stay in anonymity (due to the confidentiality of the data provided). This company focuses on the extraction of mineral resources in many locations in the Czech Republic.