eISSN 2255-0569

ORIGINAL

Investigating the safety and health risks ranking in the hospital using the integrated approach of failure modes and effects analysis (FMEA) and Fuzzy- based Multiple Criteria Decision Making (MCDM) method

Investigación de la clasificación de los riesgos para la seguridad y la salud en el hospital mediante el enfoque integrado del análisis de los modos de fallo y los efectos (FMEA) y el método de toma de decisiones con criterios múltiples (MCDM) basado en Fuzzy

Hossein Armin[1], Somayeh Toussani[2], Seyed Nouredin Hosseini Gousheh[2], Reza Gholamnia[1,3], Shokooh Sadat Khaloo[1]

1. Graduated from Health, Safety and Environment, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran. 2. Social Determinants of Health Research Center, Yasuj University of Medical Sciences, Yasuj, Iran. 3. Workplace Health Promotion Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Corresponding author
Seyed Nouredin Hosseini Gousheh
Yasuj University of Medical Sciences, Yasuj, Iran
E-mail: nh_hse@yahoo.com.

Received: 21 - IX - 2021
Accepted: 14 - XI - 2021

doi: 10.3306/AJHS.2022.37.01.41

Abstract

Introduction: Hospitals are considered as one of the most risky and stressful work environments. Given the importance of the issue, it is necessary to evaluate the various occupational hazards factors to hospital staff in order to make appropriate decisions regarding their management and control. Nowadays, the use of Multiple Criteria Decision Making (MCDM) methods has become widespread in risk assessment and ranking. Therefore, the present study was conducted to determine the importance of occupational hazards and to rank the most important potential health and safety risks in the hospital.

Methods: In the present study, potential failure cases were identified in all wards of Shahid Beheshti Hospital in Yasouj (Yasouj, Iran) using the opinions of experts. The method of analysis of failure factors and its effects is one of the most widely used and traditional methods in risk assessment and management. However, there are limitations such as the same weight of severity indicators, the probability of occurrence and the ability to detect, as well as the same risk priority score. To eliminate the shortcomings in calculating the definite risk score and reduce inconsistencies in decision making as well as achieve more accurate results, the fuzzy TOPSIS method was used and then, the order of priority of different risks was determined using the fuzzy TOPSIS method.

Results: A total of 112 important risks were identified for the 14 main wards of the studied hospital (nursing and clinical wards, laboratory, operating room, CSR, radiology, MRI, kitchen, pharmacy, laundry, facilities, services, waste and administration), which threatens the safety and health of hospital staff. The highest significance of health risks was related to airborne pathogens, blood and other body fluids (including bacteria, viruses and parasites, 35.42% critical). The highest importance of safety risks was related to cuts caused by sharp tools (needle, angiocatheter, suture, razor, knife, 35.09% critical).

Conclusion: Using an integrated approach of failure analysis and its effects along with MCDM methods increases the speed of this process and obtains more reliable results.

Keywords: Risk assessment, failure analysis and its effects, fuzzy hierarchical analysis process, occupational safety and health.

Resumen

Introducción: Los hospitales están considerados como uno de los entornos laborales más arriesgados y estresantes. Dada la importancia del tema, es necesario evaluar los distintos factores de riesgo laboral para el personal de los hospitales con el fin de tomar decisiones adecuadas en cuanto a su gestión y control. En la actualidad, el uso de los métodos de toma de decisiones con criterios múltiples (MCDM) se ha generalizado en la evaluación y clasificación de riesgos. Por lo tanto, el presente estudio se llevó a cabo para determinar la importancia de los riesgos laborales y clasificar los riesgos potenciales más importantes para la salud y la seguridad en el hospital.

Métodos: En el presente estudio, se identificaron los casos de fallos potenciales en todas las salas del Hospital Shahid Beheshti de Yasouj (Yasouj, Irán) utilizando las opiniones de los expertos. El método de análisis de los factores de fallo y sus efectos es uno de los más utilizados y tradicionales en la evaluación y gestión de riesgos. Sin embargo, existen limitaciones como el mismo peso de los indicadores de gravedad, la probabilidad de ocurrencia y la capacidad de detección, así como la misma puntuación de prioridad de riesgo. Para eliminar las deficiencias en el cálculo de la puntuación definitiva de los riesgos y reducir las incoherencias en la toma de decisiones, así como lograr resultados más precisos, se utilizó el método TOPSIS difuso y, a continuación, se determinó el orden de prioridad de los diferentes riesgos mediante el método TOPSIS difuso.

Resultados: Se identificaron un total de 112 riesgos importantes para las 14 salas principales del hospital estudiado (salas de enfermería y clínica, laboratorio, quirófano, RSC, radiología, resonancia magnética, cocina, farmacia, lavandería, instalaciones, servicios, residuos y administración), que amenazan la seguridad y la salud del personal del hospital. La mayor importancia de los riesgos para la salud estaba relacionada con los patógenos transmitidos por el aire, la sangre y otros fluidos corporales (incluidas las bacterias, los virus y los parásitos, 35,42% de importancia crítica). La mayor importancia de los riesgos para la seguridad estaba relacionada con los cortes causados por herramientas afiladas (aguja, angiocatéter, sutura, navaja, cuchillo, 35,09% crítico).

Conclusión: El uso de un enfoque integrado de análisis de fallos y sus efectos junto con los métodos MCDM aumenta la velocidad de este proceso y obtiene resultados más fiables.

Palabras clave: Evaluación de riesgos, análisis de fallos y sus efectos, proceso de análisis jerárquico difuso, seguridad y salud en el trabajo.

Introduction

The hospital is the main and at the same time the most risky center for providing health services. Therefore, hospital staff are exposed to various occupational hazards[1]. In addition to providing the medical needs of patients, hospitals are also a place for education and research. Therefore, there are a large number of potential hazards such as: radiation, chemicals, toxins, biological hazards, heat, sound, dust and stress... in the hospital[2]. Due to the special conditions in the hospital in terms of crowds, the existence of complex equipment and devices as well as chemicals, exposure to hazardous factors in the workplace will be inevitable, if the principles of safety are not observed[3,4]. One of the main factors in health and safety management is risk assessment, which examines the status of the organization in order to ensure the success of health and safety programs[5]. Risk management is the creation of a culture and infrastructure in a logical and systematic way that enables the organization to minimize losses and maximize benefits[6].

Risk assessment is a valuable tool that can help managers and employees in various health sectors to improve the provision of care services. If health organizations identify, assess, and manage risks and hazards at a certain level in a certain way, then they will be able to reduce real and potential risks and identify opportunities for improving the health system[7]. Failure analysis and its effects is an engineering technique that is widely used to design, identify, and eliminate the potential or known risks, problems and errors from the system. This method provides a framework for analyzing the cause and effect of potential product defects[8]. In fact, analyzing failure modes and their effects is a powerful preventive method for risk management[9]. One of the most important problems in the risk assessment process is the existence of several parameters that affect the amount of risk. This leads to incorrect assessment of the level of risk. Therefore, it is necessary to use Multiple Criteria Decision Making (MCDM) methods to eliminate the effects of individual judgments of evaluators in the evaluation process[10].

The TOPSIS method was first proposed in 1981 and considered as one of the best multiple criteria decision making models in order to solving real-world problems[11]. This method is based on the concept that the selected option should have the shortest distance to the positive ideal solution (best possible case) and the maximum distance to the negative ideal solution (worst possible case). In this method, it is assumed that the desirability of each index is increasing or decreasing uniformly. The distance of an option from the positive or negative ideal is calculated through the Euclidean distance or as the absolute value of the linear distances, which depends on the exchange rate and the exchange between the indices[12]. However, in studies such as the study of Kutlu and Ekmekçioglu (2012), they used a combination of AHP, fuzzy FMEA and TOPSIS methods for risk assessment using D, O and S methods. In this method, the weight of three fuzzy AHP indices is calculated and the final ranking of failure cases is done by TOPSIS method[11]. In the study of Emblemsvåg and Kjølstad (2002), the factors influencing the risk assessment factors and resolve the ambiguity of the assessment process were investigated using fuzzy sets[13]. Jiang et al. (2017) proposed failure modes and effects analysis method based on a new fuzzy method that examines risk factors with fuzzy membership degree[14]. But in general, few studies have been conducted on risk assessment in the proposed method, especially in a hospital setting. Among the studies conducted in this field is the study of Dağsuyu et al. (2016) with the aim of comparing the traditional FMEA method and fuzzy FMEA[15]. In the study of Chanamool and Naenna (2016), failure factors were evaluated and prioritized using the fuzzy FMEA method[16]. Jamshidi et al. (2015) also suggested choosing the best strategy for maintaining sensitive devices in important wards of the hospital[17]. The risk assessment method in the present study was a comprehensive method, so that a widely used and appropriate method was used to initially identify risk centers, and then the best available software (BT Fuzzy Topsis Solver, which corresponds to mathematical equations) was used to model and determine the weight of criteria and ranking options[18].

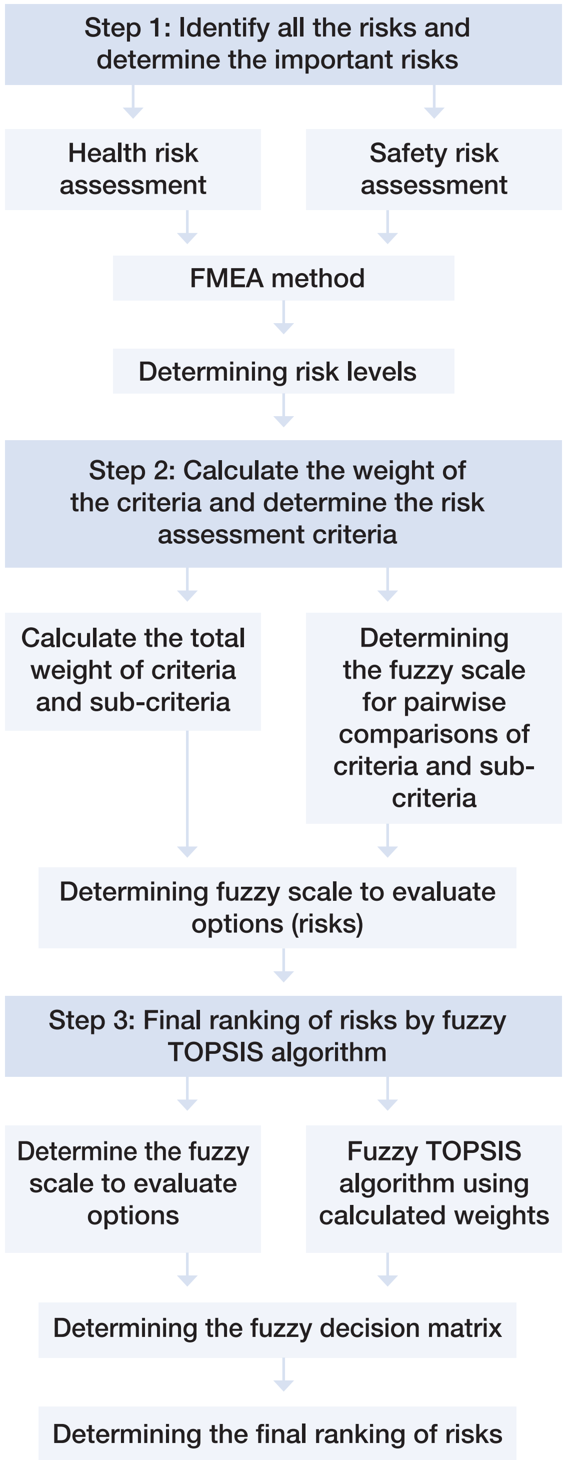
Although several studies have been conducted on the use of failure modes and effects analysis method in different work environments, however, this method has some limitations. Therefore, researchers have tried to compensate for its weaknesses by combining failure modes and effects analysis with other methods, such as multiple criteria decision making. In the present study, the primary foci of risk were first identified by the FMEA method. Then, the fuzzy logic method was used to determine the weight of the criteria and the order of priority of risks in Shahid Beheshti Hospital in Yasouj (Yasouj, Iran).

Materials and methods

Figure 1 shows the research method used in this study.

The present study was performed using the FMEA method in the hospital to assess occupational safety and health risks. At first, the risks of all hospital units were classified into two groups of health and safety risks in each hospital unit based on the literature review, observation and interview. Safety and health risks were identified and classified based on occupational injuries and occupational diseases, respectively. For this purpose, activities and resources have been identified through field visits and interviews with occupational health experts, and then the results of scoring and prioritizing risks have been performed according to the mentioned method

Figure 1: Research method.



(**Figure 1**). This method is based on the calculation and evaluation of risk scores, which are displayed by three tables of effect intensity, probability of occurrence and detectability. This method can only be used as a guide, so in the present study, the fuzzy approach allows experts to use verbal variables in order to evaluate the parameters of the risk assessment technique. Finally, the distance of options in the weighted matrix from the ideal - positive and negative points were determined as well as the final score of each option was determined (percentage of risk criticality)[19].

In order to estimate the risk values by FMEA method, the risk priority number (RPN) was calculated by multiplying the effect severity, occurrence probability and detectability (Equation 1).

[Equation 1]: RPN= S x O x D, where: (S) severity, (O) occurrence and (D) detectability.

In calculating the PRN number, it should be noted that the determination of numbers should be based on the type of activity of the organization. Corrective action should be considered mainly for hazards with high severity and occurrence rates. Given that individuals' judgments about preferences are often opaque in estimating the exact numerical value, fuzzy logic is useful for obtaining problems of ambiguity and uncertainty. Implementation of fuzzy TOPSIS technique in this research was performed in six stages. The decision matrix was created in the first stage.

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

Each column represents a measurement index and each row represents an option. Xij represents the quantity of the "I" option under the" J" sub-criterion. Also, the sub-criteria may be negative or positive depending on the effect on the options. In this study, verbal expressions and fuzzy numbers of **table I** have been used to evaluate the options for each criterion[20].

In the second step, the decision matrix was normalized. At this point we need to convert the fuzzy decision matrix of people's opinions into a matrix without fuzzy scale (R˜). In order to obtain the matrix R., it is sufficient to normalize the decision matrix based on the equation 3-1 and 3-2.

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

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \; and \; c_j^* = \max_i c_{ij} \qquad [4]$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \; and \; a_j^- = \min_i a_{ij} \qquad [5]$$

In the third step, a normal weight matrix was created: generate a matrix without fuzzy weight scale V˜ with the assumption of the vector W˜_ij based on the equation:

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

$$\tilde{v}_{ij} = \tilde{r}_{ij}.\tilde{w}_j \qquad [6]$$

Table I: Verbal expressions and fuzzy numbers for pairwise comparisons.

	Priorities			Fuzzy equivalent of priorities
	O	S	D	Low limit (L)
1	Almost impossible	None	Almost certain	(1,1,1)
2	Unlikely	Very low	Very much	(1,2,3)
3	Low	Insignificant	Much	(2,3,4)
4	Relatively low	Low	Relatively high	(3,4,5)
5	Medium	Medium	Medium	(4,5,6)
6	Relatively high	Significant	Low	(5,6,7)
7	High	High	Very low	(6,7,8)
8	Duplicate defects	Severe	Unlikely	(7,8,9)
9	Much	Dangerous with warnings	Very unlikely	(8,9,10)
10	Extremely high	Dangerous without warning	Almost impossible	(9,10,10)

In the fourth step, the values of positive and negative ideal were determined. In this step, positive and negative ideals were determined based on Equations 7 and 8[26]:

$$A^{+} = (\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*) \; where \; \tilde{v}_j^* = (\tilde{c}_j^*, \tilde{c}_j^*, \tilde{c}_j^*) \; and \; \tilde{c}_j^* = \max_i\{\tilde{c}_{ij}\} \quad [7]$$

$$A^{-} = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-) \; where \; \tilde{v}_j^- = (\tilde{a}_j^-, \tilde{a}_j^-, \tilde{a}_j^-) and \; \tilde{a}_j^- = \min_i\{\tilde{a}_{ij}\} \quad [8]$$

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

In the fifth step, the distance between the options and the ideals was calculated. The calculation of the sum of the distances of each component from the positive fuzzy ideal and the negative fuzzy ideal was obtained by the following equation (A and B are two fuzzy numbers):

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

$$D(A,B) = \sqrt{\frac{1}{3}[(a_2 - a_1)^2 + (b_2 - b_1)^2 + (c_2 - c_1)^2]} \quad [9]$$

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

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij} - \tilde{v}_j^*) \qquad i = 1,2,\dots,m \quad [10]$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij} - \tilde{v}_j^-) \qquad i = 1,2,\dots,m \quad [11]$$

In the sixth step, the similarity index to the ideal option (CL) was calculated using Equation 12:

$$Cl_i = \frac{d_i^-}{d_i^* + d_i^-} \qquad i = 1,2,\dots,m \quad [12]$$

In the seventh stage, the options were ranked in descending order of CL[21].

Results

Fuzzy TOPSIS

In the present study, the fuzzy TOPSIS method was used to rank hospital risks in two categories: health and safety. Therefore, risks were initially identified in 14 hospital wards. It was then scored by the 1 to 10 fuzzy spectrum of **table I** based on three criteria: risk severity (S), probability of occurrence (O) and detectability (D). This is the formation of the decision matrix and is given in **tables II** and **III**. Then, using Equations 4 and 5, the evaluation matrix was normalized and by Equation 6, the normal matrix was multiplied by the weight of the criteria to obtain the weighted matrix. Positive and negative ideals were then identified by Equations 7 and 8. Finally, the distance of the options in the weighted matrix from the positive and negative ideals was determined by equations 10 and 11. Equation 12 was used to determine the final score of each option (percentage of risk criticality). The results are given in **tables II** and **III**.

Discussion

Different modes of failure and its causes were identified in all wards of the hospital in the present study. Then, to evaluate and prioritize them, in addition to the three traditional indicators used in FMEA (severity, occurrence, and detection), we used a fuzzy integrated approach to rank hazards using fuzzy real-world numbers instead of definite numbers[22]. Then, in total, 112 important types of risks were identified separately from a large number of different risks in 14 sections and in 2 groups of safety and health risks and were classified using fuzzy TOPSIS method. According to the results of the in-class ranking of risk assessment, in the group of health risks, the highest risk scores were related to the following: pathogens (35.42%), night shift (32.08%), ergonomic factors (32.05%) and psychological factors (32.03%). In the group of safety risks, the highest final weights of the risks extracted from the results of the combined method were: Injuries caused by sharp objects (35.09%), electric shock (35.01%), slipping and falling (32.71%) and fire and burns (32.20%), respectively.

It should be noted that the overall ranking of the most important risks was obtained in all wards of the hospital, and accordingly, in order to manage the risks, a grouping was proposed according to the critical situation of each risk. It should be noted that risk management is not able to eliminate all risks simultaneously and can only suggest appropriate solutions to manage them. Therefore, each risk

Table II: Health risks.

Wards (sections)	The most important risk	S	O	D	Percentage of criticality	Rank
Clinical departments (Nursing)	Ergonomic (heavy workload, incorrect posture)	(2,3,4)	(3,4,5)	(5,6,7)	24.40%	3
	Airborne, blood and other body fluids pathogens (bacteria, viruses, parasites)	(2,3,4)	(4,5,6)	(6,7,8)	28.66%	1
	Night shift	(1,2,3)	(4,5,6)	(4,5,6)	32.08%	4
	Psychological factors (job stress-chronic fatigue)	(2,3,4)	(5,6,7)	(3,4,5)	32.05%	2
Clinical departments (Practical Nurse)	Ergonomic (improper posture - patient transport)	(2,3,4)	(4,5,6)	(5,6,7)	29.42%	2
	Night shift	(1,2,3)	(4,5,6)	(4,5,6)	24.31%	3
	Airborne, blood and other body fluids pathogens (bacteria, viruses, parasites)	(2,3,4)	(4,5,6)	(6,7,8)	31.55%	1
	Latex sensitivity	(1,2,3)	(2,3,4)	(2,3,4)	14.72%	4
Laboratory	Airborne, blood and other body fluids pathogens (bacteria, viruses, parasites)	(2,3,4)	(5,6,7)	(6,7,8)	35.42%	1
	Hazardous chemicals (solvents-acid and base)	(2,3,4)	(2,3,4)	(2,3,4)	18.28%	3
	Ergonomic (improper workstation, repetitive work, improper work tool)	(2,3,4)	(3,4,5)	(5,6,7)	28.02%	2
	Psychological factors (job stress-chronic fatigue)	(2,3,4)	(2,3,4)	(2,3,4)	18.28%	3
Operating room	Hazardous chemicals (anesthetic gases: N2O)	(3,4,5)	(3,4,5)	(5,6,7)	32.00%	1
	Ergonomic (heavy workload, incorrect posture)	(2,3,4)	(4,5,6)	(5,6,7)	28.29%	2
	Psychological factors (job stress-chronic fatigue)	(3,4,5)	(2,3,4)	(4,5,6)	24.03%	3
	Ionized and non-ionizing rays (X, alpha, laser, ultraviolet, beta, gamma)	(2,3,4)	(2,3,4)	(3,4,5)	19.00%	4
CSR	Hazardous chemicals (ethylene oxide - glutaraldehyde- mercury)	(2,3,4)	(3,4,5)	(6,7,8)	28.37%	2
	Airborne, blood and other body fluids pathogens (bacteria, viruses, parasites)	(2,3,4)	(3,4,5)	(5,6,7)	26.27%	3
	Ergonomic (improper posture - patient transport)	(2,3,4)	(4,5,6)	(5,6,7)	28.78%	1
	Latex sensitivity	(1,2,3)	(2,3,4)	(3,4,5)	16.57%	4
Radiology	Ionizing rays (X-rays and radioactive isotopes)	(2,3,4)	(4,5,6)	(6,7,8)	30.74%	1
	Night shift	(1,2,3)	(5,6,7)	(5,6,7)	28.23%	2
	Ergonomic (improper workstation, repetitive work)	(2,3,4)	(3,4,5)	(4,5,6)	23.97%	3
	Magnetic and electric fields	(2,3,4)	(2,3,4)	(2,3,4)	17.07%	4
MRI	Magnetic and electric fields	(2,3,4)	(4,5,6)	(6,7,8)	33.77%	1
	Non-ionizing radiation of radio waves	(2,3,4)	(2,3,4)	(4,5,6)	23.59%	3
	Psychological factors (job stress)	(2,3,4)	(2,3,4)	(2,3,4)	18.75%	4
	Ergonomic (improper workstation, repetitive work)	(2,3,4)	(3,4,5)	(3,4,5)	23.90%	2
Pharmacy	Ergonomic (long standing and sitting, repetitive tasks)	(2,3,4)	(3,4,5)	(3,4,5)	26.63%	2
	Psychological factors (disturbance of mental and physical balance due to repeated exposure)	(1,2,3)	(2,3,4)	(3,4,5)	20.21%	4
	Night shift	(1,2,3)	(5,6,7)	(3,4,5)	29.23%	1
	Contact with hand-made drugs or narcotics - drug abuse	(2,3,4)	(3,4,5)	(2,3,4)	23.94%	3
Kitchen	Ergonomic (pulling and lifting and repetitive tasks)	(2,3,4)	(4,5,6)	(4,5,6)	30.27%	2
	Foodborne Diseases (Escherichia coli, Salmonella, Staphylococcus aureus ..)	(2,3,4)	(2,3,4)	(2,3,4)	19.51%	3
	Thermal stress (increase in body temperature, excessive transpiration, workload, decrease in capacity and adaptation)	(3,4,5)	(3,4,5)	(4,5,6)	30.70%	1
	Psychological factors (job stress)	(2,3,4)	(2,3,4)	(2,3,4)	19.51%	3
Laundry	Hazardous chemicals (disinfectants-detergents)	(2,3,4)	(3,4,5)	(3,4,5)	23.76%	2
	Thermal stress (increase in body temperature, excessive transpiration, workload, decrease in capacity and adaptation)	(1,2,3)	(4,5,6)	(3,4,5)	23.46%	3
	Ergonomic (long standing, incorrect posture and excessive force)	(3,4,5)	(4,5,6)	(4,5,6)	32.05%	1
	Noise	(1,2,3)	(3,4,5)	(3,4,5)	20.73%	4
Waste	Ergonomic (prolonged standing work, incorrect posture and excessive force)	(2,3,4)	(4,5,6)	(6,7,8)	27.56%	2
	Hazardous infectious and chemical wastes	(3,4,5)	(5,6,7)	(6,7,8)	32.21%	1
	Thermal stress (cold and heat)	(1,2,3)	(4,5,6)	(4,5,6)	21.23%	3
	Noise	(1,2,3)	(3,4,5)	(4,5,6)	19.00%	4
Installations	Noise	(2,3,4)	(5,6,7)	(5,6,7)	30.18%	1
	Gases and vapors from welding and cutting	(2,3,4)	(3,4,5)	(4,5,6)	24.86%	3
	Thermal stress (cold and heat)	(2,3,4)	(2,3,4)	(2,3,4)	17.70%	4
	Ergonomic (incorrect posture and excessive force)	(3,4,5)	(2,3,4)	(4,5,6)	25.26%	2
Administrative	Ergonomic (long standing and sitting, repetitive tasks)	(2,3,4)	(4,5,6)	(3,4,5)	30.69%	1
	Light and brightness	(2,3,4)	(2,3,4)	(2,3,4)	25.82%	2
	Psychological factors (job stress)	(1,2,3)	(3,4,5)	(1,2,3)	22.33%	3
	Thermal stress (cold and heat)	(1,2,3)	(1,2,3)	(1,2,3)	15.15%	4
Services	Ergonomic (heavy carrying-patient handling)	(4,5,6)	(4,5,6)	(5,6,7)	31.39%	1
	Chemicals (disinfectants-detergents)	(2,3,4)	(5,6,7)	(3,4,5)	24.42%	3
	Airborne, blood and other body fluids pathogens (bacteria, viruses, parasites)	(2,3,4)	(3,4,5)	(6,7,8)	25.89%	2
	Dust (cleaning)	(2,3,4)	(4,5,6)	(1,2,3)	18.30%	4

should be controlled or eliminated, after identifying, analyzing and evaluating the risks. It should be noted that if this is not possible, they should be reduced to an acceptable level[23].

Conclusion

In this study, a new approach to prioritize failure modes was investigated in order to improve the risk priority number. The results obtained from the failure modes and effects analysis method used in this study show that if two or more failure modes have the same risk priority number, it is possible to evaluate and ranking the failure modes using risk prioritization codes. On the other hand, an attempt was made to determine the weight for each of the indicators of severity, probability of occurrence and detectability based on their importance using the method of hierarchical analysis process in fuzzy environment and

Table II: Safety risks.

Wards (sections)	The most important risk	S	O	D	Percentage of criticality	Rank
Clinical departments (Nursing)	Cutting and tearing caused by sharp tools (needle, angiocatheter, suture, razor, knife)	(2,3,4)	(3,4,5)	(2,3,4)	23.13%	3
	Electric shock	(2,3,4)	(2,3,4)	(2,3,4)	20.05%	4
	Slip and fall	(2,3,4)	(3,4,5)	(5,6,7)	31.02%	1
	Oxygen gas fire in case of leakage and burns	(3,4,5)	(2,3,4)	(3,4,5)	25.80%	2
Clinical departments (Practical Nurse)	Cutting and tearing caused by sharp tools (needle, angiocatheter, suture, razor, knife)	(2,3,4)	(4,5,6)	(2,3,4)	26.70%	2
	Slip and fall	(2,3,4)	(3,4,5)	(5,6,7)	32.71%	1
	Electric shock	(2,3,4)	(2,3,4)	(2,3,4)	20.49%	4
	Falling people (patient from bed or in elevator)	(4,5,6)	(1,2,3)	(1,2,3)	21.10%	3
Laboratory	Electric shock	(2,3,4)	(2,3,4)	(1,2,3)	19.56%	4
	Cutting and tearing caused by sharp tools (needle, angiocatheter, suture, razor, knife)	(2,3,4)	(4,5,6)	(4,5,6)	35.09%	1
	Burns and blisters (hot surfaces of sterile objects)	(2,3,4)	(2,3,4)	(2,3,4)	22.38%	3
	Slip and fall	(2,3,4)	(3,4,5)	(1,2,3)	22.98%	2
Operating room	Leakage and explosion of compressed and anesthetic gases	(3,4,5)	(1,2,3)	(3,4,5)	26.48%	2
	Cutting and tearing caused by sharp tools (needle, angiocatheter, suture, razor, knife)	(2,3,4)	(2,3,4)	(3,4,5)	26.36%	3
	Slip and fall	(2,3,4)	(3,4,5)	(2,3,4)	26.83%	1
	Electric shock	(2,3,4)	(2,3,4)	(1,2,3)	20.32%	4
CSR	Cutting and tearing caused by sharp tools (needle, angiocatheter, suture, razor, knife)	(2,3,4)	(3,4,5)	(2,3,4)	26.44%	1
	Slip and fall	(2,3,4)	(3,4,5)	(2,3,4)	26.44%	1
	electric shock	(3,4,5)	(2,3,4)	(1,2,3)	23.53%	4
	Elevator crash	(4,5,6)	(1,2,3)	(1,2,3)	23.60%	3
Radiology	Electric shock	(2,3,4)	(2,3,4)	(1,2,3)	23.95%	2
	Fire and burns	(2,3,4)	(2,3,4)	(1,2,3)	23.95%	2
	Conflict with moving parts of equipment and devices	(2,3,4)	(2,3,4)	(1,2,3)	23.95%	2
	Slip and fall	(2,3,4)	(3,4,5)	(1,2,3)	28.14%	1
MRI	Electric shock	(2,3,4)	(3,4,5)	(2,3,4)	29.66%	1
	Contact with sharp and win objects	(2,3,4)	(2,3,4)	(1,1,1)	18.23%	4
	Conflict with moving parts of equipment and devices	(2,3,4)	(2,3,4)	(2,3,4)	25.71%	3
	Slip and fall	(2,3,4)	(3,4,5)	(1,2,3)	26.39%	2
Pharmacy	Falling objects	(1,2,3)	(2,3,4)	(1,1,1)	18.60%	3
	Slip and fall	(2,3,4)	(2,3,4)	(1,2,3)	28.88%	2
	Electric shock	(2,3,4)	(3,4,5)	(1,2,3)	33.93%	1
	Cutting and tearing caused by winning tools	(1,2,3)	(2,3,4)	(1,1,1)	18.60%	3
Kitchen	Fire and burns caused by hot surfaces	(2,3,4)	(3,4,5)	(1,2,3)	23.31%	3
	Slip and fall	(2,3,4)	(4,5,6)	(1,2,3)	26.69%	1
	Unprotected equipment	(2,3,4)	(4,5,6)	(1,2,3)	26.69%	1
	Electric shock	(2,3,4)	(3,4,5)	(1,2,3)	23.31%	3
Laundry	Slip and fall	(2,3,4)	(2,3,4)	(1,2,3)	30.57%	1
	Electric shock	(2,3,4)	(4,5,6)	(4,5,6)	20.75%	3
	Elevator crash	(3,4,5)	(3,4,5)	(4,5,6)	27.92%	2
	Fire and burns	(1,2,3)	(2,3,4)	(2,3,4)	20.75%	3
Waste	Electric shock	(3,4,5)	(2,3,4)	(3,4,5)	17.94%	3
	Fire and burns	(4,5,6)	(1,2,3)	(2,3,4)	32.20%	2
	Cutting and tearing caused by winning tools	(3,4,5)	(2,3,4)	(2,3,4)	32.33%	1
	Slip and fall	(2,3,4)	(3,4,5)	(3,4,5)	17.53%	4
Installations	Electric shock	(3,4,5)	(1,2,3)	(1,2,3)	26.36%	1
	Danger of boiler explosion	(2,3,4)	(2,3,4)	(1,2,3)	23.66%	3
	Fire of heating devices, storage of flammable materials, defective wiring system	(2,3,4)	(1,2,3)	(1,2,3)	23.62%	4
	Throwing metal objects and particles, smoke	(3,4,5)	(3,4,5)	(3,4,5)	26.36%	1
Administrative	Fire	(2,3,4)	(3,4,5)	(2,3,4)	30.47%	1
	Electric shock	(3,4,5)	(3,4,5)	(1,2,3)	32.01%	2
	Slip and fall	(2,3,4)	(4,5,6)	(3,4,5)	29.35%	3
Services	Fire and explosion of cylinders	(2,3,4)	(2,3,4)	(1,2,3)	35.01%	1
	Elevator crash	(2,3,4)	(4,5,6)	(4,5,6)	22.14%	4
	Contact greasy hand of service with oxygen cylinder	(3,4,5)	(3,4,5)	(4,5,6)	22.64%	3
	Equipment and patient collide with cylinders	(1,2,3)	(2,3,4)	(2,3,4)	27.56%	2

formation of paired comparison matrix. This causes each of the indicators to effect on each failure mode based on their importance[24]. Fuzzy values were used to scoring three indices for each failure mode[25]. The use of an integrated approach leads to an increase in the efficiency of the FMEA method and greater confidence in the results[25]. Fuzzy Multi-criteria Risk Assessment method has been proposed to deal with obstacles and difficulties in calculating the definite risk score and reducing inconsistencies in decision making. In the present study, it has been tried to compensate the weaknesses of the case failure modes and effects analysis method by presenting new concepts and combining the FMEA method with Fuzzy- based Multiple Criteria Decision Making (MCDM) method. Therefore, in this respect, it is a completely new, comprehensive and accurate method that can be used by researchers, relevant officials, employers, companies, etc.

Interests conflict

The researchers declare that they have no conflict of interest.

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