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Research Paper

Choosing the Appropriate Strategy of 4.0 Industries for the Implementation of Intelligent Methods in Mining Engineering

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Abstract: The application of new technologies has a significant effect on increasing the efficiency and improving the productivity of production factors in various industries, such as the mining industry. This requires implementing correct and practical strategies, and any incorrect procedure can cause companies and businesses to waste resources. Accordingly, the main aim of this study is to determine attractive strategies for the use of so-called fourth-generation technologies (industry 4.0) in the mining sector of Iran. To do this, a multi-criteria decision-making (MCDM) problem was employed. Therefore, this study presents a new method for evaluating and prioritizing smart mine strategies using a combination of Z-number theory and fuzzy weighted VIKOR technique with a fuzzy cognitive map (FCM). In this regard, questionnaires containing five strategies (options) and 11 criteria were designed and presented to a team of eight experts. The results obtained from the prioritization of the proposed hybrid model confirm that the strategy of "provision of government incentives to mines to use up-to-date technologies" is the most appropriate alternative for implementing industries 4.0 in large-scale mines in Iran. Furthermore, a parametric sensitivity analysis was performed to determine the effectiveness of the proposed strategies. Results showed that the proposed strategy is a fixed mechanism for ranking smart mining engineering strategies. Meanwhile, the weight of the strategy does not affect their ranking.

Keywords: Smart mining, Industry 4.0, Z-number theory, Fuzzy cognitive map.

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INTRODUCTION

Despite the experience of three major industrial revolutions globally, new technologies within the concept of fourth-generation industries (industry 4.0) have been considered since 2011 by researchers and industry owners. The mining sector requires identifying and selecting effective strategies to maximize the use of this new capacity in various areas of production, pollution reduction, safety, and productivity. Improving productivity, efficiency, and ensuring employees' health is of particular importance, and the use of new technologies meets these requirements [1]. Many mining companies worldwide are attempting to reduce costs and increase efficiency. Meanwhile, the manufacturing sector has been able to use new technologies such as advanced production and industry 4.0 in its activities and has significantly increased productivity. The mining industry is not up to date in the use of new technologies compared to other sectors and many of its activities are still performed in traditional ways [2].

Based on the literature review, researchers have focused on using 4.0 industries. However, the type of strategies in this industry is different from the factors that affect their implementation, and it is difficult to make decisions without identifying the factor that affects them. Therefore, identifying and evaluating the direct effects of influential factors is of particular importance. After identifying the factors influencing the selection of industry 4.0 strategies, this study determined their significance and effectiveness using the fuzzy cognitive map.

METHODS

This paper presents a new method for evaluating and prioritizing industry 4.0 strategies, emphasizing the use of smart technologies. For this purpose, fuzzy VIKOR and fuzzy cognitive map techniques are combined. In the first step, strategies and criteria are identified. Therefore, a questionnaire was designed to complete the decision matrix to determine the weight between criteria and strategies. In this study, in addition to formulating a strategy for implementing industry 4.0 in the country's mining sector, the Z-number theory has been used to ensure the answers of experts [3]. This means that experts express the reliability of their opinion. FCM theory is structured to calculate the weight of criteria based on causal-effect relations between concepts. Finally, the appropriate industry 4.0 strategy is selected using the Fuzzy VIKOR method.

FINDINGS AND ARGUMENT

In the theory of fuzzy cognitive map, experts expressed the causal-effect relationship between the criteria and stated their level of confidence. The reliability of each expert opinion was then affected in response to an accurate view of each. Finally, the obtained matrix was defuzzied to be used in the fuzzy cognitive map. Figure 1 shows the conceptual model of the fuzzy cognitive map. In the next step, the FCM simulation was performed and the initial matrix was updated; then, the final matrix was obtained. The weight variations of criteria in each simulation are illustrated in Figure 2. After calculating the weight of each criterion, the fuzzy best value and fuzzy worst value were calculated. Then, the normalized fuzzy difference was computed. After normalizing the obtained matrix, the indexes S, R, and Q were determined. Finally, each S, R, and Q value is ranked descending (Table 1). According to the obtained results, the ranking of 4.0 industry strategies in group Q can be sorted as follows:

A1> A3> A4> A5> A2

The first strategy (A1), "provision of government incentives to mines to use up-to-date technologies", ranks first in S, R and Q.

CONCLUSION

Although mining as an essential industrial activity has a significant impact on a country's economy, it faces fundamental challenges in various areas such as environmental hazards, occupational hazards and low productivity. Developed countries involving mineral resources have attempted to reduce the obstacles as much as possible by using new technologies and smart methods. Undoubtedly, given the growing importance of the mining industry in Iran to distance itself from the oil economy, the use of industry 4.0 can be an important step in facing the challenges and increasing production. Therefore, in this study, we tried to provide a framework for implementing industry 4.0 strategies in large-scale mines in Iran.

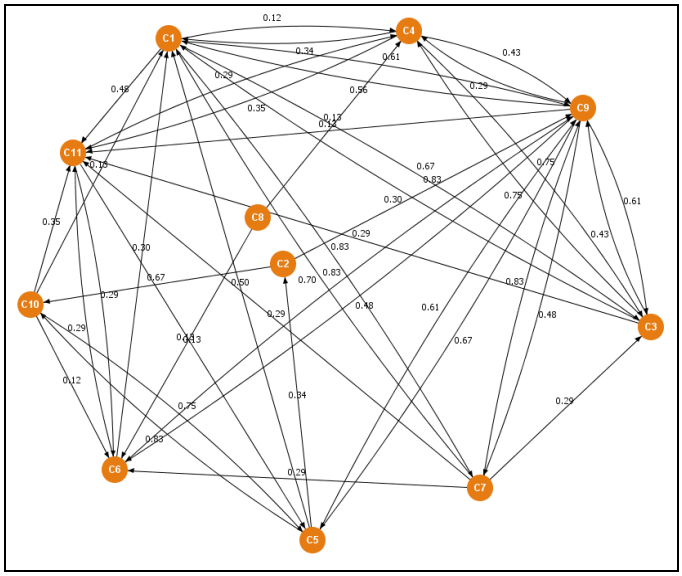

Figure 1. Fuzzy cognitive map of criteria for determining industry 4.0 strategies

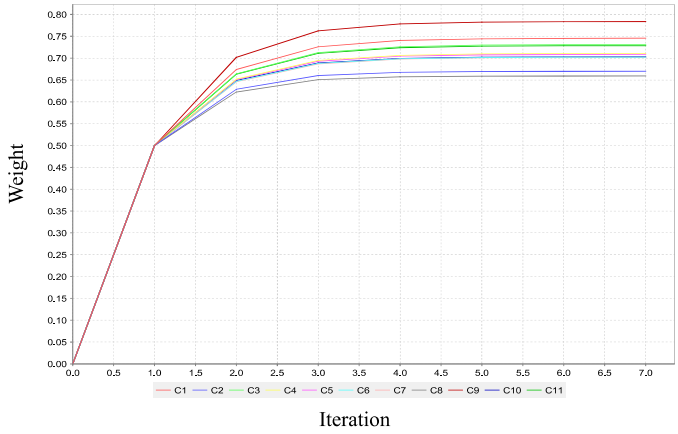

Figure 2. Criterion weights in different iterations

Table 1. Ranking of alternatives

Alternative	S	R	Q	Rank of S	Rank of R	Rank of Q
A1	3.543	0.659	0.000	1	1	1
A2	4.678	0.745	0.847	5	4	5
A3	4.027	0.709	0.412	4	2	2
A4	3.870	0.731	0.432	3	3	3
A5	3.600	0.784	0.525	2	5	4

This paper evaluated and prioritized industry 4.0 strategies by integrating the fuzzy VIKOR method and the Z-number-based fuzzy cognitive map theory. Based on this, 11 main criteria were defined as employment (C1), energy consumption (C2), hazards (C3), trained human resources (C4), marketing and sales (C5), environment (C6), risk (C7), culture (C8), technology (C9), quality of mineral products (C10), legislations (C11) along with five strategies, emphasizing the implementation of industry 4.0 strategies. The combined approach of the fuzzy cognitive map and Z-number was used to determine the importance of the criteria and prioritize their importance. This approach indicated that the “technology” criterion has the most and the “culture” criterion has the most negligible impact on the industry 4.0 strategies. By applying the

proposed method and solving the initial matrix, the values of S, R, and Q were ranked and the best smart mining strategies were identified. Based on the prioritization results, "provision of government incentives to mines to use up-to-date technologies" was selected as the most appropriate alternative. Also, the sensitivity analysis results show that the ranking of strategies was not affected by the value of v. The obtained results proved the accuracy of the ranking. The selected option is a suitable solution for smartening large-scale mines in Iran based on the evaluations.

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