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Ranking criteria used for underground mining method selection applying Z-numbers Theory

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ABSTRACT: Due to its nature, mining operations are associated with many uncertainties. The effective factors in selecting the appropriate mining method in underground mines are also associated with uncertainties. The uncertainty associated with these parameters can cause various life-threatening/ mortal and financial risks. Considering the risk and uncertainty related to these parameters, ranking and determining their importance, not only helps to choose the best (the safest and the most profitable) mining method before starting the mining process, but also to design a better and safer mine and reducing subsequent risks. Fuzzy parameters are generally estimated through expert knowledge, but the degree of confidence in the opinion of different experts is different and the uncertainty and difference in the reliability of their opinion cannot be ignored. In this research, Z-numbers Theory was used to solve the mentioned challenge. To conduct the present study, first the influencing factors in the selection of underground mining methods were studied and classified into 4 main groups of criteria, 13 sub-criteria 1 and 78 sub-criteria 2. Then, the Z-numbers theory was used to rank and determine their importance. After calculating the final weight of each parameter, in order to check the validity and accuracy of the findings, the results were compared with the parameters considered for choosing the underground mining method in Angouran lead and zinc mine. The results show that in each group of parameters, the more weighted factors (the results of the present research) match the parameters related to choosing the mining method in Angouran mine.

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1- Introduction

The selection of an appropriate underground mining method to extract minerals from a deposit is one of the first and most important decisions in mining engineering activities from the perspective of safety, productivity, and economic issues. Selecting the most suitable method for an ore deposit is a critical and challenging task owing to its compliance with a set of criteria. A number of these influencing criteria in the selection of underground mining methods face uncertainty and they are difficult to quantify [1]. Fuzzy theories can, to some extent, fully address this uncertainty in computations. Fuzzy parameters are generally estimated through expert knowledge, but the degree of confidence in the opinion of different experts is different and the uncertainty and difference in the reliability of their opinion cannot be ignored. In this regard, Zadeh (2011) proposed a concept called Z-numbers. Uncertainty and unreliability in these factors can be expressed as $Z=(\tilde{A},\tilde{R})$ numbers [2-4]. Figure 1 shows a graphical display of A Z-number. For example, the "deposit depth" parameter follows the fuzzy number $\tilde{A}$; While the reliability of this prediction by the expert can be indicated by another fuzzy number such as $\tilde{R}$.

In the present study, due to the nature of mining and the existence of uncertainty in the factors influencing the selection of underground mining method (such as geological, operational, and geotechnical parameters, etc.), the Z-numbers theory has been used to study and classify these factors.

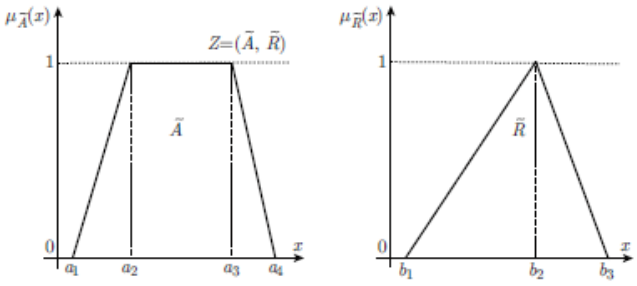

Fig. 1. Graphical display of A Z-number (is a trapezoid fuzzy number and is a triangular fuzzy number)

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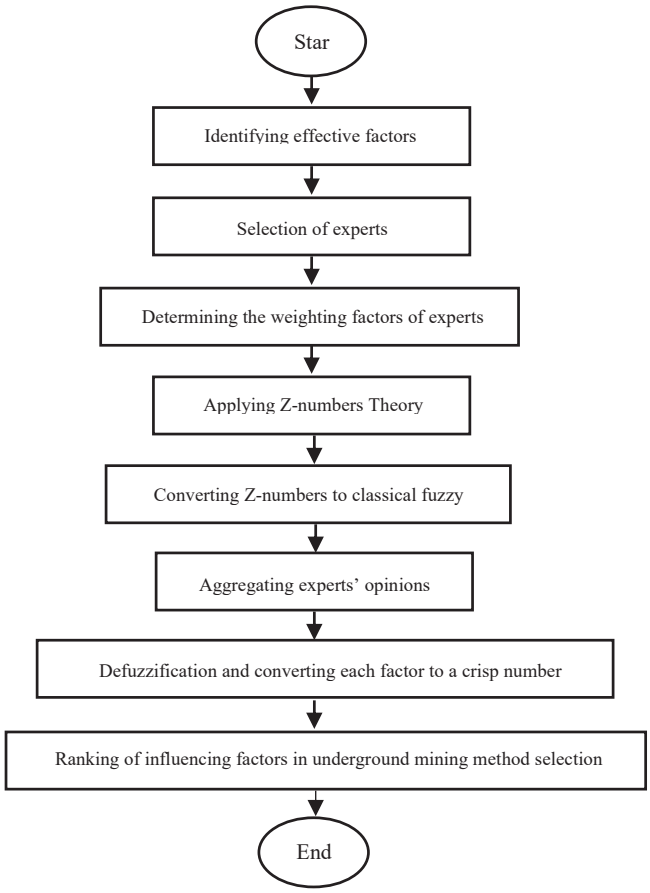

Fig. 2. Steps of the methodology

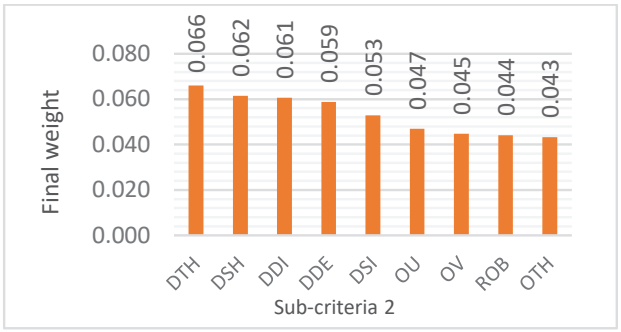

Fig. 3. The final weightings determined for geometry conditions factors

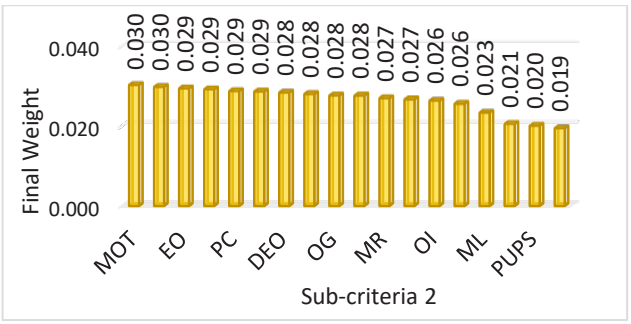

Fig. 4. The final weightings determined for productivity factors

2- Methodology

In this study, based on the Z-numbers theory, a method is proposed to rank and classify factors affecting the selection of underground mining methods. Figure 2 shows the schematic flowchart of the steps of the suggested method. After identifying the influential factors and selecting the experts, the weighting factors of experts are determined. In order to reduce the uncertainty, the Z-numbers theory is applied. To use Z-numbers, they are first converted to classical fuzzy numbers, and then fuzzy numbers perform calculations. The experts' opinions are aggregated in the following steps, and each fuzzy factor is converted to a crisp number. Finally, the influencing factors in underground mining method selection are ranked based on their final weights.

3- Results and Discussion

To implement the study, first the influencing factors in the selection of underground mining methods were identified and classified into 4 main groups of criteria, 13 sub-criteria 1 and 78 sub-criteria 2. In the next step, 15 experts were selected to determine the weights of the influencing criteria. First, the weighting factor of each expert was calculated. Then, to use experts' opinions, some questionnaires were sent to them, and in this form, experts were asked to mark very low, low, medium, high, and very high scores according to their individual opinions. Therefore, experts, based on their knowledge and experience in selecting the appropriate underground mining method, estimated the importance of each factor $(\tilde{A})$ and the reliability of their predictions about each factor $(\tilde{R})$.

The uncertainty of influencing criteria was quantified by implementing the suggested method, and their final weights were calculated. Then, these factors were ranked based on their final weights. Some results of applying the suggested method and ranking the influencing criteria are summarized in Figures 3-6.

In order to check the validity and accuracy of the findings, the results of this research were compared with the factors considered for choosing the underground mining method for the sulfur section in Angouran lead and zinc mine [5]. By comparing the results, it can be found that in each group of factors, the more weighted factors (the present research results) match the factors related to choosing the best underground mining method in the Angouran lead and zinc mine.

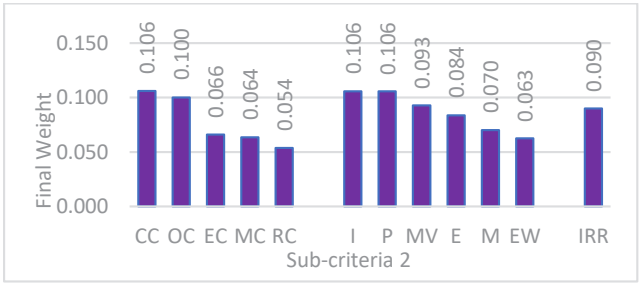

Fig. 5. The final weightings determined for economic factors

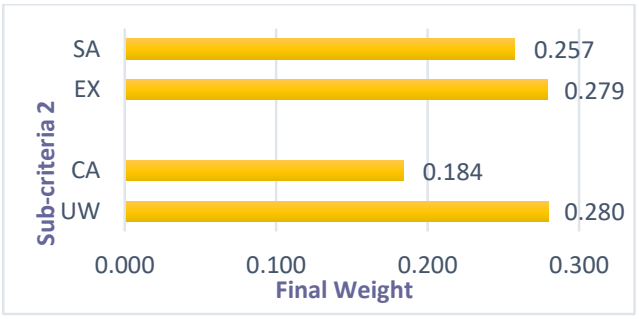

Fig. 6. The final weightings determined for ambient factors

4- Conclusion

Due to its nature, the mining operation is associated with many uncertainties. The uncertainty associated with the influential factors in selecting the appropriate mining method in underground mines can cause various life-threatening/mortal and financial risks. The purpose of this study is to consider the uncertainty associated with these factors. In this research, the Z-numbers theory was used to solve the mentioned challenge. Then, a method was proposed to rank and determine their importance. After calculating the final weight of each factor, in order to check the validity and accuracy of the findings, the results of this research were compared with the factors considered for choosing the underground mining method for the sulfur section in Angouran mine. The results show that in each group of factors, the more weighted factors (the present research results) match the factors related to choosing the mining method in Angouran mine. Considering the risk and uncertainty related to these factors, ranking and determining their importance not only helps to choose the best (the safest and the most profitable) mining method before starting the mining process but also to design a better and safer mine and reduce subsequent risks.

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