How to Cite:
Armin, H., Nasab, A. Y., Dehbaraftab, S. M. H., & Far, H. E. Assessment and ranking of occupational health and safety risks in the machinery maintenance unit of dam construction projects using the combined approach of methods (Fmea and Fuzzy Topsis). *International Journal of Health Sciences*, 5710-5723. Retrieved from https://sciencescholar.us/journal/index.php/ijhs/article/view/13386

Assessment and ranking of occupational health and safety risks in the machinery maintenance unit of dam construction projects using the combined approach of methods (Fmea and Fuzzy Topsis)

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***Abstract*---**A dam construction project is exposed to various risks due to the amount of investment, duration of implementation, the complexity of design and implementation, etc., and these risks will lead to human and financial losses. Thus, based on three principles, including (i) time, (ii) quality, and (iii) cost, identifying, assessing, ranking risks, and Occupational Safety and Health (OSH) can have a significant impact on project objectives. The machinery maintenance unit has the largest share of the organization's cost model. Manpower, tools, spare parts, and working standards of planning and scheduling are the most important elements of the implementation of the maintenance process in these organizations. Methodology In the

Manuscript submitted: 9 May 2022, Manuscript revised: 18 July 2022, Accepted for publication: 27 August 2022

present research, first, all the failure modes of the machinery maintenance unit were identified. Then, to assess and rank them, in addition to the three traditional attributes in Failure Modes and Effects Analysis (FMEA) (severity-S, occurrence-O, and detection-D) and calculate the Risk Priority Number (RPN), we used fuzzy numbers corresponding to real-world problems instead of crisp numbers for risk ranking. Also, to deal with the shortcomings and problems of crisp risk score calculation and decrease the inconsistency in decision-making, and reach more accurate results, a combined fuzzy approach was used, and then, the different risks priority ranking was determined using the fuzzy TOPSIS method. Findings According to the intradepartmental ranking results of risk assessment, the highest final weights of occupational health and safety risks extracted from the results of the combined method (in terms of the criticality of the risk) are related to the codes (A2, A16, A21, A24, A17, A26, A18, A1) which the most important of these risks include the use of non-standard tools, performing work in an unsafe manner, not performing technical inspection of tools, equipment, and devices, unsafe service, welding and cutting in oily environments, and not using appropriate personal protective equipment. Conclusions The purpose of this research is to provide an approach to assessing and ranking occupational health and safety risks in one of the most dangerous parts of the dam construction project. In the proposed approach, the main focus was on maintaining the simplicity of the analysis method of failure factors and their effects and increasing its efficiency by eliminating the limitations and shortcomings of this method. The results showed that the use of a combined approach of FMEA and Multi-Attribute Decision-Making (MADM) used in a fuzzy environment increases the speed of this process and obtains more reliable results. The following steps, facilitate the decision-making process.

Keywords---Risk assessment, Fuzzy analytical hierarchy process, Occupational health and safety.

Introduction

Dam construction projects are exposed to various risks due to high investment, long duration of implementation, and complexities of design and implementation. These risks may lead to human and financial losses. Thus, according to three principles of time, quality, and cost, identification, assessment, and ranking of risks have a great impact on project objectives (1). The construction industry, especially dam construction, is one of the high-risk industries due to the complexity of the nature of the work and the unsafe conditions of the work environment, where the rate of accidents is very high (2). Many changes in the work environment, use of multiple resources, inappropriate working conditions, reduced job security, and unfavorable work environment (things like noise, dust, bad weather conditions, and moving heavy equipment) have increased these risks in this industry (3) so that the rate of fatal and non-fatal accidents in this industry is high (4-6). The use of heavy machinery such as trucks, bulldozers, and rollers has created an unsafe environment for construction workers. A significant part of the capital in mining, construction, and road construction-oriented organizations is employed in the form of machines for various projects. Repairs and maintenance of light and heavy machinery have the largest share in the cost model of these organizations. Manpower, tools, spare parts, and planning and scheduling standards are among the most important elements of implementing the maintenance process in these organizations. Also, there are risks such as fire and explosion risks, electric current risks, construction equipment risks, risks related to the installation and operation of scaffolding and workstations, risks related to skeleton construction and working at height, and risks related to excavation operations and foundation implementation (7). The FMEA is a powerful preventive method for risk management and its purpose is to eliminate possible shortcomings. It is used to identify failure modes and suggests necessary actions to prevent failures (8). The method of quantitative risk assessment in this research was comprehensive, and at first, a widely used and suitable method was used for the initial identification of risk centers, and then, the best available software (BT Fuzzy TOPSIS solver) which is in accordance with mathematics equations was used to model and determine the weight of the criteria and rank the options (9). One of the most important problems in the risk assessment process is the presence of multiple parameters affecting the risk level, each of which affects the risk level to a different extent. This problem causes the assessor to be confused and misjudge the level of risk. Thus, it is necessary to use Multiple Criteria Decision-Making (MCDM) to eliminate the effects of individual judgments or assessors in the assessment process (10). The fuzzy TOPSIS method is one of the best MADM models for solving real-world problems (11). This method is based on the concept that the selected option should have the smallest distance from the positive ideal solution (the best possible state) and the greatest distance from the negative ideal solution (the worst possible state). In this method, it is assumed that the desirability of each attribute is increasing or decreasing uniformly. The distance of an option from the positive or negative ideal is calculated through the Euclidean distance or as an absolute sum of linear distances, which depends on the rate of exchange and replacement among the attributes (12).

2. Necessity of research

One of the most important problems in the risk assessment process is the presence of uncertain parameters in it. In 2011, in this field, Yaqiang et al. proposed the use of fuzzy environments in safety risk assessment in their investigations (13). Another problem in the risk assessment process is the impact of different criteria on the amount of risk that should be considered in the risk ranking. In this field, Omidvari et al. suggested the use of decision-making tools as a suitable method for determining the criteria weight and risk attributes (14). In 2017, Jiang et al. proposed a new fuzzy method to overcome the shortcomings of the FMEA method, better modeling, and existing uncertainty, in which risk factors are assessed with a fuzzy membership degree. The advantages of the proposed method were that it not only could cover the variability and uncertainty of risk assessment but also increase the reliability of RPN. Experimental results showed that this method is suitable and effective for real applications (15). On the other hand, Moradi and Nadershahi used the combination of Fuzzy Analytic

Hierarchy Process (FAHP), FMEA, and TOPSIS methods for a fuzzy Multi-Criteria Risk Assessment (MCRA) based on the decision-making method and matrix, so that in this approach of the matrix method, two attributes of FMEA are assessed, i.e. the probability of risk and its severity when it occurs and these two parameters are weighted using the FAHP and then the priority of different risks is determined by the Fuzzy TOPSIS (FTOPSIS) method (16). Many studies have been conducted on FMEA, and some studies conducted in different work environments are mentioned in the literature review section. Since this method has shortcomings and limitations, researchers have tried to compensate for the shortcomings of FMEA by providing new concepts and combining the FMEA method with other methods such as MADM. Hence, researchers thought of improving this method. One of the existing solutions to solve shortcomings is to combine this approach with fuzzy logic. When sufficient data is not available or data is available in the form of expressions and linguistic and mental variables, fuzzy logic is considered a suitable tool (17). The fuzzy knowledge-based system can generally combine the knowledge and expertise of experts in an FMEA analysis (18).

3. Materials and methods

3.1 Risk assessment

This research is descriptive-analytical with a combination of TOPSIS decision-making technique and multi-criteria FMEA. The target community in this research is the machinery maintenance unit of the dam construction industry. In this research, by using the criteria of exposure, severity, consequence, and probability (based on the FMEA method) the risks were identified and the risk level was determined. Finally, the risk assessment and ranking of options were done using the TOPSIS method.

3.2 Fuzzy TOPSIS method

After determining the subcriteria weight, the options should be prioritized. This process is as follows using the fuzzy TOPSIS technique presented by Huang and Yun in 1981 (19).

Step 1: Creating a decision matrix of people's opinions

Suppose the decision matrix of people's opinions is as follows:

$$\widetilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \quad i = 1,2,\dots,m; \;\; j = 1,2,\dots,n$$

In which, the rows list out the potential options and the columns outline the various decision-making criteria to consider. X_{ij} represents the quantity of i-th option in the j-th subcriterion. Also, the subcriteria may be negative or positive depending on the impact on the options. In this research, linguistic terms and fuzzy numbers in Table 3 are used to assess options for each criterion.

Table 1.

Linguistic terms and corresponding fuzzy numbers for risk ranking

The fuzzy equivalent of priorities			Code
Upper limit (U)	Medium limit (M)	Lower limit (L)	
1	1	0	1
3	2	1	2
4	3	2	3
5	4	3	4
6	5	4	5
7	6	5	6
8	7	6	7
9	8	7	8
10	9	8	9
10	10	9	10

Step 2: Normalizing the decision matrix

In this step, we convert the fuzzy decision matrix from people's opinions into a fuzzy scaleless matrix ($\tilde{R}$). To get the matrix $\tilde{R}$, it is enough to normalize the decision matrix based on equation (1-3).

$$\tilde{R} = [\tilde{r}_{ij}]_{m\times n}$$

)3-1(

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \ and\ c_j^* = \max_i c_{ij}$$

Step 3: Creating the weighted normalized decision matrix

Creating a fuzzy weighted scaleless matrix $\tilde{V}$ assuming the vector $\widetilde{W}_{ij}$ is based on the below equation:

$$i = 1,2,\dots,m \quad j = 1,2,\dots,n \quad \tilde{V} = [\tilde{v}_{ij}]_{m\times n}$$

)3-2(

$$\tilde{v}_{ij} = \tilde{r}_{ij}.\widetilde{w}_j$$

Step 4: Identification of the ideal positive and ideal negative values

In this step, the positive and negative ideals are determined based on relations 3-9 and 3-10 (19).

)3-3(

$$A^{+} = (\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*) \ where\ \tilde{v}_j^* = \left(\tilde{c}_j^*, \tilde{c}_j^*, \tilde{c}_j^*\right) and\ \tilde{c}_j^* = \max_i\left\{\tilde{c}_{ij}\right\}$$

)3-4(

$$A^{-} = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-)\ where\ \tilde{v}_j^- = \left(\tilde{a}_j^-, \tilde{a}_j^-, \tilde{a}_j^-\right) and\ \tilde{a}_j^- = \min_i\left\{\tilde{a}_{ij}\right\}$$

$\forall i = 1,2, \dots, m; \quad j = 1,2, \dots, n$

Step 5: Calculating the distance of the options from the ideals

Calculation of the sum of the distances of each component from the fuzzy positive ideal and the fuzzy negative ideal. If A and B are two fuzzy numbers as described below, then the distance between these two fuzzy numbers is obtained by the following relation:

$\tilde{A} = (a_1, b_1, c_1) \qquad \tilde{B} = (a_2, b_2, c_2)$

)3-5(

$$D(A,B) = \sqrt{\frac{1}{3}[(a_2 - a_1)^2 + (b_2 - b_1)^2 + (c_2 - c_1)^2]}$$

According to the above explanations about how to calculate the distance between two fuzzy numbers, we obtain the distance of each component from ideal and anti-ideal:

)3-6(

$$d_i^* = \sum_{j=1}^{n} d\left(\tilde{v}_{ij} - \tilde{v}_j^*\right) \qquad i = 1,2, \dots, m$$

)3-7(

$$d_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij} - \tilde{v}_j^-\right) \qquad i = 1,2, \dots, m$$

Step 6: Calculating the similarity index to the ideal option (CL)

This similarity is calculated as follows.

)3-8(

$$Cl = \frac{d_i^-}{d_i^* + d_i^-} \qquad i = 1,2, \dots, m$$

Step 7: Ranking the options

The available options for the given problem can be ranked based on the descending order of CL.

3.3 The results of the TOPSIS method

In this section, the critical risks extracted from the RPN method are ranked and validated with the fuzzy TOPSIS method. The list of critical risks of RPN is given in Table 2, which includes 28 risks.

Table 2.
Critical risks in RPN

Code	Risk
A1	Earthing and electrical connection of devices, non-insulated cables, depreciation of the electrical system of devices, and oil spilled on the floor of the repair shop.
A2	Using a non-standard tool (such as a scaffolding tube to hold up the room), performing work in an unsafe manner (such as not using a lathe next to the jack), not technically inspecting the jacks, removing or unloading the key and jack during puncture repair and service.
A3	Carelessness, not evacuating the service area to prevent contact with the paint.
A4	Carelessness, not following safety rules, spilling oil, starting a fire near flammable materials, smoking, and negligence.
A5	Carelessness in moving things and unsafe transportation.
A6	Using a faulty jack that is disproportionate to the machine's weight, not using four lathes under the truck cabin or the jack, and using a scaffolding tube to hold the truck.
A7	Non-insulation of cables, depreciation of electrical system of devices, and lack of connection of the earthing system.
A8	Carelessness, lack of protection in the transmission part.
A9	Damaged jack, no use of support.
A10	Damaged jack, not use the support or not use a right holder.
A11	Using of improper equipment, improper restraint of the truck cabin with safety equipment, using of improper jack, and jacking in improper conditions.
A12	Standing on the bumper of the device in greasy and slippery conditions, turning on the device, checking the engine, and carelessness.
A13	Wear, a wire connection.
A14	Loose work clothes, carelessness, use of Chafee or handkerchief.
A15	Not using personal protective equipment.
A16	Welding and cutting in oily environments, not carwashing the equipment before welding, not properly maintaining the tanks, not using flashback, non-standard transportation, and no mobile car wash.
A17	Contact of sharp and cutting objects with electric cables, unfavorable insulation of cables, welding in wet and humid environments, the existence of non-standard bypasses, inappropriate tools, and non-use of personal protective equipment.
A18	Not using appropriate personal protective equipment (work clothes, safety helmets and shoes, filter masks, protective headphones, safety glasses, shields, etc.).
A19	Using scaffolding tube to hold the room, insufficient strength of this tube,

Code	Risk
	and risk of falling of this energized device.
A20	Not performing a technical inspection of the equipment before starting work and performing work in an unprincipled manner.
A21	Welding tanks soaked in fuel and oil, not washing and drying the tanks before starting this work.
A22	Not restraining tanks, placing tanks on top of each other, keeping tanks lying down, not using chains to store the tanks vertically, not using shade and resistant walls around them, and necessary natural ventilation.
A23	Lack of carwash, improper car wash, and not having a mobile carwash.
A24	Welding and cutting in greasy and oily environments, unsafe and unprincipled maintenance of pressure vessels, not using flashback, throwing molten materials into flammable environments.
A25	Not using a frame and buying a non-standard stone plate.
A26	Not restraining tanks, placing tanks on top of each other, keeping tanks lying down, not using chains to store the tanks vertically, not using shade and resistant walls around them, and necessary natural ventilation.
A27	Cutting oily environments, not carwashing the equipment before welding, improper storage of tanks, not using flashback, non-standard transportation, and not having a mobile car wash.
A28	Not washing, drying, and cleaning the tank, not separating the tank before welding.

The first step in the fuzzy TOPSIS method is the formation of the decision matrix. The purpose of forming the decision matrix is to assess 28 risks based on the three criteria of occurrence, severity, and detection, which are converted into fuzzy numbers based on the fuzzy systems 1-10 of Table 1. The matrix is given in Table 3. In this matrix, three criteria are placed in the columns and 28 risks are placed in the rows.

Table 3. Fuzzy TOPSIS decision matrix

	Occurrence	Severity	Detection
A1	(8,9,10)	(7,8,9)	(6,7,8)
A2	(8,9,10)	(8,9,10)	(7,8,9)
A3	(7,8,9)	(5,6,7)	(6,7,8)
A4	(6,7,8)	(7,8,9)	(5,6,7)
A5	(7,8,9)	(6,7,8)	(6,7,8)
A6	(6,7,8)	(8,9,10)	(6,7,8)
A7	(7,8,9)	(7,8,9)	(5,6,7)
A8	(6,7,8)	(6,7,8)	(5,6,7)
A9	(8,9,10)	(6,7,8)	(6,7,8)
A10	(7,8,9)	(8,9,10)	(5,6,7)
A11	(7,8,9)	(5,6,7)	(7,8,9)
A12	(4,5,6)	(4,5,6)	(3,4,5)
A13	(6,7,8)	(6,7,8)	(5,6,7)
A14	(6,7,8)	(6,7,8)	(6,7,8)
A15	(8,9,10)	(6,7,8)	(6,7,8)

	Occurrence	Severity	Detection
A16	(8,9,10)	(8,9,10)	(7,8,9)
A17	(8,9,10)	(8,9,10)	(6,7,8)
A18	(7,8,9)	(7,8,9)	(7,8,9)
A19	(4,5,6)	(4,5,6)	(4,5,6)
A20	(7,8,9)	(7,8,9)	(6,7,8)
A21	(7,8,9)	(8,9,10)	(7,8,9)
A22	(8,9,10)	(8,9,10)	(6,7,8)
A23	(8,9,10)	(7,8,9)	(5,6,7)
A24	(7,8,9)	(8,9,10)	(7,8,9)
A25	(8,9,10)	(7,8,9)	(6,7,8)
A26	(8,9,10)	(8,9,10)	(6,7,8)
A27	(6,7,8)	(7,8,9)	(7,8,9)
A28	(8,9,10)	(7,8,9)	(5,6,7)

After forming the decision matrix, normalization and weighting operations were performed, then the final scores and risks rank was determined as shown in Table 4. As can be seen, its results are consistent with the RPN method.

Table 4. The scores and a final ranking of risks

Rank	Final score	The distance from the negative ideal	The distance from the positive ideal	Risk code	Risk title
1	0.797	0.525	0.134	A2	Using a non-standard tool (such as a scaffolding tube to hold up the room), performing work in an unsafe manner (such as not using a lathe next to the jack), not technically inspecting the jacks, removing or unloading the key and jack during puncture repair and service.
1	0.797	0.525	0.134	A16	Welding and cutting in oily environments, not carwashing the equipment before welding, not properly maintaining the tanks, not using flashback, non-standard transportation, and no mobile car wash.
2	0.752	0.492	0.163	A21	Welding tanks soaked in fuel and oil, not washing and drying the tanks before starting this work.
2	0.752	0.492	0.163	A24	Contact of sharp and cutting objects with electric cables, unfavorable insulation of cables, welding in wet and humid environments, the existence of non-standard bypasses, inappropriate tools, and non-use of personal protective

Rank	Final score	The distance from the negative ideal	The distance from the positive ideal	Risk code	Risk title
					equipment.
3	0.746	0.488	0.166	A17	Not restraining tanks, placing tanks on top of each other, keeping tanks lying down, not using chains to store the tanks vertically, not using shade and resistant walls around them, and necessary natural ventilation.
3	0.746	0.488	0.166	A26	Welding and cutting in greasy and oily environments, unsafe and unprincipled maintenance of pressure vessels, not using flashback, throwing molten materials into flammable environments.
4	0.706	0.459	0.192	A18	Not using appropriate personal protective equipment (work clothes, safety helmets, shoes, filter masks, protective headphones, safety glasses, shields, etc.).
5	0.700	0.456	0.195	A1	Earthing and electrical connection of devices, non-insulated cables, depreciation of the electrical system of devices, and oil spilled on the floor of the repair shop.
5	0.700	0.456	0.195	A25	Not using a frame and buying a non-standard stone plate.
6	0.657	0.427	0.223	A27	Cutting oily environments, not carwashing the equipment before welding, improper storage of tanks, not using flashback, non-standard transportation, and not having a mobile carwash.
7	0.654	0.423	0.224	A20	Not performing a technical inspection of the equipment before starting work and performing work in an unprincipled manner.
8	0.651	0.423	0.226	A6	Using a faulty jack that is disproportionate to the machine's weight, not using four lathes under the truck cabin or the jack, and using a scaffolding tube to hold the truck.
8	0.651	0.423	0.226	A9	Damaged jack, no use of support.
8	0.651	0.423	0.226	A15	Not using personal protective equipment.
9	0.646	0.420	0.230	A10	Damaged jack, not use of the support or a right holder.
9	0.646	0.420	0.230	A23	Lack of car wash, improper car wash, and not having a mobile carwash.

Rank	Final score	The distance from the negative ideal	The distance from the positive ideal	Risk code	Risk title
9	0.646	0.420	0.230	A28	Not washing, drying, and cleaning the tank, not separating the tank before welding.
10	0.607	0.395	0.256	A11	Using of improper equipment, improper restraint of the truck cabin with safety equipment, using of improper jack, and jacking in improper conditions.
11	0.605	0.391	0.255	A5	Carelessness in moving things and unsafe transportation.
12	0.599	0.387	0.259	A7	Non-insulation of cables, depreciation of electrical system of devices, and lack of connection of the earthing system.
13	0.555	0.358	0.287	A14	Loose work clothes, carelessness, use of Chafee or handkerchief.
14	0.555	0.359	0.288	A3	Carelessness, not evacuating the service area to prevent contact with the paint.
15	0.550	0.355	0.291	A4	Carelessness, not following safety rules, spilling oil, starting a fire near flammable materials, smoking, and negligence.
16	0.500	0.322	0.322	A8	Carelessness, lack of protection in the transmission part.
16	0.500	0.322	0.322	A13	Wear, a wire connection.
17	0.254	0.166	0.488	A19	Using scaffolding tube to hold the room, insufficient strength of this tube, and risk of falling of this energized device.
18	0.203	0.134	0.525	A12	Standing on the bumper of the device in greasy and slippery conditions, turning on the device, checking the engine, and carelessness.

Discussion

In the present research, first, all the failure modes of the machinery maintenance unit were identified. Then, to assess and rank them, in addition to the three traditional attributes in FMEA (severity/S, occurrence/O, and detection/D) and calculate the RPN, we used fuzzy numbers corresponding to real-world problems instead of crisp numbers for risk ranking (20). Usually, FMEA results are recorded and presented in FMEA worksheets. The number of risks identified and investigated in this research was 67 and included 14 specific sheets or tables (Table 2). On the other hand, by using the analytic hierarchy process in the fuzzy environment and forming a Pairwise Comparison Matrix (PCM), a weight was determined for each of the attributes of severity, probability of occurrence, and detection based on their importance in the studied work environment (Table 3), and this made each attribute affect each failure mode based on its importance.

Thus, the proposed method for assessing RPN values in FMEA design is beneficial when two or more failure modes have the same RPN or when the assessment team does not have the same opinion on the ranking scale of attributes of severity, probability of occurrence, and detection (21). In the end, the fuzzy TOPSIS method was used to determine the final score of each of the risk factors, which, in addition to maintaining the simplicity of the FMEA method, leads to the possibility of using fuzzy numbers in the calculations of this method. By using the combination approach, the efficiency of the FMEA method has increased and this method can be used with more confidence than in the past (Table 4) (22).

Conclusions

The purpose of this research was to provide an approach to identify, assess, and prioritize risks using FMEA and fuzzy MADM methods. In the proposed approach, the main focus was on maintaining the simplicity of the FMEA method and increasing its efficiency by eliminating its shortcomings. Table 2 shows the results of occupational health and safety risk assessment using the FMEA method in a fuzzy environment. According to the obtained final score, occupational health and safety risks are divided into several levels in terms of consequences that lead to occupational injuries and accidents: Level 1 corresponds to risk with codes of A2, A16, A21, A24, A17, A26, A18, and A1, which are critical and have the highest importance. Level 2 is related to risk with codes of A25, A27, A20, A6, A9, A15, A10, A23, A28, and A11, which are very important, and level 3 is related to risk with codes of A5, A7, A14, A3, A4, A8, A13, A19, and A12 whose importance is less than other levels, but they are still very important. According to the intradepartmental ranking results of risk assessment, the highest final weights of the occupational health and safety risks extracted from the results of the combined method (in terms of the criticality of the risk) are related to code A2, which includes the use of a non-standard tool (such as a scaffolding tube to hold up a room), doing work in an unsafe manner (such as not using a lathe next to the jack), not technically inspecting the jacks, removing or emptying the key and jack during puncture repair and servicing (0.797%). Code A16 includes welding and cutting in oily environments and not carwashing equipment before welding, not properly maintaining tanks, not using flashback, non-standard transportation, and not mobile carwashing (0.797%). Code A21 includes welding tanks soaked in fuel or oil and not washing and drying the tanks before this work. (0.752%). Code A24 includes the contact of sharp and cutting objects with electric cables, unfavorable insulation of cables, welding in wet and humid environments, the presence of non-standard bypasses, inappropriate tools, and non-use of personal protective equipment (0.752%). Code A17 includes not keeping tanks, placing tanks on top of each other, storing tanks horizontally, not using chains to store tanks vertically, lack of shade, and resistant walls around it with necessary natural ventilation (0.746%). A general ranking was obtained for the most important risks in machinery maintenance. To manage risks and propose appropriate control criteria, a grouping was suggested according to the critical conditions of each risk. Risk management is not able to solve all risks at the same time and can only suggest appropriate solutions to manage them. Therefore, after identifying, analyzing, and assessing the risks, each risk should be controlled or eliminated. It should be noted that if this is not possible, they should be reduced to an acceptable level (23).

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