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Assessment Optimization of Safety and Health Risks Using Fuzzy TOPSIS Technique (Case Study: Construction Sites in the South of Iran)

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ABSTRACT

Introduction: Safety and health risk assessment in industries is associated with uncertainties due to the variables affecting it. Therefore, in this research, optimizing safety and health risk assessment was investigated in construction sites by combining a multi-criteria decision-making technique (TOPSIS) and a fuzzy system. In the present study, to answer this question, a new method was used to optimize health risk assessment in construction workshops.

Materials and Methods: The case study was construction sites in Lar, a city in the south of Iran. Based on previous studies and expert opinions, ten criteria were determined to assess safety and health risks in the construction sites. Also, 15 safety and health risks were identified resulting from 12 types of activities in the construction sites. Triangular fuzzy numbers were used for linguistic variables in Fuzzy TOPSIS with R version 1.1 software.

Results: Based on the results, the risk of the collapse of adjacent buildings related to the excavation process was the most important safety and health risk in the construction sites with a coefficient value of 0.5.

Conclusion: This method can provide desired results with the least uncertainty in prioritizing safety and health risks.

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Introduction

In the face of the complexity of industries, it is necessary to use new methods for safety and health risk assessment [1]. Health and safety researchers try to assess the potential hazards of workplaces using the most efficient techniques available to prevent or decrease the repercussions of risks [2]. Currently, to reduce safety and health risk levels, it is required to identify and control hazards [3]. Due to differences between industries, activities, and processes, there is not only a specific risk and limited to a certain period, but in an industrial process, it affects many and varied risks of employees [4]. To lower the level of risk in industries, the risk management method can be defined following the existing conditions and variables. Thus, safety and health risk management can be framed for an optimum management structure [5]. Construction projects present the most hazards due to their pervasiveness[6]. The existence of various risks and harmful factors in executive and construction workshops has made the construction industry one of the riskiest industries in the world [7]. On the other hand, unlike other industries, construction activities are physically scattered in

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different areas making it challenging to monitor safety and health [8]. In 2020, 651279 workplace deaths were reported, about 29% of which were related to construction sites [9].

In Iran, annual reports have shown that about 35% of work-related accidents (one-third of work-related accidents in the country) are related to construction and civil engineering activities, many of which lead to death and the rest to severe injuries or disabilities [10]. Also, according to unofficial statistics published in 2015, 46% of all occupational accidents in Iran have occurred in construction sites, and most of the victims of work-related accidents are construction workers. The construction industry is considered a high-risk industry due to its high accident rate. These statistics show that the construction industry needs further investigation in the field of safety [10].

Optimization is a key issue in various fields. Optimizing art is finding the best answer among existing situations [11]. Optimization techniques, mathematical planning, and optimization-based methods are used to present and review learning models to classify data to make the best decision. Risk optimization aims to measure and control risks based on various indicators, such as impact rate and probability of occurrence [12]. The risk rating is a key part of the optimization process; since by ranking the risks, the priority of each risk based on the specified indicators is determined against other risks. As a result, the decision-maker can plan on resources allocated to deal with each risk. Therefore, by optimizing risk assessment, the uncertainty of safety and health risk assessments results can be greatly reduced [13]. Many studies have been conducted to assess safety and health risks in the construction industry. Several indicators have been proposed to assess safety and health risks. Baccarini and Hertz emphasized the calculation of risk based on the cost of outcome [14-16]. Typical indicators, such as the severity of outcome, probability of occurrence, and frequency of risk have also been suggested by researchers in various methods, such as FMEA, HAZOP, and JHA. The level of risk protection is also one of the indicators proposed by Ramírez-Marengo, Markowski, and Mahdinia [17-19].

Other researchers, such as Tah and Preyssl have introduced managers' approach to safety and health risk management as an important indicator [20, 21]. In studies conducted to assess the risk of construction projects, such as El-Sayegh and Jing, the complexity of the construction workshop was presented as an important criterion [6, 22]. Criteria, such as the level of risk perception of employees and the establishment of safety management systems in the workshop were also presented as effective indicators in risk assessment. However, it was tried to find out whether or not it is possible to provide a new and effective way to assess safety and health risks in the construction industry by aggregating the results of these studies and using a multi-criteria decision-making technique.

Multi-criteria decision-making techniques, such as TOPSIS have gained momentum in risk-related studies. Because of flexibility in determining the criteria, the weight and importance of each criterion, and scoring each option based on variable conditions, these methods can prioritize risks [23]. Another technique used to reduce uncertainty in results has been widely used in computation [24]. Many studies have used a combination of multi-criteria decision-making techniques, such as TOPSIS with fuzzy inference systems to assess safety, health, and environmental risks. With this tool, the safety risk assessment process can be optimized. The status of the main and sub-variables related to risk assessment can be determined before applying routine risk assessment methods and reducing uncertainty in the results [25].

In the present study, to answer this question, a new method was used to optimize health risk assessment in construction workshops.

Materials and Methods

The case study was conducted in construction workshops in Lar, a city in southwestern Iran. Its geographical position is 27 ° 34 '49 "N and 54 ° 49' 21" E.n (Figure 1). The area of this region is 20964 square kilometers, and its population in 2020 was about 221,000. The new fabric of the city comprises a large number of tall buildings and many active construction workshops.

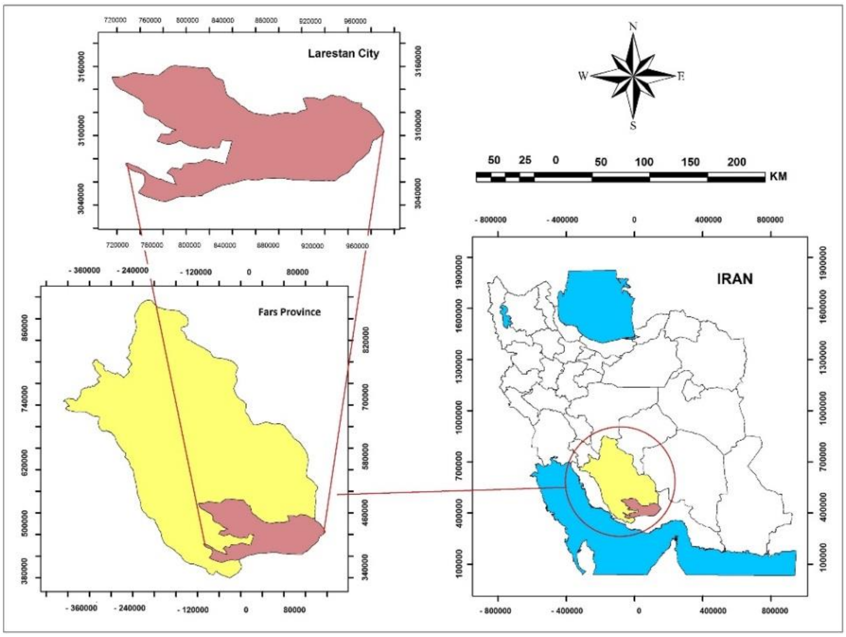

Figure 1: Location of the studied area in Southwestern Iran.

Previous research aimed at assessing health risks in various industries, including building construction, has used the classical methods defined for assessment. However, in this study, all possible criteria affecting the risk prioritization process were considered. By combining the multi-criteria decision-making technique (TOPSIS) with the fuzzy inference system, a systematic way was reached to prioritize potential risks in the construction process. The analysis was done with R version 1.1 software and ArcGIS 9.x.

The FTOPSIS algorithm is one of the most effective compensatory methods in the analysis and ranking of risks. In addition to quantitative measures, we face qualitative and linguistic criteria. In the Fuzzy technique for ordering performance by similarity to ideal solution, the fuzzy numbers' linguistic variables are introduced by assigning them to the decision-making matrix, criterion, or both [26].

In prioritizing criteria in multi-criteria decision-making methods, the most important goal is to prioritize criteria and options. Multi-criteria decision-making techniques can achieve the desired options by correctly passing the options of lower importance [27].

Classical multi-criteria decision-making (MCDM) techniques have uncertainties in determining the main options. However, in combination with these techniques, the fuzzy sets proposed by Lotfi-Zadeh can reduce uncertainty in results [28]. In the method presented in the present study, the main criteria in assessing safety and health risks in the construction sites were obtained through previous studies, which are presented in Table 1.

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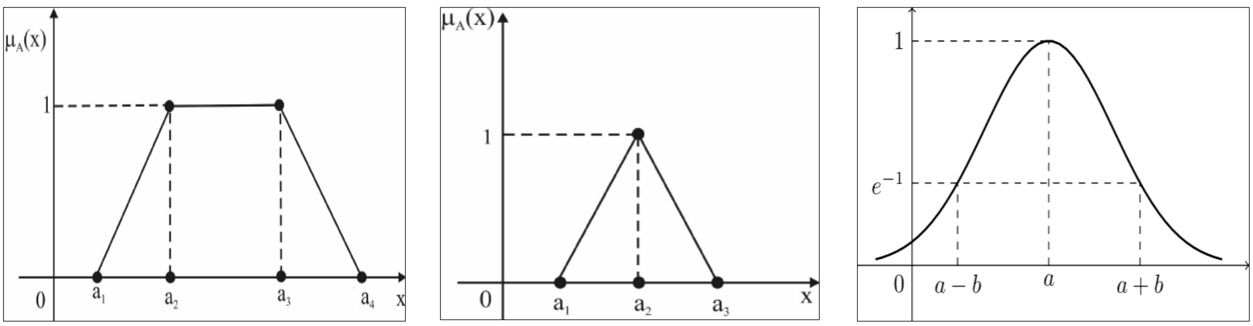
Table 1: Factors affecting risk levels in previous studies

Criteria		Reference
Routine criteria	Economic costs of risk	29-32
	Level of protection from the risk	17-19
	Risk severity based on injury to the people	14,33,15,16
	Likelihood	1,34,35,36
	Frequency	1,7,37,38,16
	Level of understanding the risk by the staff	39,40,41
	Risk detection coefficient	3,42,43
Construction site criteria	Managers safety approach	20,21,44,45,5
	Complexity of construction site	46,6,47,48
	Implementation of safety management systems in the construction site	33,49,50,51,52

In addition to criteria, such as severity and probability of occurrence, other criteria used in previous research were used to assess safety and health risks in the construction sites. Evaluations were carried out in quantitative and qualitative groups. In the present study, a multi-criteria decision-making method and a fuzzy system were proposed to assess safety risks in the construction site. In the fuzzy process, fuzzy numbers must be defined for the scale of each criterion. Fuzzy numbers were represented in various forms, such as triangular, trapezoidal, or Gaussian (Figure 2) [53].



a b c

Figure 2: Types of fuzzy numbers (a: trapezoid, b: triangular, c: Gaussian).

Each triangular fuzzy number is defined by three main numbers, such as A = (s, l, r), with membership function based on Eq. 1 [1]:

$$\mu_M(x)=\begin{pmatrix} 0 \\ \frac{x-a}{b-a} \\ \frac{c-x}{c-b} \\ 0 \end{pmatrix} \quad x<0,\ a \le x \le b,\ b \le x \le c,\ x > c \qquad \text{Eq.1}$$

After identifying the main criteria in assessing the safety risks of the construction sites, the following steps should be taken to achieve risk prioritization by fuzzy TOPSIS method:

1. Decision matrix

Suppose we have m alternative, n criterion and k decision maker. Decision matrix (based on *m* alternatives and *n* criteria) forms to the following matrix (Eq. 2):

$$A_{ij}=\begin{bmatrix} a_{11}a_{12},,,a_{1n} \\ a_{21}a_{22},,,a_{2n} \\ . \\ . \\ . \\ a_{m1}a_{m2},,,a_{mn} \end{bmatrix} \qquad \text{Eq.2}$$

In the decision matrix, A_{ij} = (p, q, r), the performance of the *m*th option is in relation to the *n*th criterion for fuzzy triangular numbers, where m = 1, 2, 3... nandn = 1, 2, 3… n. Linguistic variables and their corresponding triangular fuzzy numbers for ranking options and evaluating criteria are shown in Table 2. Linguistic variables to assess (a) the main criteria and (b) the safety of alternatives in the construction sites are presented in Figure 3.

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Table 2: Linguistic variables to assess the main criteria and safety of alternatives in the construction sites

Linguistic variables to assess the main criteria		**Linguistic variables to assess the safety of alternatives in the construction sites**	
Linguistic variable	**Corresponding fuzzy number**	**Linguistic variable**	**Corresponding fuzzy number**
Very low preferred	(0, 0, 1)	Safe	(0, 0, 0.1)
Low preferred	(0, 1, 3)	Acceptable	(0, 0.1, 0.3)
Medium-low preferred	(1, 3, 5)	Low-undesirable	(0.1, 0.3, 0.5)
Indifferent	(3, 5, 7)	Moderate	(0.3, 0.5, 0.7)
Medium-high preferred	(5, 7, 9)	Moderate-undesirable	(0.5, 0.7, 0.9)
High preferred	(7, 9, 10)	Undesirable	(0.7, 0.9, 1)
Very high preferred	(9, 10, 10)	Extremely undesirable	(0.9, 1, 1)

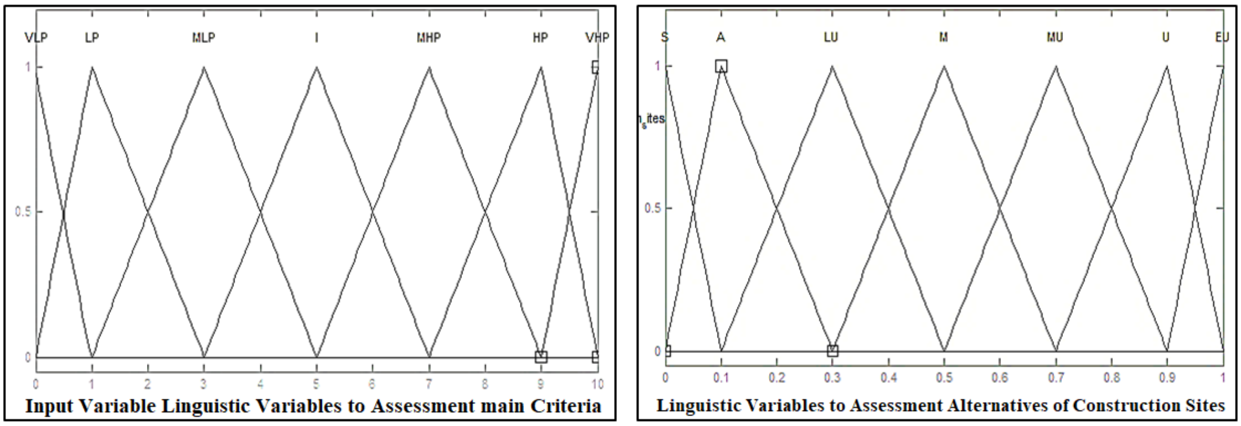

Figure 3: Linguistic variables to assess (a) the main criteria and (b) safety of alternatives in the construction sites

2. Determining the weight of the criteria matrix

Where A1, A2,…, An are the alternatives to be selected or prioritized. C1, C2,…, Cn are evaluation criteria or characteristics. It indicates the degree of alternative Ai to the criterion or characteristic Cj by the evaluator K. In order to integrate the fuzzy Xij fuzzy performance score of the K evaluator, the mean value method was used.

The weight of the criteria matrix was determined based on Eq. 3, where the relation of each component w_j (weight of each criterion) is w_j = (w_j1, w_j2, w_j3) when fuzzy triangular numbers are used as below:

$$W = [w_1, w_2, ...wn] \qquad \text{Eq.3}$$

3. Normalization of the fuzzy decision matrix

Normalization of the fuzzy decision matrix considering fuzzy triangular numbers for decision matrix elements was computed for positive and negative criteria, based on Eqs. 4 and 5:

$$\ddot{r}_{ij}=\left(\frac{a_{ij}}{c_j^*},\frac{b_{ij}}{c_j^*},\frac{c_{ij}}{c_j^*}\right);\ c_j^* = max_i c_{ij}; \qquad \text{Eq.4}$$

$$\ddot{r}_{ij}=\left(\frac{a_j^-}{c_{ij}},\frac{a_j^-}{b_{ij}},\frac{a_j^-}{a_{ij}}\right);\ a_j^- = min_i a_{ij}; \qquad \text{Eq.5}$$

Depending on different weights within each criterion, as per the following formula, the weighted normalized decision matrix was determined by calculating the weight of each criterion in the standard fuzzy decision matrix (Eq.6):

$$v_{ij}=r_{ij}.w_{ij} \qquad \text{Eq.6}$$

Where w_{ij} represents the weight of criterion c_j

4. Determining the fuzzy positive-ideal solution (FPIS) a* and fuzzy negative-ideal solution (FNIS) A⁻

The FPIS and FNIS of the alternatives were defined based on Eqs.7 and 8:

$$A^*=\{v_1,v_2,\dots,v_n\}=\{(max_j v_{ij}|i\in B),(min_j v_{ij}|i\in C)\} \qquad \text{Eq.7}$$

$$A^-=\{v^-_1,v^-_2,\dots,v^-_n\}=\{(min_j v_{ij}|i\in B),(max_j v_{ij}|i\in C)\} \qquad \text{Eq.8}$$

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Where $v\sim*I$ is the maximum value of i for all the alternatives, and $v\sim-1$ is the minimum value of i for all the alternatives. B and C represent the positive and negative ideal solutions, respectively.

5. Calculating the distance between each alternative and the fuzzy positive ideal solution a+ and the distance between each alternative and the fuzzy negative ideal solution

The distance between each alternative and FPIS and the distance between each alternative and FNIS were respectively calculated using Eqs. 9 and 10:

$$S_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*) i = 1,2,\dots,m \quad \text{Eq.9}$$

$$S_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j) i = 1,2,\dots,m \quad \text{Eq.10}$$

D is the distance between two fuzzy numbers in the above relations, and its value for fuzzy triangular numbers was obtained from Eq. 11.

$$d_v(\tilde{M}_1, \tilde{M}_2) = \sqrt{\frac{1}{2}[a_1 - a_2]^2 + [b_1 - b_2]^2 + [c_1 - c_2]^2} \quad \text{Eq11}$$

6. Calculating the closeness coefficient and ranking the alternatives

The closeness coefficient was calculated according to Eq. 12 and based on the distance between the fuzzy positive and the fuzzy negative ideal solutions for each option.

$$CC_1 = \frac{Si}{Si + Si-} i = 1,2,\dots,m \quad \text{Eq.12}$$

In the next step, the fuzzy positive ideal solution A* and fuzzy negative ideal solution A- ideas were obtained based on Eqs. 13 and 14.

$$C_i = \sum_{j=1}^{n} d(Vij, Vj) \quad \text{Eq.13}$$

$$C_1^- = \sum_{j=1}^{n} d(Vij, V_J^-) \quad \text{Eq.14}$$

7. Ranking the options

In the final step, the ranks of options were prioritized based on their closeness coefficient.

Results

This study determined ten main criteria based on experts' methods, including seven routine criteria and three criteria for construction workshops. They were consisted of economic costs of risk, protection level from the risk, risk severity based on injury to the people, likelihood, frequency, level of understanding the risk by the staff, risk detection coefficient, managers' safety approach, complexity of the construction site, and implementation of safety management systems in the construction site. Routine criteria do not consist merely of the factors affecting the construction industry. Also, 15 main risks were identified in the construction workshops in Lar based on expert methods.

The hierarchical structure of Lar construction site risks is reflected in Figure 4.

Based on the algorithm presented in Fuzzy TOPSIS [54], the weights of the indices were determined (Table 3). Based on the type of construction industry studied in this study in Lar region and based on the opinions of 5 experts, the criteria presented in Table 1 were scored in the fuzzy system (fuzzy scores provided are the mean scores given by experts).

The item "risk severity based on injury to the people" was the most important criterion among the identified cases. Other effective items in safety assessment in construction sites were "economic costs of risk" and "likelihood".

After criteria weighting, the scores of each risk identified in Table 3 were performed by five construction safety experts in the fuzzy system, which are presented in Table 4.

In the next step, the fuzzy positive ideal solution A* and fuzzy negative ideal solution A- ideas were obtained based on Eqs. 11 and 12 in Table 5.

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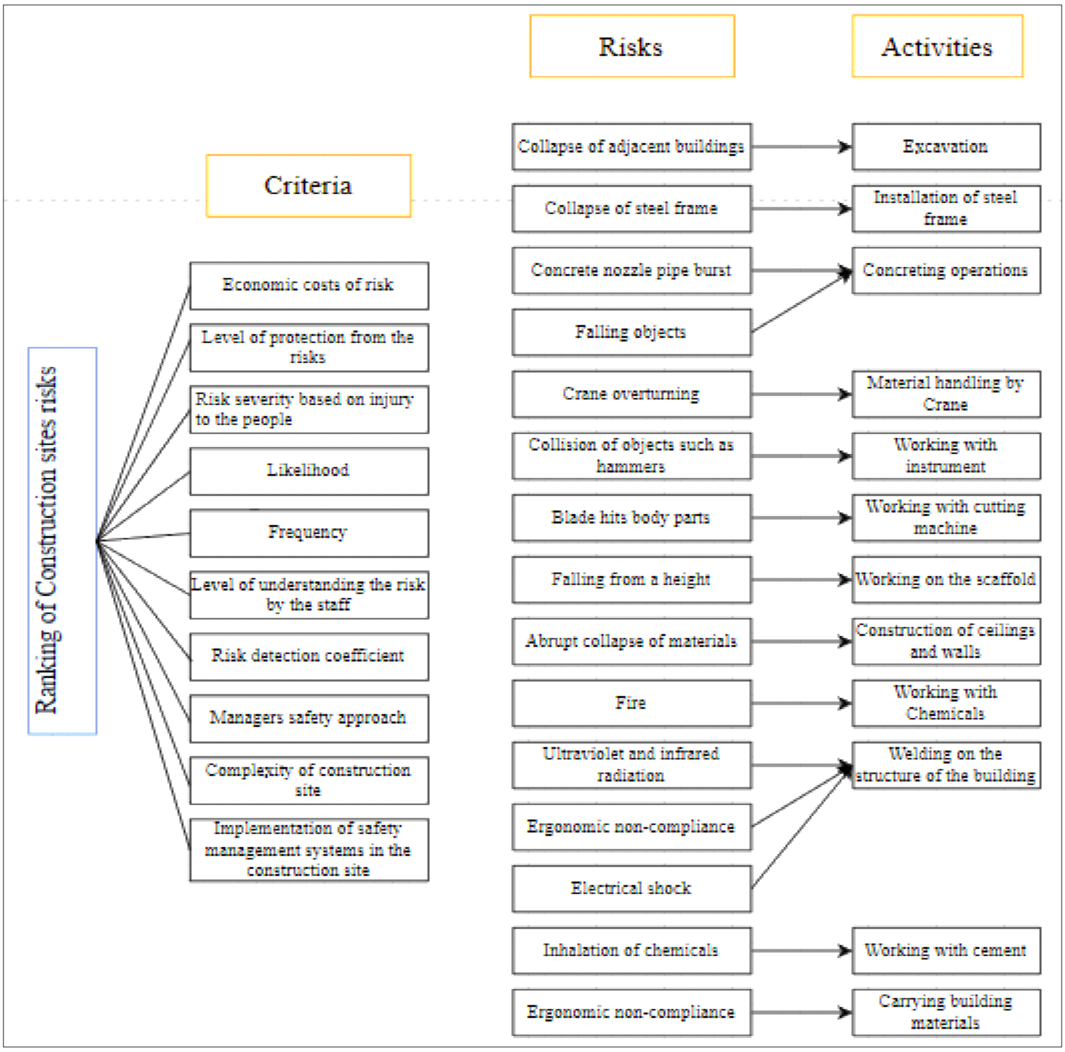

Figure 4: The hierarchical structure of Lar construction site risks

Table 3: Weighting and ranking of criteria in fuzzy system

Criterion weight	Criteria
Risk severity based on injury to the people(C_1)	0.71, 0.83, 0.94
Economic costs of risk(C_2)	0.67 , 0.71 , 0.83
Likelihood (C_3)	0.55 , 0.66 , 0.72
Level of protection from the risk(C_4)	0.46 , 0.56 , 0.63
Risk detection coefficient(C_5)	0.36 , 0.45 , 0.55
Frequency (C_6)	0.3 , 0.37 , 0.44
Managers safety approach(C_7)	0.26 , 0.31 , 0.39
Level of understanding the risk by the staff(C_8)	0.12 , 0.22 , 0.32
Complexity of construction site(C_9)	0.06 , 0.12 , 0.23
Implementation of safety management systems in the construction site(C_{10})	0 , 0, 0.11

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Table 4: Matrix of fuzzy decision

Criteria alternatives	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	(0.9, 1, 1)	(0.9, 1, 1)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0.7, 0.9, 1)	(0, 0.1, 0.3)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0.5, 0.7, 0.9)	(0, 0.1, 0.3)
A2	(0.9, 1, 1)	(0.7, 0.9, 1)	(0, 0.1, 0.3)	(0, 0.1, 0.3)	(0.3, 0.5, 0.7)	(0, 0.1, 0.3)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0.3, 0.5, 0.7)	(0.1, 0.3, 0.5)
A3	(0.7, 0.9, 1)	(0.5, 0.7, 0.9)	(0.1, 0.3, 0.5)	(0, 0.1, 0.3)	(0.5, 0.7, 0.9)	(0.1, 0.3, 0.5)	(0.1, 0.3, 0.5)	(0.3, 0.5, 0.7)	(0.7, 0.9, 1)	(0.1, 0.3, 0.5)
A4	(0.3, 0.5, 0.7)	(0, 01.1, 0.3)	(0.9, 1, 1)	(0.5, 0.7, 0.9)	(0, 0.1, 0.3)	(0.9, 1, 1)	(0.5, 0.7, 0.9)	(0.3, 0.5, 0.7)	(0, 0.1, 0.3)	(0, 0, 0.1)
A5	(0.7, 0.9, 1)	(0.5, 0.7, 0.9)	(0, 0, 0.1)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0, 0, 0.1)	(0.1, 0.3, 0.5)	(0.1, 0.3, 0.5)	(0.5, 0.7, 0.9)	(0.1, 0.3, 0.5)
A6	(0.1, 0.3, 0.5)	(0, 0.1, 0.3)	(0.7, 0.9, 1)	(0.7, 0.9, 1)	(0, 0.1, 0.3)	(0.7, 0.9, 1)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0.3, 0.5, 0.7)	(0.1, 0.3, 0.5)
A7	(0.7, 0.9, 1)	(0.5, 0.7, 0.9)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0.3, 0.5, 0.7)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0, 0.1, 0.3)	(0.7, 0.9, 1)	(0, 0.1, 0.3)
A8	(0.7, 0.9, 1)	(0.5, 0.7, 0.9)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0, 0.1, 0.3)	(0, 0.1, 0.3)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0, 0.1, 0.3)	(0, 0.1, 0.3)
A9	(0.5, 0.7, 0.9)	(0.7, 0.9, 1)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0.1, 0.3, 0.5)	(0.1, 0.3, 0.5)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0.3, 0.5, 0.7)	(0.1, 0.3, 0.5)
A10	(0.7, 0.9, 1)	(0.9, 1, 1)	(0, 0, 0.1)	(0, 0.1, 0.3)	(0.5, 0.7, 0.9)	(0, 0.1, 0.3)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0.1, 0.3, 0.5)	(0, 0.1, 0.3)
A11	(0.3, 0.5, 0.7)	(0, 0.1, 0.3)	(0.9, 1, 1)	(0.5, 0.7, 0.9)	(0, 0, 0.1)	(0.7, 0.9, 1)	(0.7, 0.9, 1)	(0.1, 0.3, 0.5)	(0.3, 0.5, 0.7)	(0, 0, 0.1)
A12	(0.3, 0.5, 0.7)	(0, 0, 0.1)	(0.7, 0.9, 1)	(0.5, 0.7, 0.9)	(0, 0, 0.1)	(0.5, 0.7, 0.9)	(0.7, 0.9, 1)	(0.3, 0.5, 0.7)	(0, 0.1, 0.3)	(0, 0.1, 0.3)
A13	(0.7, 0.9, 1)	(0.5, 0.7, 0.9)	(0, 0.1, 0.3)	(0, 0.1, 0.3)	(0.5, 0.7, 0.9)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0.3, 0.5, 0.7)	(0.5, 0.7, 0.9)	(0, 0.1, 0.3)
A14	(0.1, 0.3, 0.5)	(0, 0, 0.1)	(0.5, 0.7, 0.9)	(0.7, 0.9, 1)	(0, 0.1, 0.3)	(0.3, 0.5, 0.7)	(0.9, 1, 1)	(0.3, 0.5, 0.7)	(0.1, 0.3, 0.5)	(0.1, 0.3, 0.5)
A15	(0.3, 0.5, 0.7)	(0.1, 0.3, 0.5)	(0.7, 0.9, 1)	(0.7, 0.9, 1)	(0, 0.1, 0.3)	(0.5, 0.7, 0.9)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0, 0.1, 0.3)	(0, 0.1, 0.3)

Table 5: Distance between each alternative and (S*i, S-i) and closeness coefficient

	Alternatives	Distance of fuzzy positive ideal solution(S+)	Distance of fuzzy negative ideal solution	Closeness coefficient
1	The collapse of adjacent buildings(A1)	2.7679	2.7675	0.5
2	Concrete nozzle pipe burst(A3)	2.9905	2.7658	0.4805
3	Ergonomic non-compliance welding(A15)	2.9559	2.6164	0.4695
4	Ultraviolet and infrared radiation(A11)	2.9315	2.5707	0.4672
5	Falling objects(A4)	2.9419	2.5788	0.4671
6	-Electrical shock(A13)	3.1188	2.4998	0.4449
7	Collapse of steel frame(A2)	3.094	2.4135	0.4382
8	Blade hits body parts(A7)	3.2321	2.4452	0.4307
9	Ergonomic non-compliance(A12)	3.1711	2.3526	0.4259
10	Fire(A10)	3.1458	2.3196	0.4244
11	Collision of objects such as hammers(A6)	3.2254	2.346	0.4211
12	The abrupt collapse of materials-carrying construction materials (A9)	3.2454	2.3026	0.415
13	Inhalation of chemicals(A14)	3.2732	2.2674	0.4092
14	Falling from a height(A8)	3.314	2.2239	0.4016
15	Crane overturning(A5)	3.4189	2.1416	0.3851

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By performing the calculation steps in the Fuzzy TOPSIS method, each risk proximity coefficient to the positive criteria was calculated. Risk ratings are shown in Figure 5. Accordingly, the risk of collapse of adjacent buildings related to the excavation process with a coefficient of about 0.5 was identified as the principal safety and health risk in the construction sites.

Concrete nozzle pipe burst with a weight of 0.48 and ergonomic non-compliance-welding with a weight of 0.46 were the second and third most important risk in the construction process, respectively.

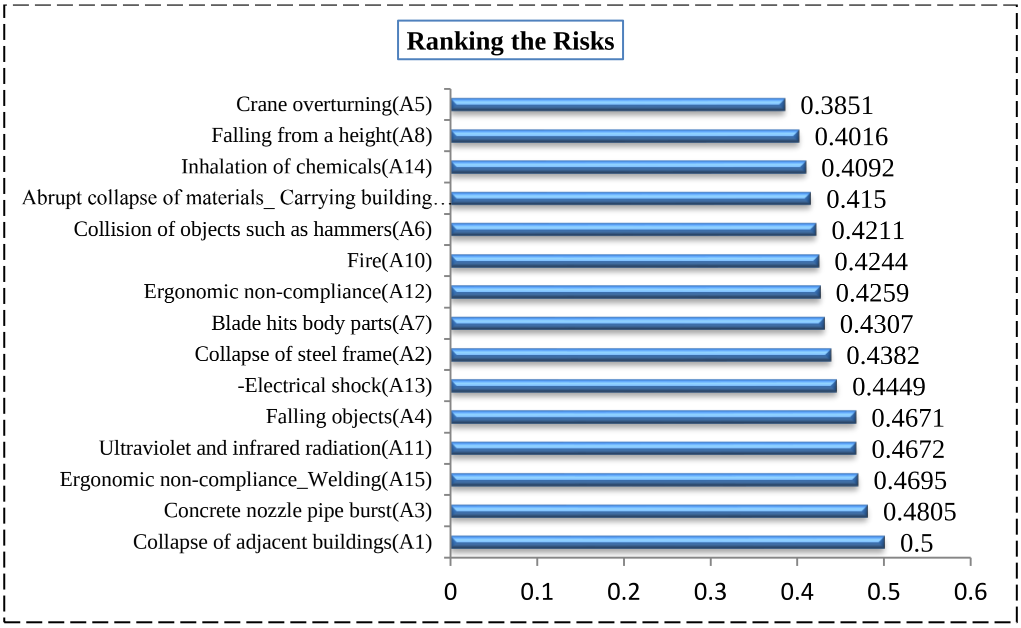

Figure 5: Ranking of Alavian dam project risks by Fuzzy TOPSIS

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Discussion

The most important achievement of risk testing is the achievement of risk priorities to reduce the level of risk [51]. The output should provide risk solutions to control the resulting risk [55]. Regarding assessment and control of risks, comprehensive information is required from the workplace, hazards, employees, management, and other components [12]. In the current study, ten criteria were set to assess safety and health risks in the construction sites. Also, 15 safety and health risks resulting from 12 types of activities in the construction workshops were identified. Major criteria in the present study comprised the severity of risk consequences on human health with a mean score of 0.82 in assessing the risk and the collapse of adjacent buildings during excavation operations with a coefficient of nearly 0.5 in the risk of construction site. The current research proposes the application of diverse and effective components in risk management with criteria varying in industries and workshops. Earlier studies have focused on risk assessment criteria in industries [56,57]. In the construction industry, other criteria are at play, such as cost, severity, likelihood, frequency, and coefficient of detection. For example, type of building (in terms of area and floors), use or non-use of machines, such as tower crane and concrete pump, level of safety knowledge and understanding workers' risk, safety approach of managers, and use of comprehensive safety management systems in the project, have an important impact on risk management. The results of various research studies have confirmed the efficiency of multi-criteria decision-making techniques, such as TOPSIS in decision making and selection of options. Krohling stated that the performance of fuzzy TOPSIS in safety and health is better than other multi-criteria decision making techniques. Evas et al. stated that identifying risks and prioritizing risks in the workplace is an important principled step in safety management. Hamilton et al. stated that the safety management process in industries requires the integration of criteria and risks. To integrate these factors in the final risk assessment, the use of a multi-criteria decision technique, such as Fuzzy TOPSIS is recommended. The present study results showed that the collapse of adjacent buildings is the most important risk in the construction process. Gürcanli, in addition to the collapse of adjacent buildings, also cited the risks associated with tower cranes as a very dangerous factor in construction workshops. The results of the present study showed that in the construction industry, there was a set of risk factors, such as equipment-related risks (like crane and concrete pump), ergonomic harms, fire, the collision of objects, radiation from the welding, dust inhalation, and falling from a height. The results showed that the use of MCDM techniques increased the possibility of identifying and prioritizing risks.

Conclusion

The results showed that applying all criteria in achieving risk priorities can optimize the risk assessment process. Although part of the safety and health risks in a construction site was assessed based on a case study, the method used in this study can be the basis for risk assessment in other construction sites and even other industries. In the present study, some risks could increase the severity or likelihood of others. For example, excavation increases dust and respiratory harm. Therefore, some risks can have different intensity and probability scores in different situations, which is one of the limitations of risk assessment studies. It is suggested to consider it in future studies. It can be concluded that this method can provide the desired results with the least uncertainty in prioritizing safety and health risks.

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Conflict of interest

The authors declare that they have no conflict of interest.

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