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Ranking Occupational Risk Levels of Emergency Departments Using a New Fuzzy MCDM Model: A Case Study In Turkey

Elif Kılıç Delice[1,*] *and Salih Zegerek*[1,2]

[1] Department of Industrial Engineering, Atatürk University, 25240, Erzurum, Turkey
[2] Ugur Balkuv Triko A.Ş., Genç Osman Mah. Davutpaşa Cad. No:42, Güngören, 34165, İstanbul, Turkey

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Abstract: Health care personnel, particularly those working in emergency departments (EDs), perform activities involving various occupational risks from diseases to accidents. The identification of these risks are critical to taking effective preventive measures, which would improve the health and life quality of this professional group. However, risk assessment is a Multi-Criteria Decision Making (MCDM) problem involving quantitative and qualitative risk factors; it contains imprecise information from the lack of knowledge of health workers. In the present study, the new Fuzzy MCDM model is proposed incorporating the fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) and fuzzy Grey Relational Analysis (GRA) to rank the occupational risk levels of EDs considering the dependencies among risk factors. The proposed model is used to rank the risk levels of EDs of three hospitals according to risk factors in the city of Erzurum, Turkey. This study provides a reliable and effective model to obtain the risk levels in EDs and determine necessary precautions according to risk factors. However, proposed model can help managers obtain the risk levels in different hospital departments.

Keywords: fuzzy DEMATEL, fuzzy GRA, emergency department, occupational injuries and illnesses, risk factors

1 Introduction

When work hazards cannot be avoided, risks may occur, leading to work-related health problems, accidents, occupational diseases, and other disorders such as disability, incapacity for work, and absenteeism from work. The main objective in risk assessment is to take precautions against dangerous situations, and to reduce any hazard and health risk resulting from working conditions to an insignificant level for human health [1,2].

Risk assessment is of utmost importance in health care sector as its workers encounter numerous hazards at work, including needle stick injuries, back injuries, latex allergy, violence and stress. These hazards may be hindered or minimized, but still the injuries and illnesses that health care workers are exposed to in the workplace cannot be completely eliminated. Statistics reveals that nonfatal occupational injuries and illnesses are more common in health care sector than in other sectors such as agriculture and construction, which are commonly considered to pose the greatest work hazard [3]. Especially, healthcare workers in the EDs are subject to high rates of fatal and nonfatal injuries and illnesses as well as many occupational hazards [4,5]. EDs involve such duties as lifting patients and equipment, treating patients with infectious illnesses, handling hazardous chemical and body substances, and participating in the emergency transport of patients in ground and air vehicles, which overall increases the risk. These duties are risk factors which threaten seriously the physical and psychological well-being of healthcare workers. Once these risk factors are identified, some protective measures may be taken to improve the working conditions of the health professionals [6].

The recent studies on EDs focuses on different fields such as occupational hazards [7], violence and stress at work [8,9,10,11,12,13], burnout syndrome [14,15,16,17,18,19], performance evaluation [20,21] and patient and personnel satisfaction [22,23,24,25]. To the best of the authors' knowledge, the study which analyzes all of

* Corresponding author e-mail: elif.kdelice@atauni.edu.tr

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the risk factors together exposed ED workers has not been addressed in literature so far. This paper aims to propose a new fuzzy Multi Criteria Decision Making (MCDM) model to rank EDs considering all of the risk factors. No studies exist the risk assessment of EDs with MCDM methods has not been addressed. However, determining risk levels for EDs is a complex MCDM problem analyzing quantitative and qualitative risk factors or criteria, and a process entailing subjectivity, uncertainty and fuzzy conditions. Also, there are dependent and hierarchies among the risk criteria, so it is appropriate to use the proposed fuzzy MCDM model to rank EDs under a fuzzy environment. The proposed fuzzy MCDM model combines the fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) with fuzzy Grey Relational Analysis (GRA) methods. In this model, first, the decision making team (DMT) determines the risk criteria of EDs. Then, these risk criteria are weighted by the fuzzy DEMATEL method. To find the weights of the criteria, both the hierarchies among the criteria levels and interactions between the criteria in the same level are considered. Weights obtained through fuzzy DEMATEL method are further analyzed with fuzzy GRA method so that the rank of EDs according to risk levels are obtained. In recent studies, one can find several examples of the application of fuzzy DEMATEL and fuzzy GRA methods in various fields such as personnel selection, supplier selection, product selection, partner selection, prioritizing the compensation mechanisms, human resource management, service quality, logistics systems and green innovation [26,27,28,29,30,31,32,33,34,35]. However, there are no examples in the literature of combining fuzzy DEMATEL and fuzzy GRA methods to determine risk levels in the EDs.

A real world application for EDs in the city of Erzurum, Turkey, demonstrates the validity of the proposed model. Since 25% of people going to a hospital in Turkey are ED patients, it is crucial to secure the health and safety of ED staff [36]. Thus, this study is expected especially to make a significant contribution to the related managers of hospitals in Turkey.

The rest of the paper is structured as follows: Section 2 describes fuzzy DEMATEL and fuzzy GRA. Section 3 explores the proposed fuzzy MCDM model. Section 4 presents a real world example of this model and results and discussion are explained in section 5. Finally, section 6 presents conclusion and recommendations for future research.

2 Methodology

In this section, the fuzzy DEMATEL and fuzzy GRA are presented. Based on these basic concepts, a novel fuzzy MCMD model is proposed in the next section.

2.1 The fuzzy DEMATEL method

The DEMATEL method by Gabus and Fontela [37] has been widely used to reveal the hierarchical structure of criteria [38]. It is used not only to confirm the relationships among various criteria but also to seek the most accurate risk criteria weights. In this method, the relationships among criteria are generally expressed in crisp values to establish a structural model. However, crisp values may be inadequate, and evaluations made using crisp values may be flawed. Thus, the DEMATEL method is enriched by fuzzy set theory [39] to developed the modified fuzzy DEMATEL method which is briefly described as follows [27,40]:

Step 1. Setting up the direct relation fuzzy matrix: To measure the relationship between criteria $C_i = \{C_1, C_2, \ldots, C_n\}$, p experts were asked to make sets of pair-wise comparisons in linguistic terms and then convert triangular fuzzy numbers to linguistic terms so that p fuzzy matrices $\tilde{Z}^{(1)}, \tilde{Z}^{(2)}, \ldots, \tilde{Z}^{(p)}$ are obtained. $\tilde{Z}^{(k)}$ is the direct-relation fuzzy matrix of expert k, in which $\tilde{z}_{ij}^{(k)}$ indicates the degree to which the criterion C_i affects criterion C_j, and all principal diagonal elements $\tilde{z}_{ii}^{(k)}$ are set to zero as shown below:

$$\tilde{Z}^{(k)} = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \ldots & C_n \end{array} \\ \begin{bmatrix} 0 & \tilde{z}_{12}^{(k)} & \ldots & \tilde{z}_{1n}^{(k)} \\ \tilde{z}_{21}^{(k)} & 0 & \ldots & \tilde{z}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{n1}^{(k)} & \tilde{z}_{n2}^{(k)} & \ldots & 0 \end{bmatrix} \end{array}, \; k = 1, 2, \ldots, p \quad (1)$$

where $\tilde{z}_{ij}^{(k)} = (z_{ij,l}^{(k)}, z_{ij,m}^{(k)}, z_{ij,u}^{(k)})$.

Step 2. Normalizing the direct relation fuzzy matrix: A linear scale transformation is used in the normalization process [41], and the direct-relation fuzzy matrix is normalized. The normalized direct-relation fuzzy matrix of expert k, denoted as $\tilde{X}^{(k)}$ is expressed by:

$$\tilde{X}^{(k)} = \begin{bmatrix} \tilde{x}_{11}^{(k)} & \tilde{x}_{12}^{(k)} & \ldots & \tilde{x}_{1n}^{(k)} \\ \tilde{x}_{21}^{(k)} & \tilde{x}_{22}^{(k)} & \ldots & \tilde{x}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1}^{(k)} & \tilde{x}_{n2}^{(k)} & \ldots & \tilde{x}_{nn}^{(k)} \end{bmatrix}, \quad k = 1, 2, \ldots, p \quad (2)$$

$$x_{ij}^{(k)} = \frac{\tilde{z}_{ij}^{(k)}}{r^{(k)}} = \left(\frac{z_{ij,l}^{(k)}}{r^{(k)}}, \frac{z_{ij,m}^{(k)}}{r^{(k)}}, \frac{z_{ij,u}^{(k)}}{r^{(k)}}\right) \quad (3)$$

$$r^{(k)} = \max_{1 \le i \le n} \left(\sum_{j=1}^{n} z_{ij,u}^{(k)}\right) \quad (4)$$

It is assumed that at least one i such that $\sum_{j=1}^{n} z_{ij,u}^{(k)} < r^{(k)}$.

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The average matrix $\tilde{X}$ of the matrices $\tilde{X}^{(1)}, \tilde{X}^{(2)}, \ldots, \tilde{X}^{(p)}$ can be calculated by using following equation:

$$\tilde{X} = \frac{\tilde{X}^{(1)} \oplus \tilde{X}^{(2)} \oplus \ldots \oplus \tilde{X}^{(p)}}{p} \tag{5}$$

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \ldots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \ldots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \ldots & \tilde{x}_{nn} \end{bmatrix}$$

where $\tilde{x}_{ij}$ consists of $(x_{ij,l}, x_{ij,m}, x_{ij,u})$. $\tilde{X}$ is called the initialized direct relation fuzzy matrix which represents experts' opinion on the effect of each criterion on the others.

Every fuzzy number in this matrix can be calculated as:

$$\tilde{x}_{ij} = \frac{\sum_{k=1}^{p} \tilde{x}_{ij}^{(k)}}{p} \tag{6}$$

Step 3. Attaining the total relation matrix: The fuzzy numbers within $\tilde{X}$ can be separated into separate sub matrices, that is (X_l, X_m, X_u). It was proven that $\lim_{w\to\infty}(X_s)^w =$O and $\lim_{k\to\infty}(I + X_s + X_s^2 + \ldots + X_s^k) = (I - X_s)^{-1}, \forall s = l, m, u$, where O is the null matrix and I is the identity matrix [42]. The total relation fuzzy matrix $\tilde{T}$ can be acquired by calculating the following term:

$$\tilde{T} = \lim_{w\to\infty}(\tilde{X} + \tilde{X}^2 + \ldots + \tilde{X}^w) = \tilde{X}(I - \tilde{X})^{-1}$$

$$= \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \ldots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \ldots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \ldots & \tilde{t}_{nn} \end{bmatrix} \tag{7}$$

where $\tilde{t}_{ij} = (t_{ij,l}, t_{ij,m}, t_{ij,u})$ is the overall influence rating of all experts for each criterion i against criterion j.

Step 4. Producing a causal diagram: The sum of rows and columns of the sub-matrices T_l, T_m, T_u, which are denoted by the fuzzy numbers $\tilde{D}_i$ and $\tilde{R}_i$ can be obtained using equations (8-9), respectively:

$$\tilde{D}_i = \sum_{j=1}^{n} \tilde{t}_{ij}; \quad i = 1, 2, \ldots, n \tag{8}$$

$$\tilde{R}_i = \sum_{i=1}^{n} \tilde{t}_{ij}; \quad j = 1, 2, \ldots, n \tag{9}$$

The defuzzification of $\tilde{D}_i$ and $\tilde{R}_i$ using equation (10) results in $\tilde{D}_i^{def}$ and $\tilde{R}_i^{def}$, respectively [43].

$$s(\tilde{x}_{ij}, 0) = 1/4(x_{ij,l} + 2x_{ij,m} + x_{ij,u}) \tag{10}$$

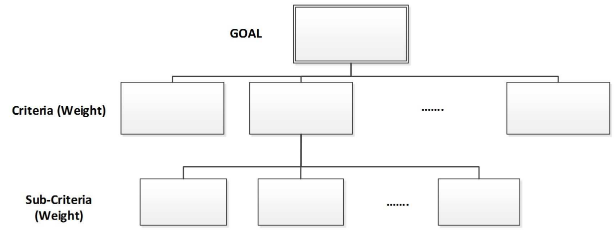

Fig. 1: Representation of goal, criteria, hierarchy and weights determination.

Then, the causal diagram can be obtained by mapping the ordered pairs of $(\tilde{D}_i^{def} + \tilde{R}_i^{def})$ and $(\tilde{D}_i^{def} - \tilde{R}_i^{def})$, where the horizontal axis $(\tilde{D}_i^{def} + \tilde{R}_i^{def})$ is called "prominence" and vertical axis $(\tilde{D}_i^{def} - \tilde{R}_i^{def})$ is called "relation" [27].

Step 5: Obtaining the weights of the criteria: Baykasoğlu et al. [28] considered both the hierarchies among the criteria levels and the interactions between the criteria in the same level to assess the weights of the criteria (Figure 1). Firstly, the weight of each criterion in each level of the hierarchy was calculated and normalized through equation (11) and equation (12), respectively [27]:

$$\omega_i = \{(\tilde{D}_i^{def} + \tilde{R}_i^{def})^2 + (\tilde{D}_i^{def} - \tilde{R}_i^{def})^2\}^{1/2} \tag{11}$$

$$w_i = \frac{\omega_i}{\sum_{i=1}^{n} \omega_i} \tag{12}$$

where w_i $(i = 1, 2, \ldots, n)$ represents the normalize weight of any criterion to be used in the decision making process. W matrix, representing the weights at the lowest level of the hierarchy after multiplying each level in the hierarchy, is obtained using the following equation [28]:

$$W = w_m w_s \tag{13}$$

where w_m and w_s are weights of the main criteria and sub-criteria [28].

2.2 The fuzzy GRA method

The GRA method, which was created by Deng Julong [44] and which has been widely used to solve the uncertainty problems under the discrete data and incomplete information, is part of the grey system theory [45]. In contrast to the traditional mathematical analysis, GRA provides a simple scheme to analyze the series of relationships or the system behavior even when there is little data. The major advantages of the GRA method are that the results are based on the original data, and the calculations are simple and straightforward. It has been widely used to solve the uncertainty problems with fuzzy

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set theory is applied to the GRA method. In the current study, the fuzzy GRA method [46] is used and this method is briefly described as follows:

Step 1: Constructing the fuzzy decision matrix: The structure of the fuzzy decision matrix can be expressed as follows:

$$\tilde{A}^{(k)} = \begin{bmatrix} \tilde{a}_{11}^{(k)} & \tilde{a}_{12}^{(k)} & \dots & \tilde{a}_{1n}^{(k)} \\ \tilde{a}_{21}^{(k)} & \tilde{a}_{22}^{(k)} & \dots & \tilde{a}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1}^{(k)} & \tilde{a}_{n2}^{(k)} & \dots & \tilde{a}_{nn}^{(k)} \end{bmatrix}, \quad k = 1,2,\dots,p \tag{14}$$

The linguistic rating $\tilde{a}_{ij}^{(k)}$ are identified by kth decision-maker to represent the performance of ith alternative under jth criteria. Here, $\tilde{a}_{ij}^{(k)}$ consists of $(a_{ij,l}^{(k)}, a_{ij,m}^{(k)}, a_{ij,u}^{(k)})$. The average fuzzy decision matrix of $\tilde{A}^{(1)}, \tilde{A}^{(2)}, \dots, \tilde{A}^{(p)}$ can be calculated as follows:

$$\tilde{A} = \frac{\tilde{A}^{(1)} \oplus \tilde{A}^{(2)} \oplus \dots \oplus \tilde{A}^{(p)}}{p} \tag{15}$$

Every fuzzy number in this matrix can be calculated as:

$$\tilde{a}_{ij} = \frac{\sum_{k=1}^{p} \tilde{a}_{ij}^{(k)}}{p} \tag{16}$$

Step 2. Normalizing average fuzzy decision matrix: To calculate the grey relational grade, the average fuzzy decision matrix is normalized and defuzzied using equations (21-22). $\tilde{R}$ denotes the normalized fuzzy decision matrix:

$$\tilde{R} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix} \tag{17}$$

The larger the target value, the better it is:

$$r_{ij} = \frac{1}{4}\left(\frac{a_{ij,l}}{a_{j,u}^{+}} + 2\frac{a_{ij,m}}{a_{j,u}^{+}} + \frac{a_{ij,u}}{a_{j,u}^{+}}\right); \quad i = 1,2,\dots,m; \quad j = 1,2,\dots,n \tag{18}$$

$$a_{j,u}^{+} = \max_i a_{ij,u}$$

The smaller the target value, the better it is:

$$r_{ij} = \frac{1}{4}\left(\frac{a_{j,l}^{-}}{a_{ij,u}} + 2\frac{a_{j,l}^{-}}{a_{ij,m}} + \frac{a_{j,l}^{-}}{a_{ij,l}}\right); \quad i = 1,2,\dots,m; \quad j = 1,2,\dots,n \tag{19}$$

$$a_{j,l}^{-} = \max_i a_{ij,l}$$

Step 3. Determining the positive and negative ideal solutions: The fuzzy positive ideal solution (A^+) and fuzzy negative ideal solution (A^-) can be defined as:

$$A^+ = (r_1^+, r_2^+, \dots, r_n^+); \quad j = 1,2,\dots,n \tag{20}$$

$$r_j^+ = \max_i \{r_{ij}\} \tag{21}$$

$$A^- = (r_1^-, r_2^-, \dots, r_n^-); \quad j = 1,2,\dots,n \tag{22}$$

$$r_j^- = \min_i \{r_{ij}\} \tag{23}$$

Step 4. Calculating grey relational coefficient: The calculation of the fuzzy grey relational coefficient of ith alternative from A^+ and A^- using the equations (24-25), respectively is as follows:

$$\zeta_{ij}^{+}(r_j^+, r_{ij}) = \frac{\min_i \min_j |r_j^+ - r_{ij}| + \rho \max_i \max_j |r_j^+ - r_{ij}|}{|r_j^+ - r_{ij}| + \rho \max_i \max_j |r_j^+ - r_{ij}|} \quad i = 1,2,\dots,m; \quad j = 1,2,\dots,n \tag{24}$$

$$\zeta_{ij}^{-}(r_j^-, r_{ij}) = \frac{\min_i \min_j |r_j^- - r_{ij}| + \rho \max_i \max_j |r_j^- - r_{ij}|}{|r_j^- - r_{ij}| + \rho \max_i \max_j |r_j^- - r_{ij}|} \quad i = 1,2,\dots,m; \quad j = 1,2,\dots,n \tag{25}$$

where distinguishing coefficient $\rho \in [0,1]$ is usually $\rho = 0.5$.

Step 5. Obtaining the grey relational grade: The fuzzy grey relational grade of ith alternative from the positive and negative ideal solutions can be obtained as follows:

$$\zeta_i^+ = \sum_{j=1}^{n} w_j * \zeta_{ij}^+; \quad i = 1,2,\dots,m \tag{26}$$

$$\zeta_i^- = \sum_{j=1}^{n} w_j * \zeta_{ij}^-; \quad i = 1,2,\dots,m \tag{27}$$

where w_j represents the importance of jth criterion.

Step 6. Calculating the relative closeness to the ideal solution: The calculation of relative closeness of ith alternative with respect to ideal solution A^+ is shown below:

$$\zeta_i = \frac{\zeta_i^-}{\zeta_i^+ + \zeta_i^-}; \quad i = 1,2,\dots,m \tag{28}$$

Step 7. Ranking the priority: The alternatives can be ranked according to the ascending order of ζ_i.

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3 Proposed Fuzzy MCDM Model

This model, composed of fuzzy DEMATEL and fuzzy GRA methods, consists of three basic stages: (1) data gathering, (2) fuzzy DEMATEL computations, (3) fuzzy GRA computations and determination of the final rank.

In the first stage, the risk criteria are determined and the decision hierarchy is formed. Then, the decision hierarchy is approved by decision making team (DMT).

In the second stage, the risk criteria are assigned weights by means of fuzzy DEMATEL. To find the weights of the criteria, both the hierarchies among the criteria levels and interactions between the criteria in the same level are considered.

In the third stage, Fuzzy GRA is used to obtain the rank of alternative EDs according to the risk levels. Here, criterion weights obtained from the fuzzy DEMATEL procedure are used grey relational grade. Finally, ranking of the EDs respect risk levels is determined. Schematic diagram of the proposed model for ranking of the EDs is provided in Figure 2.

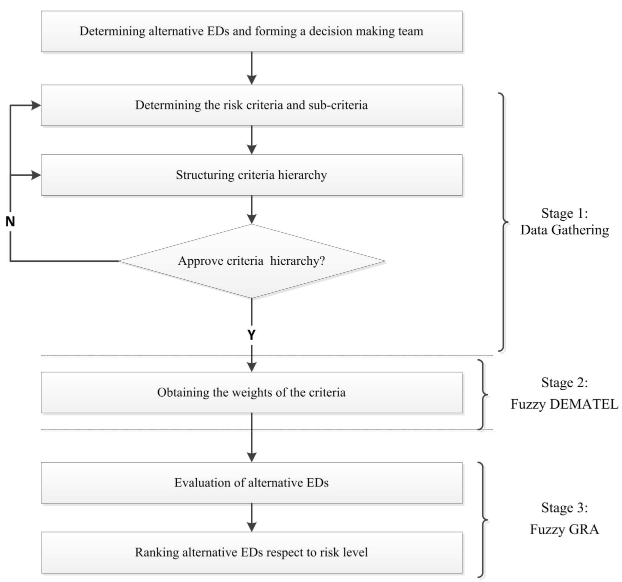

Fig. 2: Schematic representation of the proposed model for risk assessment.

4 Numerical Application of the Proposed Model

The purpose of this application is to identify risk factors that health care workers are exposed to in EDs and to rank alternatives EDs respect to risk levels. In this application, ranking risk levels of EDs of three hospitals (Atatürk University Research Hospital, Erzurum Palandöken State Hospital, and Erzurum Regional Training and Research Hospital) in the city of Erzurum, Turkey was carried out using proposed fuzzy MCDM model.The abbreviations of ED_1 , ED_2 and ED_3 are used mazily to mention EDs of these hospitals to conceal real names because of their privacy policy. A DMT consisted of 15 healthcare workers (doctors, nurses and emergency medicine technicians) working in the EDs of the above mentioned three hospitals was formed. The results of the application in each stage are then explained.

4.1 Data gathering stage

At this stage, firstly, risk criteria are found through a comprehensive literature review [1,6,47,48,49]. Then, for ED_1, ED_2, and ED_3, eight risk criteria and forty risk sub-criteria are selected according to the views of DMT, and a risk criteria hierarchy is formed (Table 1). Finally, the risk criteria hierarchy is approved by DMT.

4.2 Determining the criteria weights using the fuzzy DEMATEL method

In this stage, after forming the risk criteria hierarchy for the problem, the weights of the criteria to be used in evaluation process are calculated by using fuzzy DEMATEL method. The fuzzy DEMATEL method starts with the direct-relation fuzzy matrices $\tilde{Z}^{(1)},\tilde{Z}^{(2)},\ldots,\tilde{Z}^{(15)}$, which are all obtained by holding fuzzy pairwise comparison matrices. Hence, the DMT created fuzzy pairwise comparison matrices for the criteria and sub-criteria. Each expert in the DMT identified the relationships among the evaluation criteria and sub-criteria in linguistic terms (*very low, low, medium, high, very high*), which was followed by corresponding triangular fuzzy numbers (Table 2).

Upon the determination of direct-relation fuzzy matrices, these matrices were normalized using equations (3-4), and thus, normalized direct-relation fuzzy matrices $\tilde{X}^{(1)},\tilde{X}^{(2)},\ldots,\tilde{X}^{(15)}$ were obtained. Then, the initial direct-relation matrix ($\tilde{X}$) was calculated using equations (5-6). Table 3 shows $\tilde{X}$ matrix for the risk criteria. The total-relation fuzzy matrix ($\tilde{T}$) was then acquired using equation (7). Table 4 shows $\tilde{T}$ matrix for the risk criteria. Finally, $(\tilde{D}_i^{def}+\tilde{R}_i^{def})$ and $(\tilde{D}_i^{def}-\tilde{R}_i^{def})$ were calculated for the risk criteria using equations (8-10), and also, the weights of the main criteria were calculated using equations (11-12). Table 5 shows the prominence, relation and weights of the main risk criteria. The prominence, relation and weights of sub-criteria were computed following the same steps. Then, equation (13) was used to find the final weights of sub-criteria. Table 6 shows the

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Table 1: Risk criteria for ED_1, ED_2 and ED_3.

Criteria	Sub-criteria	Explanations
Infection risks (C_1)	$C_{1.1}$	Infection through blood or body fluid contact with skin
	$C_{1.2}$	Infection through blood or body fluid contact with eyes
	$C_{1.3}$	Respiratory tract diseases caught through inhalation
	$C_{1.4}$	Sharp object injuries during intervention on patient
Hazardous waste risks (C_2)	$C_{2.1}$	Chemical/biological/medical waste accidents
	$C_{2.2}$	Hazards associated with the inappropriate use of sharps bins/bags
Risks associated with the misuse of medical equipment (C_3)	$C_{3.1}$	Injuries and burns due to the misuse of oxygen cylinder
	$C_{3.2}$	Lack of medication and equipment, devices without a certificate or devices with invalid calibration, faulty/obsolote equipment, risks associated with equipment
	$C_{3.3}$	Injuries due to spillage and splash of chemicals
	$C_{3.4}$	Electricity burn that occur while using a defibrillator
	$C_{3.5}$	Fire due to medical equipment
	$C_{3.6}$	Exposure to radiation during radiography
Accident risks due to lack of sleep/exhaustion after night shift (C_4)	$C_{4.1}$	Car accidents due to driving after night shift
	$C_{4.2}$	Accidents at hospital due to exhaustion, carelessness and lack of concentration
Allergy risks (C_5)	$C_{5.1}$	Latex allergy resulting from the use of gloves
	$C_{5.2}$	Allergy resulting from the use of disinfectants and hand antiseptics
	$C_{5.3}$	Reaction to medication as a result of the splash of medication
Ergonomic risks (C_6)	$C_{6.1}$	Injuries due to disorganized arrangement of objects in the work environment and the fall of non-fixed objects
	$C_{6.2}$	Musculoskeletal disorders or vascular diseases due to standing for a long period of time
	$C_{6.3}$	Disorders due to inappropriate situations and working positions (patient handling and moving)
	$C_{6.4}$	Falling, sprain and wounds due to wet/slippery floor
	$C_{6.5}$	Complaints due to lack of resting place and time
	$C_{6.6}$	Impairments/accidents due to lack of necessary protection
	$C_{6.7}$	Impairments due to noise
	$C_{6.8}$	Illnesses associated with ventilation (anxiety, exhauistion, allergy)
	$C_{6.9}$	Complaints due to heat, moisture and dust
	$C_{6.10}$	Problems due to lack of enough ambient light
	$C_{6.11}$	Food poisoning
	$C_{6.12}$	Illnesses resulting from water, sewage and sanitation problems
Risks due to insecure work environment and communication problems (C_7)	$C_{7.1}$	Physical abuse (assault, pounding etc.)
	$C_{7.2}$	Verbal abuse (insult, threat, slander etc.)
	$C_{7.3}$	Sexual abuse (verbal or physical)
	$C_{7.4}$	Problems with workers or administration
	$C_{7.5}$	Theft
Psychosocial health risks (C_8)	$C_{8.1}$	Burnout syndrome
	$C_{8.2}$	Anxiety disorder
	$C_{8.3}$	Sleep disorder
	$C_{8.4}$	Various drug and substance addictions
	$C_{8.5}$	Risk of suicide
	$C_{8.6}$	Discomfort, stress, temper, rage

Table 2: Linguistic scales for the importance weight of the criteria and the rating of the alternative [50].

Linguistic variable	Corresponding triangular fuzzy numbers
Very Low (VL)	$(0, 0.1, 0.3)$
Low (L)	$(0.1, 0.3, 0.5)$
Medium (M)	$(0.3, 0.5, 0.7)$
High (H)	$(0.5, 0.7, 0.9)$
Very High (VH)	$(0.7, 0.9, 1.0)$

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Table 3: Initial direct-relation fuzzy matrix for the criteria.

Criteria	C_1	C_2	C_3	C_4
C_1	(0.000,0.000,0.000)	(0.021,0.029,0.037)	(0.029,0.037,0.041)	(0.029,0.037,0.041)
C_2	(0.046,0.059,0.082)	(0.000,0.000,0.000)	(0.021,0.029,0.037)	(0.029,0.037,0.041)
C_3	(0.041,0.046,0.059)	(0.046,0.059,0.082)	(0.000,0.000,0.000)	(0.012,0.021,0.029)
C_4	(0.041,0.046,0.059)	(0.041,0.046,0.059)	(0.059,0.082,0.137)	(0.000,0.000,0.000)
C_5	(0.059,0.082,0.137)	(0.082,0.137,0.412)	(0.137,0.412,0.000)	(0.137,0.412,0.000)
C_6	(0.041,0.046,0.059)	(0.046,0.059,0.082)	(0.059,0.082,0.137)	(0.059,0.082,0.137)
C_7	(0.041,0.046,0.059)	(0.046,0.059,0.082)	(0.059,0.082,0.137)	(0.059,0.082,0.137
C_8	(0.046,0.059,0.082)	(0.059,0.082,0.137)	(0.059,0.082,0.137)	(0.082,0.137,0.412)
Criteria	C_5	C_6	C_7	C_8
C_1	(0.012,0.021,0.029)	(0.0290.037,0.041)	(0.029,0.037,0.041)	(0.021,0.029,0.037)
C_2	(0.004,0.012,0.021)	(0.021,0.029,0.037)	(0.021,0.029,0.037)	(0.012,0.021,0.029)
C_3	(0.000,0.004,0.012)	(0.012,0.021,0.029)	(0.012,0.021,0.029)	(0.012,0.021,0.029)
C_4	(0.000,0.004,0.012)	(0.012,0.021,0.029)	(0.012,0.021,0.029)	(0.004,0.012,0.021)
C_5	(0.000,0.000,0.000)	(0.029,0.037,0.041)	(0.029,0.037,0.041)	(0.029,0.037,0.041)
C_6	(0.041,0.046,0.059)	(0.000,0.000,0.000)	(0.004,0.012,0.021)	(0.004,0.012,0.021)
C_7	(0.041,0.046,0.059)	(0.082,0.137,0.412)	(0.000,0.000,0.000)	(0.012,0.021,0.029)
C_8	(0.041,0.046,0.059)	(0.082,0.137,0.412)	(0.059,0.082,0.137)	(0.000,0.000,0.000)

Table 4: Total-relation fuzzy matrix for the criteria.

Criteria	C_1	C_2	C_3	C_4
C_1	(0.000,0.008,0.017)	(0.000,0.029,0.048)	(0.000,0.029,0.048)	(0.000,0.025,0.035)
C_2	(0.003,0.043,0.073)	(0.017,0.008,0.022)	(0.017,0.023,0.042)	(0.015,0.018,0.029)
C_3	(0.032,0.046,0.088)	(0.002,0.061,0.097)	(0.011,0.008,0.023)	(0.009,0.019,0.031)
C_4	(0.032,0.062,0.098)	(0.041,0.089,0.156)	(0.002,0.084,0.132)	(0.009,0.009,0.019)
C_5	(0.036,0.062,0.112)	(0.046,0.089,0.172)	(0.045,0.126,0.168)	(0.002,0.099,0.077)
C_6	(0.038,0.066,0.121)	(0.046,0.087,0.195)	(0.056,0.103,0.249)	(0.045,0.073,0.130)
C_7	(0.038,0.092,0.138)	(0.046,0.101,0.246)	(0.053,0.108,0.287)	(0.040,0.086,0.160)
C_8	(0.045,0.099,0.147)	(0.050,0.127,0.272)	(0.054,0.123,0.271)	(0.044,0.104,0.157)
Criteria	C_5	C_6	C_7	C_8
C_1	(0.000,0.022,0.034)	(0.000,0.023,0.034)	(0.000,0.019,0.026)	(0.000,0.018,0.024)
C_2	(0.013,0.017,0.029)	(0.014,0.016,0.029)	(0.012,0.014,0.023)	(0.012,0.012,0.019)
C_3	(0.008,0.014,0.027)	(0.008,0.014,0.027)	(0.007,0.012,0.022)	(0.005,0.012,0.020)
C_4	(0.006,0.022,0.038)	(0.005,0.022,0.038)	(0.005,0.018,0.030)	(0.006,0.016,0.026)
C_5	(0.012,0.009,0.021)	(0.012,0.022,0.038)	(0.010,0.018,0.029)	(0.009,0.017,0.026)
C_6	(0.049,0.082,0.150)	(0.010,0.008,0.025)	(0.008,0.014,0.030)	(0.008,0.013,0.028)
C_7	(0.002,0.107,0.155)	(0.055,0.110,0.207)	(0.004,0.008,0.023)	(0.004,0.019,0.037)
C_8	(0.045,0.102,0.201)	(0.002,0.122,0.226)	(0.002,0.066,0.123)	(0.009,0.008,0.022)

Table 5: Prominences, relations and weights of the criteria.

Criteria	$\tilde{D}_i^{def}+\tilde{R}_i^{def}$	$\tilde{D}_i^{def}-\tilde{R}_i^{def}$	ω_i	$w_i(w_m)$
C_1	0.647	-0.341	0.731	0.101
C_2	0.827	-0.492	0.962	0.133
C_3	0.864	-0.469	0.983	0.135
C_4	0.739	-0.095	0.745	0.103
C_5	0.810	0.040	0.811	0.112
C_6	0.871	0.169	0.887	0.122
C_7	0.862	0.516	1.005	0.138
C_8	0.914	0.672	1.135	0.156

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Table 6: Weights of the sub-criteria.

Sub-criteria	ω_i	$w_i(w_s)$	W	**Sub-criteria**	ω_i	$w_i(w_s)$	W	**Sub-criteria**	ω_i	$w_i(w_s)$	W
$C_{1.1}$	1.101	0.274	0.028	$C_{5.2}$	1.245	0.301	0.034	$C_{7.2}$	0.712	0.176	0.024
$C_{1.2}$	0.909	0.226	0.023	$C_{5.3}$	1.509	0.365	0.041	$C_{7.3}$	0.696	0.172	0.024
$C_{1.3}$	0.993	0.247	0.025	$C_{6.1}$	1.082	0.174	0.021	$C_{7.4}$	0.715	0.177	0.024
$C_{1.4}$	1.012	0.252	0.025	$C_{6.2}$	0.797	0.128	0.016	$C_{7.5}$	0.822	0.203	0.028
$C_{2.1}$	1.296	0.500	0.066	$C_{6.3}$	0.804	0.129	0.016	$C_{8.1}$	0.964	0.239	0.037
$C_{2.2}$	1.297	0.500	0.066	$C_{6.4}$	0.811	0.130	0.016	$C_{8.2}$	0.609	0.151	0.024
$C_{3.1}$	1.133	0.216	0.029	$C_{6.5}$	0.760	0.122	0.015	$C_{8.3}$	0.564	0.140	0.022
$C_{3.2}$	0.725	0.138	0.019	$C_{6.6}$	0.750	0.120	0.015	$C_{8.4}$	0.586	0.145	0.023
$C_{3.3}$	0.708	0.135	0.018	$C_{6.7}$	0.746	0.120	0.015	$C_{8.5}$	0.555	0.138	0.022
$C_{3.4}$	0.722	0.138	0.019	$C_{6.8}$	0.732	0.118	0.014	$C_{8.6}$	0.757	0.188	0.029
$C_{3.5}$	0.746	0.142	0.019	$C_{6.9}$	0.759	0.122	0.015				
$C_{3.6}$	1.216	0.232	0.031	$C_{6.10}$	0.716	0.115	0.014				
$C_{4.1}$	1.330	0.500	0.051	$C_{6.11}$	0.835	0.134	0.016				
$C_{4.2}$	1.330	0.500	0.051	$C_{6.12}$	0.932	0.150	0.018				
$C_{5.1}$	1.384	0.334	0.037	$C_{7.1}$	1.098	0.272	0.038				

second level weights (sub-criteria weights) after multiplying first level weights (criteria weights) in the hierarchy.

As seen in Table 5 and Table 6, “Psychosocial health risks” (C_8) and “risks due to insecure work environment and communication problems” (C_7) are identified as two most important main criteria. “Chemical/biological/ medical waste accidents” ($C_{2.1}$) and “Hazards associated with the inappropriate use of sharps bins/bags” ($C_{2.2}$) are two most important sub-criteria influencing the risk level of EDs at the end of this evaluation.

4.3 Ranking risk levels of EDs using fuzzy GRA

At this stage, fuzzy GRA method is used to determine the risk levels of EDs using criteria weights obtained via fuzzy DEMATEL method. Hence, EDs are ranked respect to risk levels and ED which has the highest risk level is selected. Firstly, eight DMT members, each of whom had worked in all three EDs, composed eight fuzzy decision matrices based on linguistic terms (Table 2). Then, the average fuzzy decision matrix was obtained from fuzzy decision matrices using equations (15-16) as shown in Table 7. The average fuzzy decision matrix was normalized and defuzzied using equation (18-19). The A^+ and A^- values can also be obtained using equations (20-23), and fuzzy grey relation coefficient can be determined from A^+ and A^- using equations (24-25) as shown in Table 8.

The fuzzy grey relation grade of each alternative for the positive and negative ideal solutions can be obtained using equations (26-27). Here, criterion weights (w_j) were obtained via Fuzzy DEMATEL method (Table 5 and 6).

The fuzzy grey rational grade is determined as follows:

$$\zeta_{ED_1}(r_j^+, r_{ij}) = 0.881, \qquad \zeta_{ED_1}(r_j^-, r_{ij}) = 0.514$$
$$\zeta_{ED_2}(r_j^+, r_{ij}) = 0.611, \qquad \zeta_{ED_2}(r_j^-, r_{ij}) = 0.656$$
$$\zeta_{ED_3}(r_j^+, r_{ij}) = 0.535, \qquad \zeta_{ED_3}(r_j^-, r_{ij}) = 0.836$$

Finally, the relative closeness of the *i*th alternative to ideal solution A^+ can be obtained using equation (28). The relative closeness to the ideal solution is determined as follows:

$$\zeta_{ED_1} = 0.369, \quad \zeta_{ED_2} = 0.517, \quad \zeta_{ED_3} = 0.610$$

Among the three EDs in the study, ED_1 has the highest risk level. ED_2 and ED_3 take the second and third place respectively. Therefore, the managers of ED_1 should take more precautions against occupational diseases and accidents than those of ED_2 and ED_3.

5 Results and Discussion

In ED_1, ED_2, and ED_3 the number of staff, particularly specialists, is extremely insufficient. Consequently, the number of patients per medical staff is above the standards. Moreover, in all of the EDs, the physical conditions are adverse, the workplace conditions are not designed ergonomically, the safety regulations are insufficient, and workload is immense, so it is increasingly likely that the risk criteria discussed in this study will emerge and their impact will be greater. Also, the necessary precautions, which are listed below, based on the most importance risk factors determined via the proposed fuzzy MCDM model are taken to reduce risk levels of ED_1, ED_2 and ED_3. These precautions have been considered for implementation at EDs by the hospital administration.

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Table 7: The fuzzy numbers of average decision making matrix.

Alternative	$C_{1.1}$			$C_{1.2}$			$C_{1.3}$			$C_{1.4}$		
ED_1	0.313	0.475	0.638	0.438	0.625	0.788	0.400	0.575	0.738	0.413	0.600	0.763
ED_2	0.300	0.475	0.675	0.363	0.550	0.750	0.338	0.525	0.725	0.388	0.575	0.750
ED_3	0.325	0.500	0.688	0.313	0.500	0.700	0.363	0.550	0.738	0.413	0.600	0.763
Alternative	$C_{2.1}$			$C_{2.2}$			$C_{3.1}$			$C_{3.2}$		
ED_1	0.263	0.450	0.638	0.325	0.500	0.675	0.200	0.375	0.575	0.263	0.425	0.600
ED_2	0.238	0.425	0.613	0.250	0.425	0.613	0.160	0.325	0.525	0.150	0.325	0.525
ED_3	0.213	0.400	0.600	0.200	0.375	0.575	0.160	0.325	0.525	0.225	0.400	0.600
Alternative	$C_{3.3}$			$C_{3.4}$			$C_{3.5}$			$C_{3.6}$		
ED_1	0.263	0.450	0.638	0.075	0.225	0.425	0.200	0.375	0.575	0.425	0.625	0.813
ED_2	0.188	0.375	0.575	0.113	0.275	0.475	0.150	0.325	0.525	0.400	0.600	0.800
ED_3	0.213	0.400	0.600	0.075	0.225	0.425	0.200	0.325	0.575	0.400	0.600	0.800
Alternative	$C_{4.1}$			$C_{4.2}$			$C_{5.1}$			$C_{5.2}$		
ED_1	0.470	0.675	0.850	0.525	0.725	0.888	0.425	0.625	0.813	0.338	0.525	0.713
ED_2	0.330	0.513	0.675	0.475	0.675	0.863	0.325	0.525	0.725	0.250	0.450	0.650
ED_3	0.370	0.575	0.750	0.425	0.625	0.813	0.300	0.500	0.700	0.250	0.450	0.650
Alternative	$C_{5.3}$			$C_{6.1}$			$C_{6.2}$			$C_{6.3}$		
ED_1	0.150	0.350	0.550	0.150	0.350	0.550	0.400	0.600	0.788	0.425	0.625	0.800
ED_2	0.175	0.375	0.575	0.175	0.375	0.575	0.470	0.675	0.863	0.400	0.600	0.788
ED_3	0.200	0.400	0.600	0.250	0.450	0.650	0.450	0.650	0.838	0.375	0.575	0.763
Alternative	$C_{6.4}$			$C_{6.5}$			$C_{6.6}$			$C_{6.7}$		
ED_1	0.350	0.550	0.725	0.475	0.675	0.838	0.375	0.575	0.763	0.275	0.475	0.675
ED_2	0.200	0.400	0.600	0.425	0.625	0.813	0.450	0.650	0.850	0.400	0.600	0.800
ED_3	0.300	0.500	0.688	0.375	0.575	0.750	0.450	0.650	0.838	0.400	0.600	0.788
Alternative	$C_{6.8}$			$C_{6.9}$			$C_{6.10}$			$C_{6.11}$		
ED_1	0.380	0.575	0.750	0.338	0.525	0.713	0.275	0.475	0.663	0.400	0.600	0.763
ED_2	0.330	0.525	0.713	0.313	0.500	0.700	0.300	0.500	0.688	0.350	0.550	0.725
ED_3	0.430	0.625	0.800	0.438	0.625	0.825	0.300	0.500	0.700	0.288	0.475	0.675
Alternative	$C_{6.12}$			$C_{7.1}$			$C_{7.2}$			$C_{7.3}$		
ED_1	0.325	0.525	0.713	0.425	0.625	0.800	0.550	0.750	0.900	0.138	0.300	0.488
ED_2	0.375	0.575	0.763	0.450	0.650	0.838	0.520	0.725	0.888	0.175	0.350	0.538
ED_3	0.375	0.575	0.763	0.350	0.550	0.750	0.470	0.675	0.850	0.150	0.325	0.513
Alternative	$C_{7.4}$			$C_{7.5}$			$C_{8.1}$			$C_{8.2}$		
ED_1	0.425	0.625	0.788	0.425	0.625	0.788	0.575	0.775	0.925	0.575	0.775	0.925
ED_2	0.350	0.550	0.738	0.375	0.575	0.763	0.550	0.750	0.913	0.575	0.775	0.925
ED_3	0.313	0.500	0.688	0.350	0.550	0.738	0.425	0.625	0.800	0.525	0.725	0.888
Alternative	$C_{8.3}$			$C_{8.4}$			$C_{8.5}$			$C_{8.6}$		
ED_1	0.620	0.825	0.963	0.400	0.600	0.788	0.250	0.450	0.638	0.550	0.750	0.900
ED_2	0.620	0.825	0.963	0.425	0.625	0.800	0.300	0.500	0.688	0.525	0.725	0.888
ED_3	0.550	0.750	0.900	0.288	0.475	0.663	0.238	0.425	0.613	0.400	0.600	0.775

Psychosocial health risks (C_8):

- Providing psychological support to the personnel,
  - To provide health personnel an organizational support in order to establish a satisfaction about their job,
  - To provide social facilities to hospital personnel,
  - Vocational training must be concentrated on,
  - The places where the health personnel work and relax must be designed according to the ergonomic factors.

Risks due to insecure work environment and communication problems (C_7):

- Health personnel must be trained about communication, stress management, and fury management,
- Security precautions must be established efficiently and their life safety must be provided,
- An efficient communication with the patients and their relatives must be established about the illness and treatments,
- There must be comfortable waiting zones, and patients and visitors who have delay in service acquisition.

“Chemical/biological/medical waste accidents” ($C_{2.1}$), “Hazards associated with the inappropriate use of sharps bins/bags” ($C_{2.2}$):

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Table 8: The corresponding data in calculation process.

Criterion	Indicator rating			Ideal solution		$\zeta_{ij}^{+}(r_j^{+}, r_{ij})$			$\zeta_{ij}^{+}(r_j^{-}, r_{ij})$		
	ED$_1$	**ED**$_2$	**ED**$_3$	r_j^{+}	r_j^{-}	**ED**$_1$	**ED**$_2$	**ED**$_3$	**ED**$_1$	**ED**$_2$	**ED**$_3$
$C_{1.1}$	0.494	0.500	0.523	0.523	0.494	0.333	0.391	1.000	1.000	0.692	0.333
$C_{1.2}$	0.643	0.575	0.523	0.643	0.523	1.000	0.468	0.333	0.333	0.536	1.000
$C_{1.3}$	0.594	0.549	0.571	0.594	0.549	1.000	0.333	0.500	0.333	1.000	0.500
$C_{1.4}$	0.617	0.594	0.617	0.617	0.594	1.000	0.333	1.000	0.333	1.000	0.333
$C_{2.1}$	0.468	0.442	0.419	0.468	0.419	1.000	0.484	0.333	0.333	0.517	1.000
$C_{2.2}$	0.519	0.445	0.396	0.519	0.396	1.000	0.452	0.333	0.333	0.559	1.000
$C_{3.1}$	0.396	0.347	0.347	0.396	0.347	1.000	0.333	0.333	0.333	1.000	1.000
$C_{3.2}$	0.445	0.344	0.422	0.445	0.344	1.000	0.333	0.689	0.333	1.000	0.392
$C_{3.3}$	0.468	0.393	0.419	0.468	0.393	1.000	0.333	0.434	0.333	1.000	0.590
$C_{3.4}$	0.247	0.295	0.247	0.295	0.247	0.333	1.000	0.333	1.000	0.333	1.000
$C_{3.5}$	0.396	0.344	0.396	0.396	0.344	1.000	0.333	1.000	0.333	1.000	0.333
$C_{3.6}$	0.646	0.623	0.623	0.646	0.623	1.000	0.333	0.333	0.333	1.000	1.000
$C_{4.1}$	0.695	0.529	0.591	0.695	0.529	1.000	0.333	0.443	0.333	1.000	0.573
$C_{4.2}$	0.744	0.698	0.646	0.744	0.646	1.000	0.517	0.333	0.333	0.484	1.000
$C_{5.1}$	0.646	0.545	0.519	0.646	0.519	1.000	0.386	0.333	0.333	0.709	1.000
$C_{5.2}$	0.545	0.468	0.468	0.545	0.468	1.000	0.333	0.333	0.333	1.000	1.000
$C_{5.3}$	0.364	0.390	0.416	0.416	0.364	0.333	0.500	1.000	1.000	0.500	0.333
$C_{6.1}$	0.364	0.390	0.468	0.468	0.364	0.333	0.400	1.000	1.000	0.667	0.333
$C_{6.2}$	0.620	0.698	0.672	0.698	0.620	0.333	1.000	0.600	1.000	0.333	0.429
$C_{6.3}$	0.643	0.620	0.594	0.643	0.594	1.000	0.517	0.333	0.333	0.484	1.000
$C_{6.4}$	0.565	0.416	0.516	0.565	0.416	1.000	0.333	0.605	0.333	1.000	0.426
$C_{6.5}$	0.692	0.646	0.591	0.692	0.591	1.000	0.525	0.333	0.333	0.477	1.000
$C_{6.6}$	0.594	0.675	0.672	0.675	0.594	0.333	1.000	0.926	1.000	0.333	0.342
$C_{6.7}$	0.494	0.623	0.620	0.623	0.494	0.333	1.000	0.952	1.000	0.333	0.339
$C_{6.8}$	0.594	0.545	0.646	0.646	0.545	0.492	0.333	1.000	0.508	1.000	0.333
$C_{6.9}$	0.545	0.523	0.653	0.653	0.523	0.377	0.333	1.000	0.741	1.000	0.333
$C_{6.10}$	0.490	0.516	0.519	0.519	0.490	0.333	0.818	1.000	1.000	0.360	0.333
$C_{6.11}$	0.614	0.565	0.497	0.614	0.497	1.000	0.545	0.333	0.333	0.462	1.000
$C_{6.12}$	0.542	0.594	0.594	0.594	0.542	0.333	1.000	1.000	1.000	0.333	0.333
$C_{7.1}$	0.643	0.672	0.571	0.672	0.571	0.633	1.000	0.333	0.413	0.333	1.000
$C_{7.2}$	0.766	0.744	0.695	0.766	0.695	1.000	0.611	0.333	0.333	0.423	1.000
$C_{7.3}$	0.318	0.367	0.341	0.367	0.318	0.333	1.000	0.484	1.000	0.333	0.517
$C_{7.4}$	0.640	0.568	0.519	0.640	0.519	1.000	0.457	0.333	0.333	0.552	1.000
$C_{7.5}$	0.640	0.594	0.568	0.640	0.568	1.000	0.440	0.333	0.333	0.579	1.000
$C_{8.1}$	0.792	0.769	0.643	0.792	0.643	1.000	0.767	0.333	0.333	0.371	1.000
$C_{8.2}$	0.792	0.792	0.744	0.792	0.744	1.000	1.000	0.333	0.333	0.333	1.000
$C_{8.3}$	0.841	0.841	0.766	0.841	0.766	1.000	1.000	0.333	0.333	0.333	1.000
$C_{8.4}$	0.620	0.643	0.494	0.643	0.494	0.767	1.000	0.333	0.371	0.333	1.000
$C_{8.5}$	0.464	0.516	0.442	0.516	0.442	0.418	1.000	0.333	0.622	0.333	1.000
$C_{8.6}$	0.766	0.744	0.617	0.766	0.617	1.000	0.767	0.333	0.333	0.371	1.000

- The control, gathering, decomposition, and transportation of the wastes must be done according to the hospital's waste management plan.
- The personnel have to use mask or glasses, or the management has to provide it if there is the risk of splashing of body fluids during the operation.

In addition to these precautions, to reduce the risk level in EDs, the working and relaxation hours of the personnel must be organized according to their physical and mental workload capacities because excessive tiredness and sleeplessness are the main reasons which could cause occupational accidents and illnesses. Besides these, providing sufficient amount of the health personnel and the improvements in the physical conditions of the hospital are going to be efficient in decreasing the risks of occupational accidents and illnesses.

There has to be an Occupational Health and Safety Unit at the hospital in order to protect the health personnel against the risks which are mentioned in this article. This unit is responsible for avoiding the risks or at least decreasing them. Also, Occupational Health and Safety Unit fulfil the educations about the work security

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and health of the personnel (ergonomic dangers and risks) and participation of the personnel to these trainings. Furthermore, informing the personnel about the risks at the beginning and in certain periods, taking precautions about the risks, evaluation and reporting of these risks, and proposing to the management are the responsibilities of this unit. In addition to these, it would be useful to employ health personnel like nurses and doctors, and specialists from the other disciplines in order to determine and avoid the said risks.

There are still some hospitals which do not have Occupational Health and Safety Unit, although most of them have. For this reason, the government necessitates establishing this unit in big hospitals and working with institutions providing work security and health service for the smaller hospitals till the end of 2016. We also note that, in all three EDs that we consider in this study, there is an ongoing construction process for the Occupational Health and Safety Unit. As a result of this; by taking precautions in a more precise and systematic manner, the risk that the health personnel are exposed to will decrease and more qualified service to the patients will be provided.

6 Conclusion

This study is aim to propose a fuzzy MCDM model identify the occupational risk factors in EDs and rank alternative EDs according to the risk levels they entail. In the fuzzy MCDM model, the fuzzy DEMATEL technique was used to reveal the relationships among various risk criteria and the weights of risk criteria. Moreover, the Fuzzy GRA method was used to rank the risk levels of EDs based on the risk criteria weights. To our knowledge, no study has so far combined the fuzzy DEMATEL and fuzzy GRA methods to determine risk levels in the EDs. Also, the fuzzy MCDM approach to the risk assessment of EDs was adopted for the first time.

This proposed fuzzy MCDM model provides to help the mangers both determination the risk levels of EDs and taking precautions against occupational diseases and accidents considering risk factors more easily. Also, this model considers both personnel' opinions and hospital's work conditions so that the risk assessment can be more comprehensive. The proposed the fuzzy MCDM model can help decision makers obtain the risk levels in different hospital departments. Finally, it is hoped that this study will contribute substantially to the related literature.

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Elif Kılıç Delice is Assistant Professor of Industrial Engineering at Atatürk University, Erzurum, Turkey. In 2010, she received her PhD degree in Industrial Engineering at Gazi University, Ankara, Turkey. Her main research interests are: industrial design and human factors, work study, multi criteria decision making and fuzzy programming.

Salih Zegerek is working as a planning expert at Ugur Balkuv Triko company in Istanbul, Turkey. In 2014, he received his MSc degree in Industrial Engineering at Atatürk University. His main research interests are: industrial design and human factors and multi criteria decision making.

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