ЭКОНОМИКА И УПРАВЛЕНИЕ НАРОДНЫМ ХОЗЯЙСТВОМ

УДК 338.012

К ВОПРОСУ ОБ ОЦЕНКЕ ПРОМЫШЛЕННЫХ МЕСТОРОЖДЕНИЙ ПОЛЕЗНЫХ ИСКОПАЕМЫХ

Чехлар М., Рыбар П., Михок Я., Энгел Я.

Технический университет в г. Кошице, Республика Словакия

Информация о статье
Принята 05 февраля 2020 г.

Ключевые слова: оценка месторождений, экономика, инвестиции, добыча полезных ископаемых.

DOI: 10.26730/2587-5574-2020-1-66-74

Аннотация.
В настоящее время значимость добычи минерального сырья во всем мире неуклонно повышается благодаря постоянному росту потребления различных благ как в развитых, так и в развивающихся странах. Быстро наступающая цифровизация современного мира и экспансия Индустрии 4.0 требуют постоянного увеличения добычи энергоносителей, поскольку альтернативные источники энергии не могут покрыть растущие потребности в энергообеспечении современных наций. Рост мегаполисов и соединяющих их объектов инфраструктуры немыслим без увеличения добычи строительных материалов. Все это в совокупности в долгосрочной перспективе повышает ценность месторождений полезных ископаемых и делает инвестиции в их разработку привлекательными. В связи с этим актуальным остается вопрос комплексной оценки месторождений полезных ископаемых при инвестиционном проектировании их разработки с учетом не только экономических, но и геологических, технических, технологических условий.

TO THE ISSUE OF INDUSTRIAL MINERAL DEPOSIT EVALUATION

Michal Cehlár, Pavol Rybár, Ján Mihók, Jacek Engel

Technical University of Kosice, Slovak Republic

Article info
Received February 05, 2020

Keywords:
Keywords: mineral deposit valuation, economics, investments, mining.

Abstract.
Currently, the importance of the extraction of mineral raw materials around the world is steadily increasing, due to the constant increase in the consumption of various goods, both in developed and developing countries. The rapidly advancing digitalization of the modern world and the expansion of Industry 4.0 require a constant increase in power production, since alternative energy sources cannot cover the growing energy needs of modern nations. The growth of megacities and the infrastructure facilities connecting them is unthinkable without an increase in the extraction of building materials. All of this together in the long run increases the value of mineral deposits and makes investments in their development attractive. In this regard, the issue of a comprehensive evaluation of mineral deposits during the projecting of investments in their development remains relevant, taking into account not only economic, but also geological, technical and technological conditions..

1 Introduction

At present mining practice market estimations are used mainly for the purpose of evaluating the security backing of capital loans and the evaluation of non-monetary deposits invested into the basic assets of commercial corporations. The list the following main reasons for mineral deposit evaluation [1]:

- the purchase and sale of a company;
- the increase of fixed assets;
- the entry and exit of partners;
- inheritance procedures and donations;
- the merger and splitting of companies, changes (establishment of a joint-venture, purchase of

a company by its employees, privatisation);

- the taking or increase of a loan, backing the loan;
- the identification of the financial status of suppliers or customers;
- the conclusion of insurance contracts;
- entry into the stock market;
- the detection of excessive indebtedness limits;
- the assessment of a company by its management;
- maintenance measures, liquidation;
- tax purposes (property tax;
- requirements of state administration bodies (defining economic and raw material policy, solving various conflicts of interests, statistic data in the area of national accounts).

2 Position of Mining Studies and Projects in the Process of Deposits Evaluation

Mining studies connect geology with the industrial world technically, economically, financially, and provides suitable information before verifying actual deposit [2-7]. The scheme of connection between geological and mining work in an industrial mineral deposit is shown on Fig. 1.

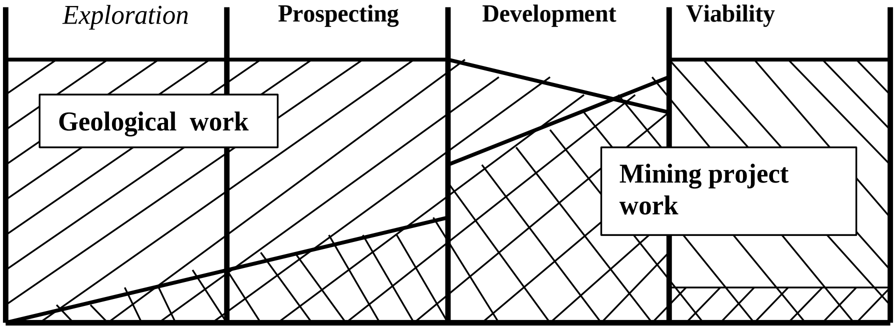

Figure 1. Schematic display of consequences between geological and mining work in an industrial mineral deposit.

The development of a mining project is a multi-disciplinary work that requires the cooperation of many experts including geologists, preparatory workers, miners, metallurgists, environmentalists, economists, lawyers, computer experts, etc. [8-13]. It is obvious that only a big company can afford such a "luxury". Small firms have to do with a three or four-member team of experts.

The development of a mining project is a cyclical work; therefore, it is advantageous to proceed step by step by gradual development of more and more intensive studies, not to invest from the very beginning into costly studies, which might result in the refusal of a project. The sequence of project studies can be as follows (Fig 2.):

1. Initial feasibility study (expert study).
2. Pre-feasibility study.
3. Detailed feasibility study.

The task of an engineer – technician in the development of a mining project is to provide technical advice and information about parameters relating to the final design of mines, mining methods, production costs, reserves, contamination, yield and other variables connected with mining activities. An engineer must provide quantitative data of variables entering the project based on technical analysis [14-16].

The role of an engineer consists in his ability to analyse information which is often not complete and provide quantified data suitable for a subsequent financial analysis.

3 Dynamic Character of the Industrial Mineral Deposit Evaluation by Means of a Mining Project

The evaluation of a deposit and mining project is a continuous process rather than a single act. Changes in budget, evaluation criteria, or in the area of costs and incomes may change results valid up to now and the views on using a deposit. Geological quantities are measurable with the help of geological conclusions and engineering calculations. Raw material reserves and their quality are defined as a substance that can be recovered with profit through current technologies and prices. This definition can result in two misunderstandings:

1. Geological reserves and the quality of raw materials are understood as variables not connected with mining activities. However, the quantity and quality of remaining reserves depends on changes in our geological knowledge, changing economic conditions, as well as on the exhaustion of reserves. The quantity of reserves and value of the cut-off grade depends not only on geological factors but also upon the methods of deposit extraction, costs and prices. Always when any variable shown in Fig. 3 changes, other variables change too, and this fact proves the changeability of reserves and quality of ore in a deposit.

2. Another mistake is connected with the price referring to vast quantities of reserves. For example, in a region, where reserves for 200-year extraction exist under unchanged conditions compared with the current situation it is assumed that if at present one ton is gained for 1.0 USD, and then the price of reserves is 1.0 USD *x* 200 years *x* the quantity of reserves extracted per year. However, today no investor would pay the same price for goods extracted nowadays as for the same goods extracted 200 years hence. This is due to the reason of the time-dependent valuation of money as well as unpredictable technical and technological developments during the future two hundred years.

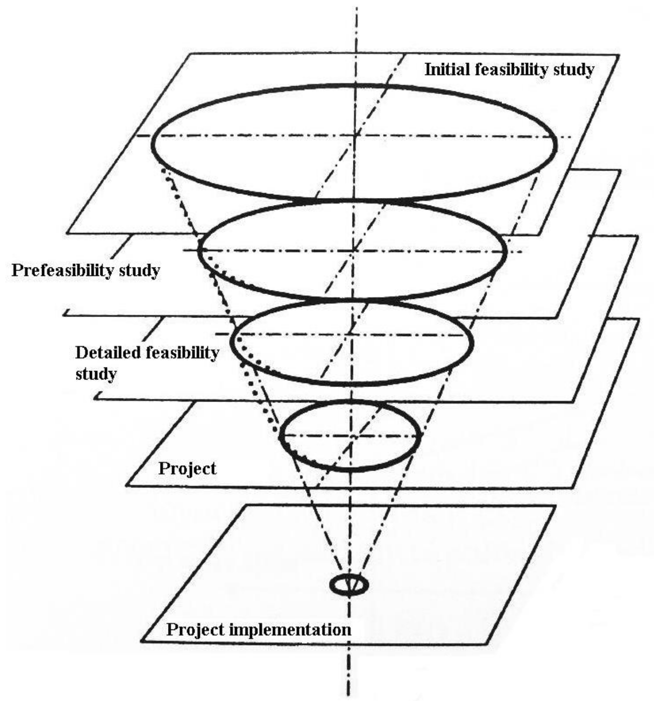

Figure 2. Sequence and goals of individual types of projects and studies.

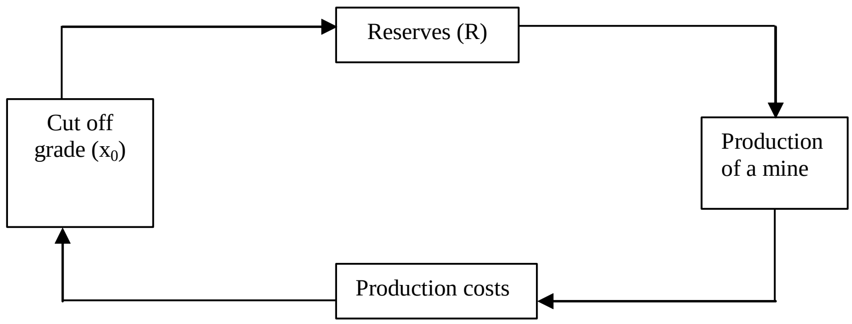

Figure 3. Impact of geological, mining and economic factors on the quantity and quality of reserves remaining for extraction.

ISSN 2587-5574

Evaluation Projects

The use of individual stages of studies in a way given in the following text depends on specific circumstances and amount of investments. Generally, the larger the investment, the more studies developed in detail have to be drafted. For example, a purchase of a small mining property in the neighbourhood of an existing mine can take a few weeks compared with the purchase of great amounts of property that can take up to several years. As shown in Fig. 4 [17], the first step in assessing the project price is to define the long and short-term interests and objectives. It may seem that setting the objectives is not the most necessary thing in the initial stage, however many projects have failed mainly because they did not define explicit criteria and project studies did not assess the project properly. The aims have to be defined in accordance with the possibilities provided by deposit reserves. All planned activities have to reflect the financial possibilities of an investor, management level and political situation in the region. It is obvious that each of the mentioned facts are time dependent.

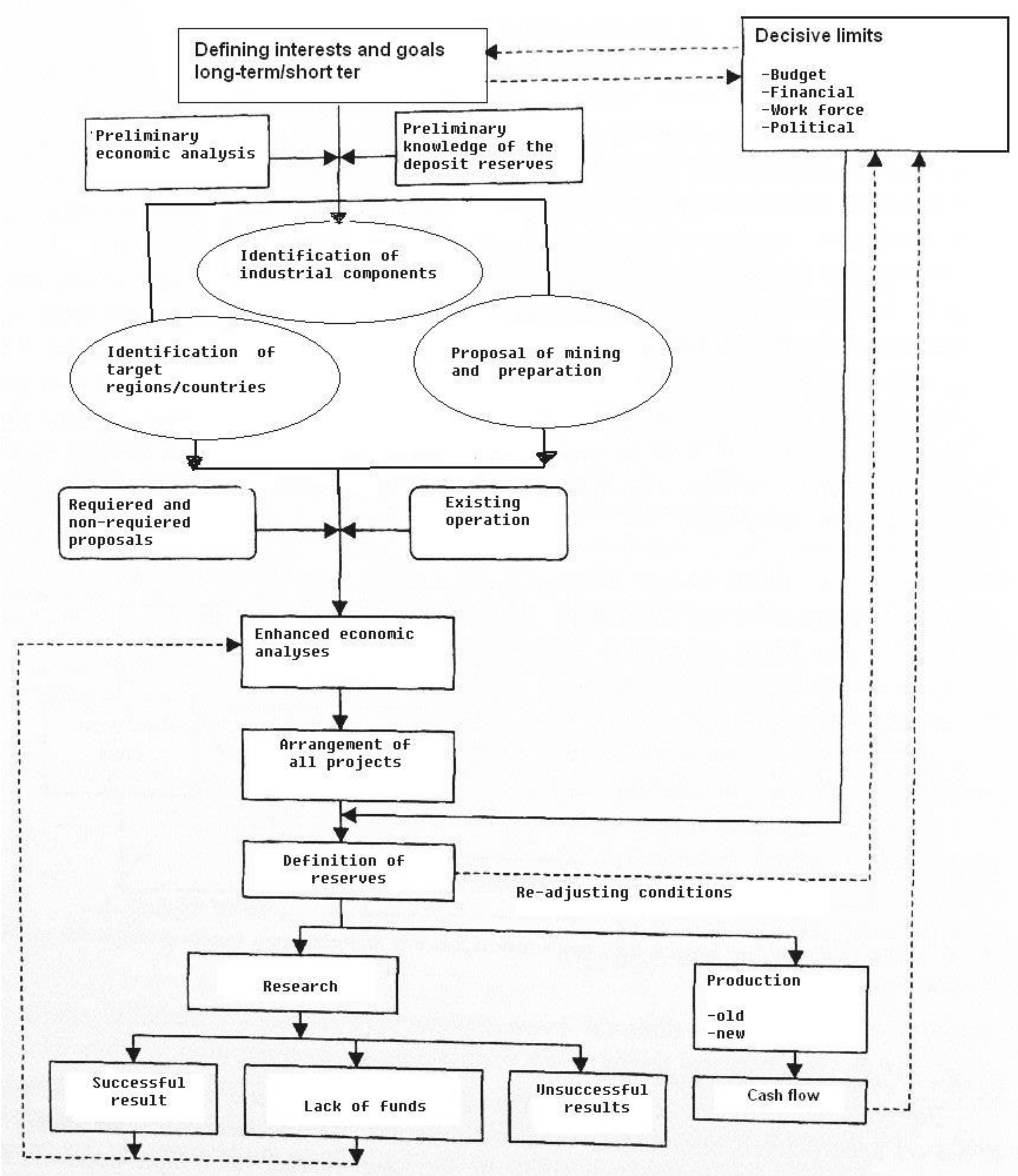

Figure 4. Schematic view of the dynamics of the mining project evaluation and its start up

Initial Feasibility Study - Expert Study

This can also be called a study of early economic diagnostics. In the past it used to be severely neglected, however at present international organizations also require this stage of a mining study. The aim of this kind of study is to:

- shut down uneconomic mining projects as quickly as possible, with the minimum of financial losses;
- provide suitable materials for costlier studies in cases where the process is not finished.

The example is shown in Tab. 1.

Table 1. The example illustrating inputs and outputs of the initial feasibility study (expert study)

Project aspect	Level of knowledge
Deposit	Knowledge gained mainly from geophysical and geochemical survey operations. As for geological work, it is mainly mapping and little drilling work.
Raw material processing	At the level of expertise and advisory service by experts who have experience with a given type of raw material.
Infrastructure	A visit to the site and a hypothetical plan are sufficient
Estimation of income	On the basis of: - market structure, - setting the method of sale, - knowing prices of assumed final products, - current exchange rate of SK and world currencies.
Investment and operational costs	Approximately estimated.
Costs and time	Costs for developing the expert study are approximately 0.01 to 0.1 % from assumed investment costs of a project.
Aim	To proceed at a higher stage of project work or to cease an uneconomic project.

Prefeasibility Study

In cases where the expert study does not result in the cancelling of a mining project, it is advantageous to include an additional stage, the so called prefeasibility study before the detailed feasibility study. Its aim is to end the process in case of uncertain results. However, the development of this study should ensure that the research programme is in harmony with other possible stages of the project studies. Tab. 2 illustrates an example, how a *prefeasibility study* characterizes an individual project's aspects.

Detailed Feasibility Study

In cases where previous stages of studies have not ended the work on a mining project, a development of the feasibility study is started. It has a certain structure and has to define a project in many details. This type of a study is carried out mainly to meet the needs of an investor, and its purpose is to prove the project's economic viability in terms understandable to the investor, while the investor's requirements of how and what should be documented by the study may vary. The feasibility study may also result in the project being suspended due to insufficient economic results which could be achieved should the assumptions stated in the study materialize. Tab. 3 shows the examples of a further continuation of the project on the basis of the previous stages of studies.

ISSN 2587-5574

Table 2. The example illustrating inputs and outputs of the prefeasibility study

Project aspect	Level of knowledge
Deposit	Knowledge gained from 10 – 30 bores and from mining survey operations. A deposit provides the following basic knowledge on: - the morphology of a deposit and distribution of the reserve quality, - approximately defined amount of reserves.
Raw material processing	At the level of laboratory work: - physical and mechanical analysis of raw material, - basic procedures of gaining utility components, - quality of the concentrate, - ideas of processing technology.
Infrastructure	The most needed objects and power supplies are proposed, and the sufficient amount of water resources is documented.
Estimation of income	Income is estimated with an accuracy of plus - minus 20 to 30 %.
Investment and operational costs	Estimated on the basis of the analogy: - investment costs with an accuracy of plus - minus 30 to 50 %, - Operational costs with an accuracy of plus - minus 20 to 30 %.
Costs and time	Costs for the development of an expert study are approximately 0.1 to 1% of the assumed project investment costs.
Aim	To proceed to a higher stage of project work or to end an uneconomical project.

There are many types of methods used to evaluate mining projects. It is partly due to the fact that needs for different types of evaluation vary significantly, and partly because of the use of ethically obsolete and inappropriate methods. However, each project should be evaluated by more than one method.

Evaluation methods can be divided into two general groups:

1. Positive evaluation methods based on measurable factors, such as their economic efficiency, costs and prices, and

2. Normative evaluation methods based more or less on non-measurable factors, such as social values, morality, individual and public opinion.

It must be borne in mind that these two groups exist and it is not suitable to create an unnecessary mix.

Economic efficiency involves the implementation of the aim of minimal costs or gains of the highest profit from a given investment.

Another approach is preferred by governments that along with the economic aspects they have to guard employment, salaries, and state budgeted income both from profits and social contributions, the health status of citizens, environmental and social issues. This approach may even be in contradiction with the purely commercial approach adopted by banks and investors.

Sample Size and Grade – Tonnage Relation in a Deposit

Geologists familiar with only classical mathematical statistics are not aware of the extraordinary effect of the sample size on a distribution of a chemical component in a deposit and on the semivariogram form. Generally, it can be stated that the increase of the sample size that has been an object of a chemical analysis and subsequently a basis for the calculation of reserves leads to an overestimation of the calculated quantity of reserves in a deposit (tonnage) and to an under-estimation of the calculated average value of a chemical component (grade) with regard to the reality.

Geostatistics has a tool to eliminate such impacts of various sample sizes. As results from the stated facts, the failure to consider the effects of mixing up values measured with samples of various sizes, can lead to erroneous conclusions as to the quantity and quality of reserves in a deposit.

Effect of Quantity of Estimated Reserves on a Subsequent Financial Analysis

If a mining company encounters a new project, one of the important requirements is to estimate the quantity of reserves in a deposit and to determine the quantity of mineable reserves by means of the cut-off grade value. The mutual relationship between the grade - tonnage relationship and economic evaluation of a deposit is illustrated by Fig. 5.

Table 3. The example illustrating inputs and outputs of a detailed feasibility study

Project aspect	Level of knowledge
Deposit	Knowledge gained from 30 – 100 bores and from mining survey operations and geotechnical work. A deposit provides the following basic knowledge on: - Deposit morphology, - Distribution of the reserve quality, - Quantity of reserves that is sufficient for the deposit's economic use, - Methods of ore excavation and preliminary design of mining work.
Raw material processing	At the level of semi-operational test results: - methods of finalization, - requirements for the processing plant equipment, - defining final sale products, - defining the preparation recovery ratio plus - minus 10 %.
Infrastructure	Preliminary design.
Estimation of income	Identifying customers for final products, Income is estimated with an accuracy of plus - minus 5 to 10 %.
Investment and operational costs	To estimate the following on the basis of price offers and price lists: - investment costs with an accuracy of plus - minus 20 to 30 %, - operational costs with an accuracy of plus - minus 15 to 20 %.
Costs and time	Costs to develop an expert study are approximately between 1 to 3 % from the assumed project investment costs, The assumed time for the study development is several months.
Aim	- investment decision, - project financing, - project suspension.

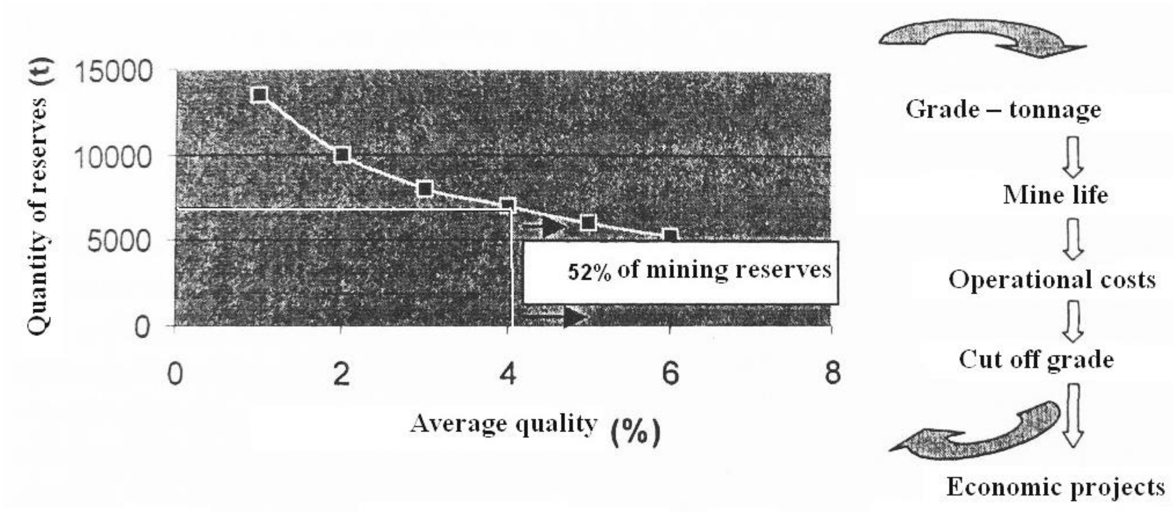

Figure 5. Preliminary economic evaluation of a deposit by means of the grade/tonnage relationship analysis and the definition of economic values of the cut-off grade. (Here 52% of reserves are available for the economical extraction in a deposit).

The time effect influences the mining project more than in the case of other long term investments. Usually it is necessary to estimate prices and costs, and this introduces an element of risk that is bigger than in other investment practices. Many prices connected with the value of mineral raw materials have a cyclical character and problems connected with the estimation of raw material prices represent one of the partial problems in the process of mining project evaluation and planning.

ISSN 2587-5574

The time factor affects mining projects more than projects connected with activities other than mining ones.

1. A long term project requires a sufficient quantity of reserves in a deposit. Reserves represent the amount of raw material that will be mined in the future. The current value of a ton of reserves will be lower in the future than the current *value* of a ton of reserves mined at present.

2. The process of a mining operation's evaluation in the early stage of excavation affects the long term value of operation in a deposit. For example, the initial mining of high quality ore increases the initial profit, but it decreases the average value of the ore remaining in a deposit, thus reducing the lifetime of both the mine and project. Moreover, economic and operational conditions can change unexpectedly during the mine's operational life.

3. It is not possible to know the trajectory of mining of reserves in time and space completely, before the deposit is worked out for two reasons. The first is geological uncertainty. The quantity and quality of reserves are defined on the basis of samples that enable statistical estimates. The second reason is economic uncertainty. The quantity and quality of reserves that have to be mined in a given time period depends on costs relating to the excavation and processing of an industrial mineral, and also on the price of a final product. As future sales prices cannot be set accurately, it is difficult to define the reserves in a deposit, even if they were defined with a higher accuracy rate that is enabled by new estimates of reserves by means of geostatistical methods.

4 Conclusion

It is usually reckoned that the project evaluation and financing is connected mainly with new mining projects, however the majority of decisions refer mainly to changes in existing mining operations. Some types of decisions refer to an industrial mineral deposit itself. Each decision requires a set if information and maybe various interpretations of obtained evaluation results. Some typical investment decisions are:

- not to invest in the intended mining project and invest somewhere else;
- to start a new operation within an existing mining company;
- to maintain, increase or decrease the output of existing mining activities;
- to shut down mining operations either temporarily or permanently;
- to re-open mining operations.

These basic decisions are different from the viewpoint of cost types. For example, initial capital costs are significant only for a decision to open or extend an operation. Maintenance, re-opening and cash operational costs are decisive for a decision on whether or not to shut down or re-launch a facility into operation, etc.

These dynamic aspects of the mining project evaluation cause many problems to designers, engineers and operators. The uncertain character of many inputs hinders planning of such basic parameters as for example an optimum recovery coefficient, the average value of industrial components in a deposit and the cut-off grade.

Список источников / References

1. Seják J., et al. Oceňování pozemku a přírodních zdrojů. Prague: Grada Publishing, 1999. 402 p.
2. Ciruelos J., Duchene M. Modele sur micro-ordinateur pour l’analyse de la faisabilite financiere d’un projet minier. Paris: Industrie minérale. Les techiniques, 1983. 108 p.
3. Cavender B. Determination of the optimum lifetime of a mining project using discounted cash-flow and option pricing techniques. New York: Mining Engineering, 1992. 405 p.
4. Armstrong M., Dowd P.A. Geostatistical simulations. Proceedings of the Geostatistical Simulation Workshop, Fountainebleau, France. 27-28 May, 1993. Boston, London: Kluwer academic publishers - Dordrecht, 1994. 255 p.
5. Coube P. Mining microeconomics in Slovakia. Paris: Centre de Geotechnique d’Exploitation du Sous-sol. Ecole Nationale Superieure des Mines, 1993. 102 p.
6. Cehlár M., Engel J., Mihók J., Rybár R. Povrchové dobývanie, Edičné stredisko. Košici: AMS, F BERG, TU, 2005. 366 p.
7. Duchene M. Economie de l’enterprise miniere. Lectures, Centre de Geotechnique d’Exploitation du Sous-sol. Paris: Ecole Nationale Superieure des Mines, 1990. 88 p.

8. Goetz D. Economie de l'enterprise miniere. Lectures Paris: Centre de Geotechnique d'Exploitation du Sous-sol, Ecole Nationale Superieure des Mines, 1995. 124 p.
9. Gentry D.W., O'Neil T.J. Mine Investment analysis. Soc. of Min. Engineers of. Am.. New York: Inst. of Min., Metall., and Petroleum Endineers 1984, 502 p.
10. O'Hara T.A. Suboleski S.C. Cost and Cost Estimation. SME: Mining Engineering Handbook, 2nd Edition, 1992. 340 p.
11. OSN. Ekonomická komisia pre Európu: Systém medzinárodnej klasifikácie zásob a zdrojov. 20, 1997.
12. Rybár P. Cehlár M. Economic Evaluations of Mining Projects. Szkola Ekonomiki i zarzadzania w Gornictwie. 1997. 97. pp. 461-475.
13. Rybár R., Kudelas D. Posudzovanie konfigurácie kolektorového poľa z pohľadu insolácie. Časopis Elektroenergetika. 2005. No. 2. pp.78-90.
14. Rybár R., Kudelas D., Fischer G. Alternatívne zdroje energie 3, 1. vyd. - Košice : Edičné stredisko/AMS, 2004. 99 p.
15. Rybár R., Tauš P., Kudelas D. Využívanie solárnych zariadení na ohrev TÚV v mestskej zástavbe Košíc. AT&P Journal, Bratislava. 2005. No. 3.
16. Seják J. Et al. Oceňování pozemku a přírodních zdrojů. Grada: Publishing, 1999.
17. Torries Th.F. Evaluating Mineral Projects: Applications and Misconceptions. Littleton: Soc. for Min., Metal. and Exploration, 1997, 153 p.

Авторы

Михал Чехлар – Технический университет в Кошице, Декан Факультета BERG, ул. Летна 9, 042 00 Кошице, Республика Словакия, e-mail: michal.cehlar@tuke.sk

Павол Рыбар – доктор наук, Технический университет в Кошице, профессор факультета BERG, ул. Летна 9, 042 00 Кошице, Республика Словакия, e-mail: pavol.rybar@tuke.sk

Ян Михок, инженер, Компания «Сидерит», Республика Словакия

Яцек Энгел - профессор, инженер, доктор техники, факультета BERG, ул. Летна 9, 042 00 Кошице, Республика Словакия

Authors

Michal Cehlár – Technical University of Kosice, Dean of the Faculty of Mining, Ecology, Process Control and Geotechnologies, Letná 9, 042 00 Košice, Slovak Republic, e-mail: michal.cehlar@tuke.sk

Pavol Rybár – Dr.h.c. prof. Faculty of Mining, Ecology, Process Control and Geotechnology, Technical University of Košice, Letná 9, 042 00 Košice, Slovak Republic, e-mail: pavol.rybar@tuke.sk

Ján Mihók – Ing. „SIDERIT", Slovak Republic

Jacek Engel Prof., Ing. Dr. of Technique, Faculty of Mining, Ecology, Process Control and Geotechnology, Technical University of Košice, Letná 9, 042 00 Košice, Slovak Republic

Библиографическое описание статьи

Чехлар М., Рыбар П., Михок Я., Энгел Я. К вопросу об оценке промышленных месторождений полезных ископаемых // Экономика и управление инновациями — 2020. — № 1 (12). — С. 66-74.

Reference to article

Cehlár M., Rybár P., Mihók J., Engel J. To the issue of industrial mineral deposit evaluation. Economics and Innovation Management, 2020, no. 1 (12), pp. 66-74.

ISSN 2587-5574