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Combining the Experimental Techniques of Mining Method Selection with Fuzzy Decision Making (Case Study: Mehdi Abad Lead & Zinc Mine)

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ABSTRACT: Mining method selection (MMS) is one of the most important decisions in conceptual and feasibility study of mine designs to selecting the least costly method of exploitation of ore which is in accordance with the reserve characteristics such as geological, geometric, and geomechanical, that safety, technical and economic constraints are taken into account. MMS techniques can be classified into three categories: qualitative techniques, empirical models, and decision making. To reduce the weaknesses of the empirical models, in this study, by combining it with the Fuzzy analytical hierarchy process (FAHP) and Fuzzy PROMETEE decision-making technique, a suitable mining method in Mehdi Abad lead & zinc reserve has been proposed. First, using the experimental patterns: Nicholas, Nicholas modified, UBC, and UBC modified, the most suitable methods were identified. These methods include: Open-pit, sublevel stopping, room and pillar, and cut and fill that obtained the highest scores. For the implementation of Fuzzy MADM methods, the technical, economic, and environmental factors affecting the selection of the extraction method were determined based on the experts' opinions and their weights were calculated with the FAHP group technique. In the last step, by applying the Fuzzy PROMETEE technique, prioritization of the mining method was performed. Accordingly, open-pit mining was selected as the most suitable alternative. The proposed model has advantages in comparison with previous mining method selection techniques including weighting criteria with group decision making by FAHP, apply of Fuzzy data according to a real condition, having a strong theoretic structure based on Fuzzy PROMETEE.

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1. INTRODUCTION

Mining method selection (MMS) is the first and most important issue in mine exploitation design. Choosing a suitable method to extract a mineral deposit is very important in terms of economics, safety, and productivity of mining operations.

Parameters, which affect choosing mining method, are mainly spatial characteristics of ore geometry (size, shape, depth, geologic and hydrologic conditions, deposit structure, the plane of weakness, uniformity, alteration, weathering, etc.), geotechnical properties of rocks, and ore (elastic properties, state of stress, consolidation, compaction, competency, and other physical properties), economic considerations (tonnage of reserves, production rate, mine life, productivity and mining cost), technological factors (mine recovery, dilution, flexibility, selectivity, concentration of workings, capital, labor, and mechanization) and environmental concerns such as ground control, subsidence and atmospheric control. In all selections, the parameters such as geological and geotechnical properties, economic and geographical factors are involved.

The appropriate mining method is the method that is technically feasible for the ore geometry and ground conditions, while also being a low-cost operation. This means that the best mining method is the one that presents the cheapest problem. There is no single appropriate mining method for the deposit. Usually, two or more feasible methods are possible. Each method entails some inherent problems. Consequently, the optimum method is the method with the least problems. Therefore, the selection of a mining method is a multi-criteria decision-making process, with many factors in this process connected. Multiple criteria decision analysis is used for the systematic assessment and comparison of alternative solutions to a problem according to qualitative and/or quantitative criteria. A review of the literature reveals that decision-making techniques have been used for a variety of mining method selections [1-3].

This research describes and verifies a new approach for the selection of a suitable mining method. The proposed strategy is applied in a case study. First, the relevant alternatives are identified with experimental techniques. This is followed by the Fuzzy analytical hierarchy process (FAHP) and Fuzzy PROMETHEE, to select the appropriate mining method. This research demonstrates the model of mining method selection

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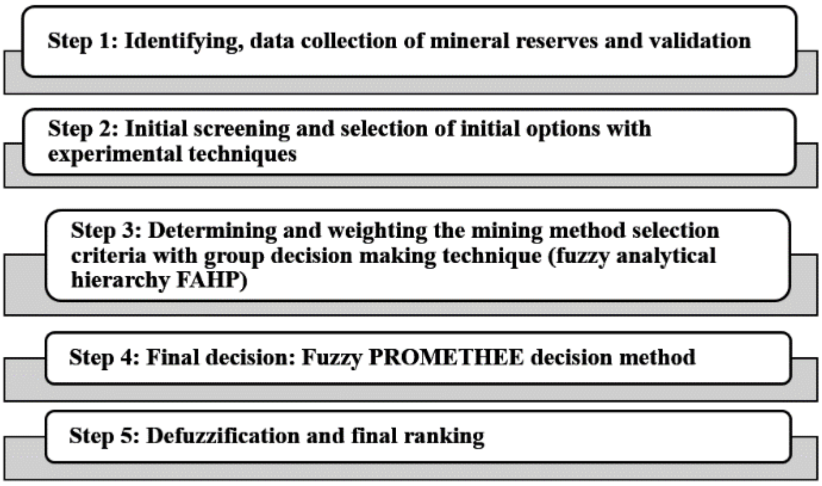

Fig. 1. Mining method selection process

based on experimental techniques and Fuzzy decision-making as applied in a real case study as follows.

2. COMBINING THE EXPERIMENTAL TECHNIQUES OF MINING METHOD SELECTION WITH FUZZY DECISION MAKING

The aim of this study is a combination of experimental techniques and multiple attribute decision analysis techniques in mining method selection. The proposed model determines initial alternatives by combining the experimental techniques and calculates the relative weights of criteria by combining the group Fuzzy AHP and applies using Fuzzy PROMETHEE to determine the overall scores. The mining decision-making model is shown in Fig. 1.

The mining method selection issue has been studied in the literature. Boshkov and Wright (1973), Morrison (1976), and Hartman (1987) suggested a selection chart for mining method selection [3]. Furthermore, several experimental techniques have been developed to evaluate suitable mining methods based on geometric parameters and geo-mechanical properties of the ore body and walls ranking. For example, Nicholas modified Nicholas, UBC, and modified UBC are based upon numerical ranking [4, 5].

In the proposed model, using the experimental techniques (Nicholas, UBC, and modified UBC), high-priority possible methods must be selected initially. In the next step, the most important factors of technical and economic criteria influencing the method selection must be determined based on expert opinions. Weights of criteria were calculated with the group FAHP technique. Finally, ranking of the selected options by applying the Fuzzy PROMETHEE technique. The techniques used in the proposed model are briefly described below.

AHP is one of the multiple attribute decision-making techniques that use hierarchical structures to solve complicated, unstructured decision problems, especially in situations where there are important qualitative aspects that must be considered in conjunction with various measurable quantitative factors. AHP was developed by Saaty [6] which was used successfully to determine the importance of effective parameters in the decision-making process. AHP method has been used as a structured approach for dealing with multi-attribute decision problems, especially when the decision process is defined hierarchically.

PROMETHEE stands for preference ranking organization method for enrichment of evaluations, and the method has evolved from PROMETHEE-I to PROMETHEE-VI since 1982. PROMETHEE-I and II were developed by Brans as the partial ranking and complete ranking, respectively [7]. After a few years, Brans and Mareschal developed an outranking based on intervals and a continuous action set extension of PROMETHEE named PROMETHEE-III and PROMETHEE IV, respectively. PROMETHEE III was an attempt to enhance indifferences, which happen rarely in practice in PROMETHEE ranking. PROMETHEE IV was applied where the set of actions is defined by decision variables and constraints, as in mathematical programming [8]. Mareschal and Brans presented geometrical analysis for interactive assistance, which is a graphical representation supporting the PROMETHEE methodology [9]. PROMETHEE method is an approach to multiple criteria decision making and has been widely used in different decisions.

PROMETHEE methodology based on classic sets logic. Classic sets logic saw the events as two values: one or zero, to exist or not to exist, and black or white. In this logic, also named Aristotle logic, the answer to a question is true or false. Values corresponding to these answers are one or zero, respectively, and there is no moderate status. But Fuzzy logic in answer to the events considers a consistent spectrum between to exist and not to exist, and see the world phenomena as gray-neither black nor white proposed by Zade. After that Zade proposed such a theory, by now this branch of mathematics has found many applications in controlling the systems and in decision making and improvements in industries [10-12].

To investigate the competence of the mining method selection model, Mehdi Abad lead-zinc deposit was chosen as a case study. Mehdi Abad lead-zinc deposit is located in the southeast of Iran, 80 km from Yazd-Kerman. The climate of the area is desert and dry with very cold winter and warm summer and very little annually raining rate. The altitude of the area on average is between 1840–1940m from sea level.

With the aim of this purpose using the Nicholas, modified Nicholas, UBC, and modified UBC methods, the possible options with the most points being selected for decision making in the beginning. According to the first and second steps of the mining method selection model for Mehdi Abad lead-zinc deposit was performed by Nicholas and UBC methods. Results of these calculations are open-pit, sublevel stopping, room and pillar, and cut and fill mining.

In the next step, the technical, economic, and environmental criteria for selecting the exploitation method were determined based on the experts' opinions as well as reviewing and reviewing the research. Then, a questionnaire was distributed to 15 expert experts and the weight of criteria was calculated by the Fuzzy AHP method. In the next step, the Fuzzy parametric method was used to prioritize the extraction methods and the open extraction method was selected as the most appropriate extraction method to verify the results, Fuzzy AHP and Fuzzy PROMETHEE method was used which the open-pit mining method. It was suggested as the most suitable extraction method in Mehdi Abad lead-zinc deposit.

3. RESULTS AND DISCUSSION

Finally, the applicability of the proposed methodology (Fig. 1) to Mehdi Abad lead-zinc deposit mining method selection is also tested in which real data is used. According to the proposed model, open-pit, sublevel stopping, room and pillar, and cut and fill as four possible alternatives, which had the highest scores, were chosen. After practicing the Fuzzy PROMETHEE technique the open-pit mining method was identified as the appropriate method. Results of the case pointed out that the proposed methodology is capable of evaluating the mining method selection certainly.

4. CONCLUSION

In this study, the integration of empirical techniques with the Fuzzy PROMETHEE technique which is one of the strongest multi-attribute decision analysis techniques was studied. The development of the proposed methodology has considerably reduced the uncertainty. In the proposed mining method selection is used group multi-criteria decision making (MCDM) methods and Fuzzy logic. According to the result of the ranking and decision based on a combination of experimental techniques and Fuzzy PROMETHEE, the open-pit mining method was selected as the most suitable method for Mehdi Abad lead-zinc deposit.

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