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ORIGINAL RESEARCH PAPER

Optimizing the Risk of Building Environments Using Multi-Criteria Decision Making

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Abstract

Construction industry is known as one of the most dangerous industries in the field of air pollution which causes damage to the environment and endangers human health. Therefore, in order to reduce and control risks by construction industry, planning is necessary. The method used to discuss the risks is MCDM. After interview with 15 experts, the weights of scales were discussed. Some criteria are used for risks; in this study, the insights and suggestions used include risk comprehension, risk evaluation, safety risk, and safety performance. Weight of four main scales was performed by Super Decision software. Paired comparison of the main scales was performed in terms of 9 hourly quantitative scale, the same as AHP process. According to the research, more weight was given to risk comprehension, and less weight was devoted to safety insight. The results show that in order to control risks, risk comprehension has high priority in building environments.

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1. Background

Construction industry plays an important role in development of economy (Liu and Tsai, 2012). Since there are many complexities in the industry, it is regarded as the most dangerous as to rate of damages and compensation to workers (McDonald et al. 2009; Mohandes et al. 2021; Xu et al. 2022). In this industry, the damages result in death, serious occupational damages, and time lost as for its nature(Lingard et al. 2010). According to the report of Larestan Construction Guilds Union, there are about 6,000 to 7,000 construction workers in Larestan, of whom 25% are from Larestan, 30% are non-natives, and most of them are from the cities of Hamedan, Kurdistan, Isfahan, Khuzestan, Rasht and Sari, and 45% are Afghans; they must be trained in the HSE aspects. In a study, the results showed that the proportion of fall accidents increased substantially, and there was evidence that the usage of fall protection has no considerable improvement. Thus, most of the fall accidents were (1) from heights<9.15 m, (2) among the roofers, (3) in new commercial buildings and residential projects with low cost, (4) during the time intervals 10:00–12:00 and 13:00–15:00, (5) among older workers who know that experience might not be enough to diminish the accident (Halabi et al. 2022). Constructional workshops are recognized in terms of many incredible factors like continued repair, frequent circulation, unsuitable working situation, exposure to different weather conditions, highly unskilled workers, and temporary workers, causing many accidents (Rozenfeld et al. 2010). Today, development of industry and technology causes constructional factories and environments play important roles in production and economic cycle and the workers are regarded as human factor who use advanced technology and valuable capital; thus, it is important to use and promote bodily and mental factors as producer forces for substantial development (Fataei et al. 2013; Zarei et al. 2014; Fataei and Mohammadian, 2015; Fataei , 2020;). In fact, human force is regarded as one of the most important factors in production and services and is affected by many factors (Abootorabi et al. 2014). Civil projects are converted constructional industry into one of the most dangerous industries because of the risks in administrative and constructional environments. In one side, regardless of other industries, constructional industry is dispersed in different parts of the world physically, and it is a challenged to supervise it for safety and health. In 2005, an average of 12.2 deadly accidents and 7.1 accidents leading to injury for per 100000 workers were registered. In Iran, statistics reported by Ministry of Labor and Social Welfare show that nearly 35% of accidents (one third of working mode) were related to construction and civil activities which resulted in death and severe injuries. Also, according to non-official statistics published in 2012, 46% of occupational accidents in Iran were in constructional sectors and more victims were construction workers (Jafari et al. 2014); thus, in order to obtain health goals in protection of working force, it is necessary to discuss risks due to workshops and constructional workers. In order to make decision on controlling and protecting workers, we need to evaluate the risks exclusively. One of the main solutions to evaluate occupational and environmental risks among constructional workers is to optimize the processes in multifaceted decision- making environment. Optimization of health risks by MCDM determines the workshop risks and enables us to make appropriate decisions to protect the workers. MCDM is used to select the best options based on relatively incompatible aims. In fact, MCDM models are applied to design (Brauers et al. 2008). In the research conducted by Jouzi et al. in 2010, the physical risks of Balaroud Khuzestan dam in constructional environment by MCDM were analyzed; they identified the activities and environmental processes as to the severity of probable outcomes and then human and equipment and classified the risks in the form of Delphi method. After using prioritization factors by TOPSIS, AHP, and integration by extraction and embankment, explosion and excavation were regarded as the most important environmental risks for Balaroud dam (Jozi et al. 2015). Mansouri and Azimi Hosseini (2015), in their study on ranking the HSE performance of Gas companies by using MCDM, performed field visiting different units of Iranian National Gas Company and then identified and classified the parameters involved in safety, health, and environment. The results show that the province gas, development and engineering, transmission and refined gas are estimated 0.74, 0.55, 0.40, and 0.19. Also, they presented MCDM and used TOPSIS fuzzy as the most efficient tool to identify, rank and optimize the risks from HSE point of view (Mapar et al. 2019). Therefore, in a study, the proposed framework was tested using the activity of climbing ladders as a case study. The results show that the proposed dynamic fall risk assessment framework is feasible to be used (Piao et al. 2019).

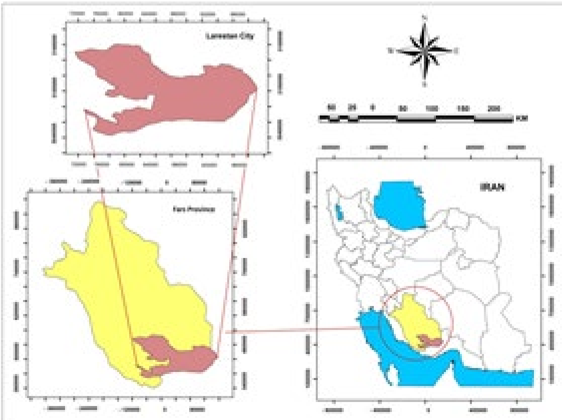

Figure 1. Geographical situation of Larestan

Zang and Ikso's research (2014) discussed the effect of application of MCDM in water electricity projects and use of MODM to optimize algorithm crowd to look for optimized solution and restore decoration system in water electricity project (Zhang et al. 2014). The aim of the present study is to discuss and plan constructional environment of Larestan city by MCDM method.

2. Materials and Methods

Geographical situation of the region under study, Larestan city, which is one of the southern cities of Fars province is shown in Figure 1.

2.1. Decision process

In the majority of cases, the decision made is suitable when it is based on some criteria; in MCDM method, instead of risk scale, some other criteria are used. From the method point of view, AHP method is suitable to model qualitative scales, and its applications for selecting, evaluating, planning and decision making are so vast (Hashemi et al. 2017). Multifaceted model is considered for some decisions, and in linear planning, it is supposed that decision makers have a one single aim. Consideration of only one aim causes problems; thus, it is necessary to use multifaceted models.

2.2. Mathematical form of MCDM

In MCDM models, instead of linear planning (which has one single aim), we were confronted with some aims. Generally, multifaceted model with k aims as f1, f2, f2… are shown as follows:

Max (Min) f1 (x1)

Xj)) f2 (Min) Max.

(xj) fk (Min) Max

gi(Xj)≤bi, i=1,2,…, m (operational limitation)

Xj≥0, j=1,2,…, n (nonnegative limitations)

in which Xj is decision variable of j and n is the number of decision variable, gi(xi) is m limitation, m is the number of limitations, and bi is nonnegative and fixed value.

AHP process is started to recognize and prioritize the elements including different methods and priority estimators. In the first step, each data was weighted and the estimators were located in the matrix and estimated as single and their weight was found. By using normalized method, we estimated all estimators; in the third step, by considering the weight of estimators and alternative points, we obtained the points of alternatives and leveled them. The final step was to determine their compatibility (Mohammadi et al. 2021).

In the modeling step, problem and decision aims were recognized as hierarchy. Decision elements were decision index and decision options. Hierarchical process needed to break a problem with some indicators and high levels showed the main aim of the decision. The second level showed the main and sub-indicators which connected to the sub-indicators and partial ones.

The last level offered decision options (Darko et al. 2019). Hierarchical decision is shown in Figure 2.

Reagents and materials

The Yellow Acid-36 dye was used in this study which is classified as azo dyes, and its chemical structure is shown in Figure2 (λ=435 nm). Synthetic solution was made of Yellow acid 36 dye, and titanium dioxide P-25 Degussa was used as the catalyst.

The solution was prepared by dissolving a defined quantity of Yellow 36 dye in double distilled water. Then, NaOH was added to the solution and ultrasonic bath was used. The absorbance in the maximum wavelength (λmax) was measured using a UV-vis spectrophotometer. For safety and prevention of UV distribution, the reactor was covered with Aluminum sheet.

Dye degradation efficacy is expressed as below:

%R = (C0 - Ct)*100/C0

R: Dye removal efficiency

C0: First absorption

Ct: After irradiation absorption

Photooxidation Experiments

All experiments were performed in a Plexiglas reactor equipped with UV lamps at a wavelength of 365 nm. The catalyst was coated on the marble surface using the slurry method. Thus, TiO_2 powder was mixed with water-Methanol (with volume ratio of 25%). The mixed solution was stirred for 10 min in 20 degree centigrade and 1500 rpm. Then, the solution was restirred for 30 min to obtain a homogenous solution and then transferred into an oven heated at 105 degree centigrade for 1 hour. Finally, the marble was covered by slurry, dried for 24 hours, and air-cooled to room temperature. The coated marble was washed thoroughly with distilled water.

Dye degradation efficacy is expressed as below:

%R = (C0 - Ct)*100/C0

R: Dye removal efficiency

C0: First absorption

Ct: After irradiation absorption

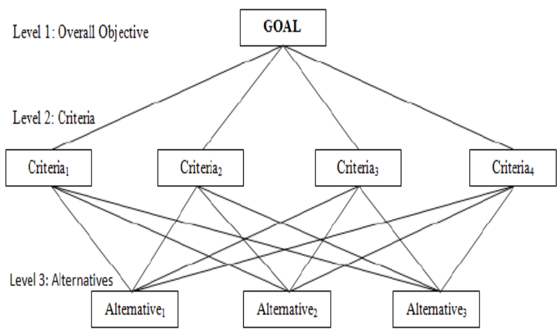

Figure 2. Hierarchical analysis process

In the pair judgment step, after designing hierarchical decision, comparisons was made among different options in terms of the index and judgment. It was done by pair comparison between decision elements (pair comparison) and by numerical points which show prioritization between the two decisions. To do so, we devoted options comparisons by m index to it and in table 1, the manner of valuing is shown(Hashemi et al. 2016).

Table 1. The paired comparison

Relative importance to another scale in paired comparison	Importance Degree
Equal importance	1
Average preferable	3
Strong preferable	5
More strong preferable	7
Severe preferable	9
	2,4,6,8

3. Results

According to hierarchical process which was selected by experts, safety performance, safety insight, risk comprehension, and risk evaluation are considered in Table 2.

3.1. Paired comparison of the main scales

Paired comparison of the main scales was performed in terms of 9 hourly quantitatively scale and was the same as the AHP process. The result of paired comparison and harmony vector that is W21 is shown in Table 3. In order to obtain suitable result, we used paired judgment and geometrical average was obtained.

3.2. Paired comparison for internal dependency of the main scales (Matrix W22)

In order to understand interactive dependencies between the main scales, paired comparison was performed to obtain matrix W22 in terms of 9 hourly quantitative scales. As to importance coefficient, each main scale (as for interactive dependency) and paired comparison (by control first scale) are shown in Table 4. The results of their internal dependency are displayed in Table 5 to 7to. According to the matrix, paired comparisons are shown in table 4 to 7; their compatibility were controlled and the matrix was calculated for the main scale, w22.

Table 2. Internal dependency of the main criteria on each other

Scales	Safety insight	Safety performance	Risk comprehension	Risk evaluation
Safety insight		✓	✓	✓
Safety performance	✓		✓	✓
Risk comprehension	✓	✓		✓
Risk evaluation	✓	✓	✓	

Table 3. The paired comparison for main scales

Scales	Risk comprehension	Safety performance	Risk evaluation	Safety insight	Normal
Risk comprehension	1				0.31
Safety performance	0.2	1			0.23
Risk evaluation	0.5	0.2	1		0.20
Safety insight	0.33	0.5	0.2	1	0.16

Table 4. Paired comparison as to the internal dependency by controlling the risk comprehension

Scales	Safety performance	Risk performance	Risk evaluation	Safety insight
Safety performance	1			0.35
Risk evaluation	0.5	1		0.29
Safety insight	0.33	0.5	1	0.22

Table 5. Paired comparison as to the internal dependency by controlling the safety performance

Scales	Risk comprehension	Safety performance	Safety insight	Normal
Risk comprehension	1			0.35
Safety performance	0.50	1		0.29
Safety insight	0.25	0.17	1	0.16

Table 6. Paired comparison for main scales as to the internal dependency by controlling the risk evaluation

Scales	Risk comprehension	Safety performance	Safety insight	Normal
Risk comprehension	1			0.38
Safety performance	0.33	1		0.29
Safety insight	0.20	0.33	1	0.19

Table 7. Paired comparison for main scales as to the internal dependency by controlling the safety insight

Scales	Risk comprehension	Safety performance	Risk evaluation	Normal
Risk comprehension	1			0.38
Safety performance	0.25	1		0.27
Risk evaluation	0.17	0.25	1	0.17

Paired comparison for the main scales as to compatibility is shown in Table 8.

3.3. Paired comparison for the main scales (matrix W22)

Importance coefficient for each scale pertaining to the main scales by paired comparison are in terms of 9 hourly quantitative; these coefficients were elements of matrix W22. The results of paired comparison are shown in Tables 9 to 12.

Table 8. Paired comparison for the main scales as to the compatibility coefficient

Scales	Risk comprehension, C1	Safety performance, C2	Risk evaluation, C3	Safety insight,4
Risk comprehension	0	0.35	0.38	0.38
Safety performance	0.35	0	0.27	0.25
Risk evaluation	0.29	0.29	0	0.19
Safety insight	0.22	0.1	0.17	0

Table 9. Matrix for the effect of the main scale of risk comprehension

Scales	E1	E2	E3	Normal
Workers' skill	1	0.33	2.00	0.16
Workers' knowledge	3.00	1	3.00	0.30
Workers' experience	0.50	0.33	1	0.08

Table 10. Matrix of the main scales for safety performance

Scales	Ec1	Ec2	Ec3	Normal
Management skill	1	0.33	2.00	o.28
Management knowledge	3.00	1	3.00	0.47
Knowledge experience	0.50	0.33	1	0.16

Table 11. Matrix for the main scale for risk evaluation

Scales	P1	P2	P3	Normal
Logistics workers p1	Expert 300	0.33	2.00	0.07
Logistics managers p2	Expert 3.00	1	3.00	0.28
Logistics facilities p3	0.50	0.33	1	0.19

Table 12. Matrix for the main scales of safety insight

Scales	S1	S2	S3	S4	Normal
Modern equipment s1	1	2.00	2.00	5.00	0.36
Modern technology s2	0.50	1	3.00	5.00	0.32
Modern repair system s3	0.50	0.33	1	2.00	0.10
Modern navigation s4	0.20	0.20	0.50	1	0.06

4. Discussion

The construction industry has always been infamous due to its staggering numbers of occupational health and safety related injuries, resulting from overlooking all the crucial aspects endangering the involved workers' lives (Mohandes et al. 2021). Application of MCDM methods is considered as one of the main elements in the framework of risk evaluation in order to help decision making and reduce and minimize negative outcomes (Sekhavati and Jalilzadeh, 2021; mohammadi et al. 2021). In management of constructional projects, evaluation of safety risk is regarded as an important step to identify the dangers and value the damages. In this study, four insights were offered to discuss the status of Larestan construction workshop which include risk comprehension, safety insight, safety performance, and risk evaluation. After interviewing with 15 experts, we discussed the weights of the scales and more weight was pertinent to the risk comprehension (0.31); also,less weight was given to the safety insight (0.16).The remaining were safety performance (0.23) and risk evaluation (0.2) which show risk comprehension is applied to further control the workshop risks. Evaluation of risks has been performed for health and occupational safety by AHP and done by Ilbahar et al. In this study, risk evaluation suitable with PFPRA which is combination of Fine Kinney hierarchical method and fuzzy inferential system was suggested for excavation dangers. Integrated method has been valued by experts (Ilbahar, Karaşan, Cebi, & Kahraman, 2018). Aminbaksh et al. discussed the necessity of risk evaluation in Turkey in constructional projects (Aminbakhsh, Gunduz, & Sonmez, 2013). In this study, for the first scale, three subscales were considered, and the importance of workers' knowledge (0.3), skill (0.16), and experience (0.08) was prioritized. The second scale (safety performance) had three subscales which were management knowledge (0.47), management skill (0.28), and management experience (0.16). For the third scale, three subscales were considered which are logistics managers (0.28), logistics facilities (0.19), and logistics workers (0.07). The last scale was safety insight which had a lower weight and had four subscales including modern equipment (0.36), modern technology (0.32), modern repair system (0.1), and modern navigation (0.06). In a study, the results showed that nearly all factors had a pivotal role, and centrality had the maximum amount because the desired occupation supported a workshop chart within the formal network relations, but communication between people is supported through personal, racial, linguistic and other characteristics within the informal network of relations (Abbasianjahromi et al. 2022). As for discussion which is used to control health risk, we can use prioritization to select and reduce the cost, increase control and health of environment for people domiciled??? and its environment???.

5. Conclusions

The present study indicated that it is possible to analyze, prioritize, and optimize the health risk of construction workers during work, using the multi-objective decision-making method combined to decrease any possible uncertainty. The results showed that for managing the risks, risk comprehension contains a high priority in building environments.

Conflict of interest

The authors declare that they have no conflict of interest.

Additional Information and Declarations

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