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Support of mining investment choice decisions with the use of multi-criteria method

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ABSTRACT

The article presents the use of Analytic Hierarchy Process (AHP) method for the support of decisions regarding the choice of mining investment. The mining investment, as understood in the analysis conducted in the article is an acquisition of a plant mining zinc and lead ore together with the processing plant producing concentrates of these metals as well as the deposits potentially viable for mining. The subject of analysis consisted of 11 polymetallic ore deposits with different degrees of utilization and mining infrastructure which could be a subject of investment activities in Serbia, Kosovo, Montenegro and Macedonia.

In order to choose the best investment solution, a hierarchic model was built which took into account 5 main criteria and 15 partial criteria. These included in particular quantitative criteria, due to which the degree of subjectivism has been reduced. The main criteria included: geological and mining conditions, technical condition of the mining infrastructure, influence of the conducted mining activity on the environment, capital expenditure for particular stages of the investment and finally – social and political background which described the investment risk.

The assessment of influence of the mining plant on the environment was conducted using the influence matrix, so called Leopold's matrix. The method allowed for identifying influences which affected the environment's components and simultaneously permitted to quantify the degree of this influence.

For each criterion, accordingly to the AHP method's principles, weights (priorities) have been calculated. The weights were then used for construction of aggregating indicators. The choice of the best investment solution was obtained thanks to the use of an aggregating indicator which is a measure of assessment of particular polymetallic ore deposits. The indicators were the base for creating a rating for the mining objects from the point of view of assessment for the investor's needs.

1. Introduction

The decision on investment is the most common problem in the functioning of commercial undertakings. Every decision entails, sometimes very far-reaching, effects and its consequences are often very complex. Because of the consequences, making the right decision is very important for the investor. The phase in which the choice is made for the future investment is a very important step in business activity.

If one chooses the optimal variant of investment, the choice must be multi-faceted, taking into account the problem's diversity. When evaluating the options, one cannot rely solely on financial analysis of the investment, but should also take into account other very important issues, such as: technical, technological, organizational, environmental or social. The problem with the assessment of these aspects is that it is often difficult to express them in quantitative terms. For example, some benefits are qualitative, like environmental factors or elements of risk – e.g. the degree of geological exploration.

The decision is often accidental choice or purely intuitive, not supported by any analysis or planned strategy. To avoid errors and randomness of choice, it is necessary to refer to scientific methods proven in practice.

Policy makers, solving multi-criteria problems, try to express them using a single criterion aggregating all the relevant consequences of the problem. Then we deal with a single-criterion analysis in which every potential option is evaluated against one *a priori* selected criterion, eg. level of costs, profit, profitability, benefit. To solve this particular problem tools like linear programming, parametric programming, intentional programming, marginal analysis, stochastic programming,

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Table 1
The assessment matrix of local and cross-border impact on the environment.

WEIGHT	*0,63*	*0,22*	*0,07*	*0,08*	
Elements of the environment (significance) ***Factors affecting the environment***	***Surface waters***	***Soil***	***Atmospheric air***	***The transformation of the landscape***	*Total points*
AMD / ARD (acidic mine drainage), heavy metals (As)	2.5	0	0	0	*1.58*
Acidic landfill effluents containing metals (As)	2.5	2.5	0	0	*2.13*
Landfill area	0	0	0	3	*0.24*
Dusting from the landfill	0	2	2	0	*0.58*
TOTAL POINTS	*3.15*	*0.99*	*0.14*	*0.24*	***4.5***
Trans-border impact					***2.5***

non-linear programming, econometric methods, game theory, and others are used. This procedure is justified only in some simple cases.

Multi-criteria decision-making defies single-criterion analysis in a sense that it tries to express a coherent family of criteria as an instrument of understandable, acceptable and comprehensive communication, which should enable the creation, justification and transformation of preferences in the decision-making process (Adamus and Gręda, 2005).

Multi-criteria decision support requires participation of many experts in the process. Experts should be selected so that their competence includes all elements of the assessment of the analyzed problem.

In terms of solving problems using multi-criteria analysis, there are many different methods of decision support. In this article, in order to choose the optimal variant of the decision-making mathematical method AHP has been applied, which is one of the most widely used methods of Multiple Criteria Decision Making (MCDM) in the world, alongside such methods as PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations), ELECTRE (Elimination et Choix Traduisant la réalité) and ANP (Analytic Network Process).

Since AHP has been applied (Saaty, 1980) in a huge variety of application fields, some recent reviews have focused on the application of AHP in specific fields: marketing (Wind and Saaty, 1980; Mark, 2001), energy (Pohekar and Ramachandran, 2004), medical and healthcare decision making (Liberatore and Nydick, 2008), research and development (R & D) project selection and resource allocation (Heidenberger and Stummer, 1999), as well as in the field of mining (Sobczyk, 2008; Bascetin, 2009), and environmental protection (Biedrawa and Sobczyk, 2010; Sobczyk at al., 2014). The AHP has been widely combined with other tools. For example, to choose the best decision alternative, the positive and negative impacts of alternatives were considered through the BOCR analysis: benefits (B), opportunities (O), costs (C) and risks (R) analysis (Sobczyk et al., 2011).

The AHP method is a method of multi-criteria decisions analysis, where more than one criterion is present and at least two-piece, finite set of decision variants is considered. In addition, this method allows for comparing quantitative and qualitative criteria.

The article presents an assessment of polymetallic ore deposits that may be subject to investment activities in Serbia, Kosovo, Montenegro and Macedonia.

2. Main and partial factors (criteria) determining the possibility of investing

The assessment of polymetallic ore deposits against the investor's needs depends to a large degree on the proper choice of statistical features. One needs to take into account the fact that the selected features will be used for development of a ranking of investment attractiveness of the analyzed deposits. The best way to choose the features is to choose by merit. It must be emphatically stressed that in any rating of objects there is no "best" set of characteristics. Obviously, with a different set of characteristics, the object hierarchy would be different. It is necessary to carefully select the features. They may not be too few, because the "multidimensionality" of evaluation is problematic, or too many as well, as it would result in a kind of averaging and trending of the indicator to a normal distribution, which is undesirable in the ordering process.

In the presented analysis, the authors lay emphasis primarily on the substantial selection of features. Furthermore, quantitative criteria above all were taken into account, which leads to reduction of the degree of subjectivity of criteria.

The main criteria have been divided into five categories:

2.1. Geological and mining conditions

This category includes following secondary criteria:

– Amount of resources [thousand tonnes].
– Ore quality [useful component content: Pb, Zn, Cu, Ag, Au].
– Perspective resources [thousand tonnes].

2.2. Technical condition of the mine plant

This category includes following secondary criteria:

– Ore transport logistics [km] – the distance between the mine and the beneficiation plant has been assessed.
– Mine's production capacity [thousand tonnes per annum] – the declared and actual production capacity has been presented, the former being the base for position in the ranking.
– Concentrate transport logistics [km] – distance between the beneficiation plant and the shipping point (railway station) allowing for its further transport has been assessed.
– Concentrate quality – the content of harmful additions in the concentrate has been characterized.

2.3. Environmental impact assessment

The environmental impact assessment of the mines and beneficiation plants was prepared in local and trans-boundary impacts context. Following secondary criteria were distinguished:

– Local impact [punctual assessment – Leopold's matrix].
– Trans-boundary impact [punctual scale].

The mine's impact assessment on local environment was conducted using simplified form of Leopold's matrix, the so-called matrix of influences. The applied method is one of the techniques common in the EIA (environmental impact assessment). The method allows for identification of impacts that affect components of environment and at the same time allows for quantifying the strength of this influence.

The most important factors were identified (related to the mining plant's operations) showing the potentially negative impact on key