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A hybrid method of Fuzzy DEMATEL/AHP/VIKOR approach to rank and select the best hospital nurses of a Years: A case study

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ABSTRACT

Nowadays, hospitals are considered as one of the most important service industries in which nurses play a vital role. Indeed, the patient's safety will be treated and the hospital credibility will be lost, if the hospital nurses do not carry out their tasks properly. In this paper, an integration of Fuzzy Decision Making Trial and Evaluation (FDEMATEL), Fuzzy Hierarchy Process Analysis (FAHP), and Fuzzy VIKOR (FVIKOR) is proposed to select the best hospital nurses of a year regarding to some qualitative and quantitative criteria. Firstly, FDEMATEL method is used to identify the most important criteria of the problem and then FAHP approach is utilized to determine the weight importance of the criteria. Finally, prioritizing of the hospital nurses is done by FVIKOR method and the proposed method is implemented in a real-world case study of one of the most prominent hospitals in the north of Iran, for the first time. The results illustrate that the proposed method is very functional and effective in both selecting and ranking the hospital nurses process.

1. Introduction

Hospitals are considered as one of the most important service provider in field of health care and patients' health depends on selecting the qualified nurses. Because, if the best doctors or surgeons do the best but the nurses do not, probably doctors' efforts would be useless. On the other word, nurses are considered as a member or coordinator of the health promotion team and they play a major role to improve, prevent and treatment of diseases. To the above mentioned, the issue of selecting the best hospital nurses in the year is a vital problem in which researchers have a particular interest to make the best decision close to the actual results. On the other hands, in choosing a qualified person both, academic and non-academic qualities are evaluated and the main point is that in most cases individual selection is done by interview or individual judgment.

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The substantial drawback of this approach is that while experienced managers avoid bias, their views are affected by their bias in most cases [1]. To solve the mentioned problem, make the best decision close to the actual results, and prioritize the available alternative, utilizing multi-choice decision-making techniques (MCDM) seems the best way.

FDEMATEL is one of the decision making methods based on paired comparisons that examines the interrelationship between the criteria and determines their associated importance numerically. In addition, it can convert the cause-and-effect relationships into a structural-visual model and identify the interdependencies between the agents. FAHP is the other well-known MCDM approach for the personal selection problems in which some considered criteria are weighted based on their importance and the candidates are assessed according to these criteria as well. Finally, the final score belongs to the most qualified candidate. The other well-known MCDM approach is FVIKOR that focuses on categorizing and selecting a set of alternatives of the problem in case of dealing with uncertainties, opposite and suitable criteria.

In this paper, a hybrid approach of FDEMATEL, FAHP and FVIKOR is proposed for selecting and prioritizing the best hospital nurses in a year. To evaluate the effectiveness and application of the proposed method, one of the most prominent hospitals located in north of Iran country is considered as a real case study for the first time. Furthermore, a team of 25 experts is selected to evaluate the performance of 25 qualified nurses based on 10 criteria and 30 vital sub-criteria (see Fig 1). Firstly, FDEMATEL approach is used to identify the most effective criteria and secondly, determining the weight importance of these evaluation criteria is done by FAHP method.

Finally, FVIKOR technique is applied to find the best prioritize of the hospital nurses. The reason of using these fuzzy methods is that the theory of fuzzy is a powerful tool for dealing with uncertainties, randomness, and ambiguity in the personnel selection problems [2, 3]. Based on our best knowledge and according to Table 1 that illustrates a summary of studies in personnel selection problems, no study has been conducted on the evaluation and selection of hospital nurses whereas the nurses, like doctors, play an essential role in patient health.

To the above mentioned, this paper proposes a hybrid approach of FDEMATEL, FAHP and FVIKOR for selecting and prioritizing the best hospital nurses in a year. The main contributions of this paper which differentiate our study from those already published in this field of study are as follows:

- designing a new health care problem for selecting and prioritizing the best hospital nurses in a year.
- utilizing an integrated method of DEMATEL, AHP and VIKOR in a fuzzy environment to select and prioritize the best hospital nurses in a year.
- implementing the presented approach in a real case study for the first time.

The rest of article is organized as follows: Section 2 provides a summary of literature review related to the problem. In Section 3, a hybrid FDEMATEL, FAHP and, FVIKOR is presented. The next section is dedicated to implementing the proposed method in a real case study. Finally, a few significant conclusions and suggestions for the future studies are presented in the final section.

2. Literature review

One of the most interesting topics that attracts researchers' attention, recently is the personal selection, which is considered as a multi-criteria decision problem [4-7]. In these types of problems, identifying effective criteria has a great importance and it is very difficult to estimate the experts' opinion based on numerical values. Because their opinions are based on imprecise and subjective judgments. Hence, the FDEMATEL approach is one of the suitable tools for determining these criteria and it has been successful used in many studies because of utilizing linguistic variables [8-10]. In other study, Salimi et al. [8] used hybrid approach of Network Analysis Process (ANP) and DEMATEL to select the best strategy of appropriate knowledge management. They examined Ansar Bank of Kermanshah province as a case study and they analyzed obtained data by using Super Decision software and SPSS. Eventually, they have selected a hybrid strategy seeking codification strategy as the dominant strategy in the organization [8].

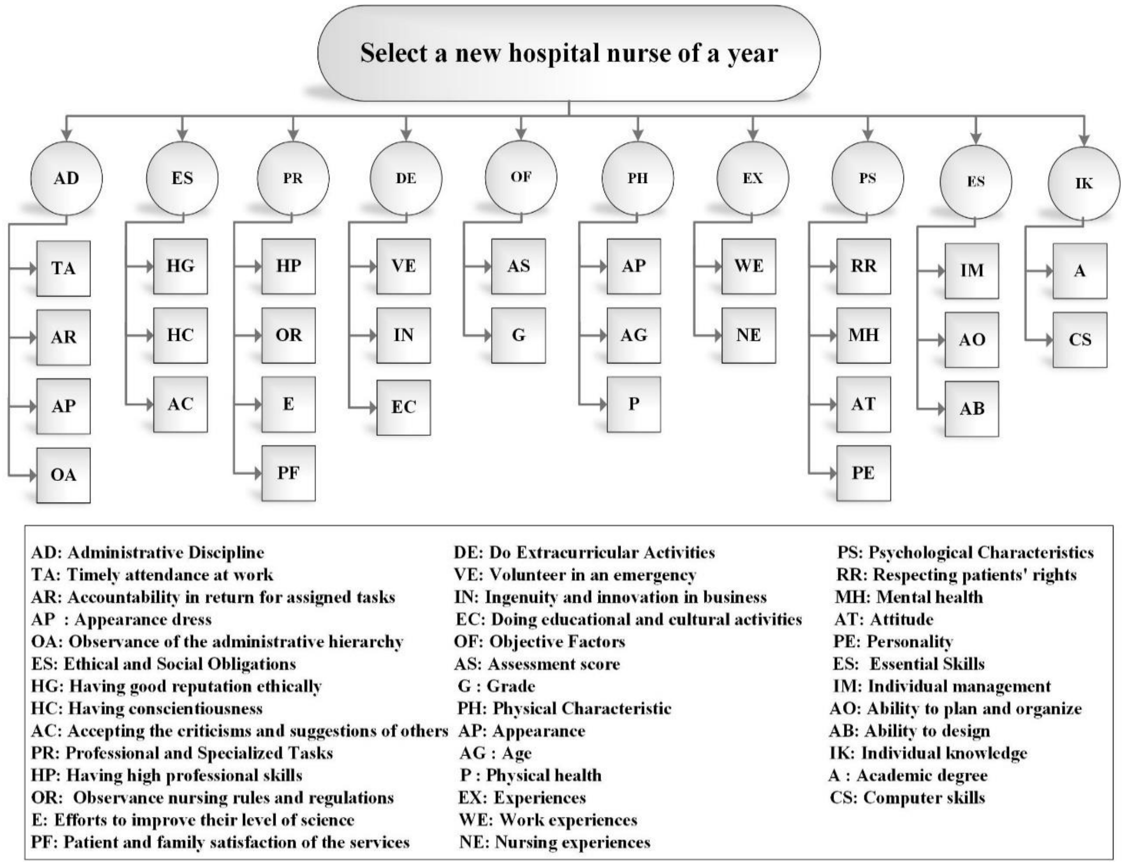

Fig ١. Criteria and sub-criteria considered for hospital nurses' selection

There are different techniques such as AHP, TOPSIS, ELECTRE, the theory of complex sets, and multi-objective programming for solving multi-criteria decision-making problems [11]. Compared to other multi-criteria decision-making approaches, AHP technique is widely used in multi-criteria decision making and other issues, successfully [6, 12]. AHP method has emerged as a useful decision- making technique for solving and analyzing the complex problems. Indeed, the AHP converts a complex problem to several simple problems and solve them [13]. For example, MacIntyre et al. [12] illustrated how the AHP and Expert Choice methods can be transformed into an integrated overall decision-making process. To this end, they have investigated a case study of construction management and engineering of Department of Civil Engineering and Construction at North Dakota State University and the manager's final selection is done through the AHP method and decision support program of Expert Choice software [12]. However, since the AHP technique is incapable of dealing with the vague decision-making problems, it has been criticized by some critics.

The other technique of multi-criteria decision-making is the VIKOR approach that evaluates the alternatives based on criteria in order to prioritize them. For example, Asgharizad et al. [14] utilized the 360-degree evaluation and VIKOR method as the decision-making technique to combine two evaluation methods of the manager performance in terms of four features: individual characteristics, human skills, perceptual skills, and technical skills in order to achieve the appropriate ranking of the managers. They reviewed the statistical sample of 30 managers of the Engineering Research Institute and they obtained the performance evaluation criteria and the associated weights using theoretical foundations, Delphi method and due to the expert opinions, respectively [14].

The main problem of utilizing the VIKOR method is that this technique is not capable of dealing with uncertainties or the issues with suitable and opposite criteria. Therefore, the combination of AHP and VIKOR methods in a fuzzy environment seems the best way to achieve the benefits of these methods and deal with the uncertainty and ambiguity in the evaluation process. As one among the carried studies, Ghazi Hosseini et al. [15] attempt to propose a model to achieve the scientific evaluation of the mineral water industry by Fuzzy AHP and VIKOR in order to identify the decision criteria and prioritize the companies due to the best and worst criteria. Also, five mineral water companies: Persam, Plover, Damavand, Solar, and Nova were selected as case studies and according to the weights obtained by the fuzzy AHP method and using the VIKOR method, the final ranking of the companies was studied by them [15].

According to our best knowledge, many researchers have focused on utilizing the integration of some MCDM methods [16-19], however, only few researchers have focused on the integration of the three methods of FDEMATEL, FAHP and FVIKOR [20]. Mobini and Yazdani [20] proposed a novel hybrid model based on AHP, DEMATEL and VIKOR technique under fuzzy environments to evaluate the investment strategy selection. In the proposed three-step method, firstly the investment problem was broken down into a simple structure and then the weight calculation of criteria was done using the AHP method. Secondly, a DEMATEL method applied to modify the weight importance of criteria due to their interdependence and eventually, FVIKOR method is used to prioritize the qualified alternatives. In addition, they investigated a case study of investing in the private sector in Iran country to prove the high ability of the proposed model to prioritize the investment strategies [20].

Therefore, to the above mentioned combining FDEMATEL, FAHP and FVIKOR method in a fuzzy environment seems a best way to gain the benefits of these methods and deal with the uncertainty and ambiguity of the evaluation process. On the other hand, health care problems have triggered an intriguing subject among researchers, recently [21]. Then, this study proposes an integrated Fuzzy DEMATEL, Fuzzy AHP and Fuzzy VIKOR method for selecting the best hospital nurses in a year as a new study which has not been studied so far due to the literature and it is investigated in this study for the first time. Besides, the summary of studies in personal selection problem reviewed by us is illustrated by Table 1, and it guarantees the case study and considered criteria in the present study are totally new.

3. Solving method

3.1 Hybrid Fuzzy DEMATEL/AHP/ VIKOR approach

In this section, a three-stage approach is proposed for selecting and ranking the hospital nurses. Since ambiguity and uncertainty can be managed by a fuzzy framework, we used an integration of FDEMATEL, FAHP and FVIKOR techniques. At first, a FDEMATEL approach is used to determine the most effective criteria and after that, a FAHP approach is utilized to calculate the weights importance of nursing evaluation criteria. Then FVIKOR is applied to prioritize alternatives based on these criteria. Fig 2 shows a flowchart of method presented in this study. We outline each approach below:

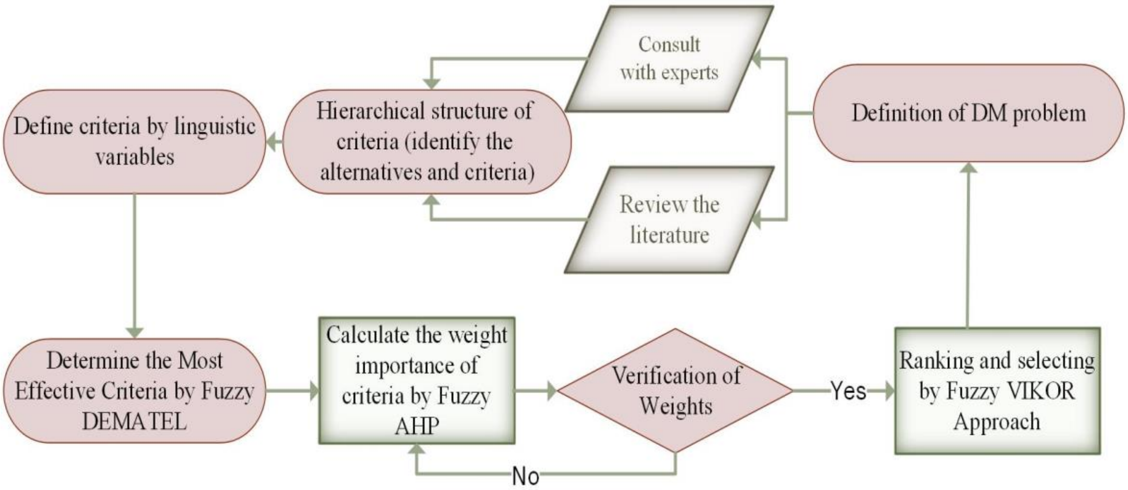

Fig 2. The proposed hybrid approach

3.2 Fuzzy DEMATEL

DEMATEL method introduced by Fontela and Gabus [23] for the first time to examine the interrelationship between the criteria numerically. It can transform causation relationships into a structural-visual model and identify the interdependencies between the criteria. However, it is very difficult to consider the experts' opinion expressed by numerical values because of the imprecise and subjective judgments. Therefore, it is required to propose a DEMATEL method in a fuzzy environment. In this method, fuzzy linguistic variables are used to facilitate the decision-making process. The steps of FDEMATEL method are as follows:

Table 1. Summary of studies in personnel selecting problems

References	Method	objective	Criteria
Asgharizad, et al. [14]	360 Degree Technique and VIKOR	Evaluating of managers' performance	Individual characteristics (character), Human skills, Cognitive skills, Technical skills
Mohaghar, et al. [22]	VIKOR-Fuzzy AHP	Selecting the best marketing strategy	Managerial capabilities, Customer linking capabilities, Market innovation capabilities, Human resource assets, reputational assets, Capabilities in product distribution.
Malik [5]	Fuzzy AHP-TOPSIS	Personnel Prioritization	Objective criteria and subjective criteria
Taghvaei, and Goodarzi [10]	FDEMATEL-ANP-AHP in the strategic model SWOT	Develop and prioritize the medical tourism development strategies in metropolitan area.	Strengths, Weaknesses, Opportunities, Threats
Chen, and Cheng [6]	The FMCGDSS three ranking methods	Information system manager selection	Analysis and design, programming, Interpersonal, business, environment and application.
Ozdagoglu, and Guler [18]	Fuzzy AHP-TOPSIS	Evaluating e-service quality of internet based banking alternatives in order to obtain the best qualified alternative.	Efficiency/System Availability, Assurance/Fulfillment, Privacy, Contact Responsiveness, Website Aesthetic and Guide.
Jain, et al. [19]	Fuzzy AHP-TOPSIS	Supplier selection	Product quality, Price/cost, Quality of relationship, Manufacturing capacity, Warranty, On-time delivery, Environmental performance, Brand name of supplier.
Asghari, et al. [17]	Delphi and Fuzzy AHP-TOPSIS	Weighting Criteria and Prioritizing of Heat stress indices in surface mining	Simplicity, Reliability, Low Cost, Comprehensiveness, Direct reading, Precision, Strong correlation with the physiological strain indices, Non-interferencing with worker activity, the work process, and quality of work, Availability, being influenced by other factors, Being standard.
Mobini, and Yazdani [20]	Fuzzy DEMATEL-AHP-VIKOR	select the best strategy for investing	Benefit factors, Opportunity factors, Cost factors, Risk factors.
Ali Mohammadian, and Shafiei [9]	Fuzzy ANP-DEMATEL-VIKOR-TOPSIS	Ranking hospitals	Finance, Internal processes, Customer, Learning and development.
Present study	Fuzzy DEMATEL-AHP-VIKOR	Selecting and prioritizing the best hospital nurses in a year	Administrative Discipline, Ethical and Social Obligations, Professional and Specialized Tasks, Do Extracurricular Activities, Objective Factors, Physical, Experiences, Psychological Characteristics, Essential Skills, and Individual knowledge.

Step 1: Establish the direct relationship matrix (M)

In order to evaluate the criteria, the experts' opinions are used to complete the matrix M according to qualitative expressions in Table 2 and the paired comparisons which is show the factors effects. Also, in order to apply the opinions of all experts (with the same importance factor), arithmetic mean is used according to Eq. 1:

Where, k is the number of experts and $\tilde{x}^1$ ، $\tilde{x}^2$ ، $\tilde{x}^2$ ، ... ، $\tilde{x}^k$ are their associated paired comparisons. Also, $\tilde{Z}$ is a triangular fuzzy number as $\tilde{Z}_{ij} =(l_{ij}, m_{ij}, u_{ij})$.

$$\tilde{Z} = \frac{\tilde{x}^1 \oplus \tilde{x}^2 \oplus \tilde{x}^2 \oplus \ldots \oplus \tilde{x}^k}{k}. \quad (1)$$

Table 2. Verbal scales of importance for triangular fuzzy number in comparison matrix

Numerical value	Preferences
(1,1,1)	Without effect
(2,3,4)	Very low impact
(4,5,6)	Low impact
(6,7,8)	Great impact
(8,9,9)	Very high impact

Step 2: Normalizing matrix M

Matrix normalization and achieve to the comparable scales are possible by following relationships:

$$\tilde{H}_{ij} = \frac{\tilde{Z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right) = (l_{ij}', m_{ij}', u_{ij}'). \quad (2)$$

Where, r is obtained from the following relationship:

$$r = max_{1\le i\le n}\left(\sum_{j=1}^{n} u_{ij}\right). \quad (3)$$

Step 3: Calculation of total relationship matrix (N)

Total relationship matrix can be obtained by integrating the obtained matrixes of previous step. Then, total fuzzy relationship matrix can be calculated by Total Relationship Matrix and following relationships:

$$N = lim_{k\to+\infty}\left(\tilde{H}^1 \oplus \tilde{H}^2 \oplus H^2 \oplus \ldots \oplus H^k\right). \quad (4)$$

Where, each element of matrix is considered as fuzzy number, $\tilde{n}_{ij} = ({l_{ij}}^n, {m_{ij}}^n, {u_{ij}}^n)$ and can be calculated by the following relations:

$$\left[{l_{ij}}^n\right] = H_l \times (I - H_l)^{-1} \quad (5)$$
$$\left[{m_{ij}}^n\right] = H_m \times (I - H_m)^{-1} \quad (6)$$
$$\left[{u_{ij}}^n\right] = H_u \times (I - H_u)^{-1} \quad (7)$$

Where, I is the Identity matrix and H_l ‘ H_m ‘ H_u are n-dimensional matrices with lower, middle, and upper bounds of fuzzy triangular numbers of the H matrix.

Step 4: Determine the relation and prominence value

In this step, total row values($\tilde{R}$) and total column values($\tilde{C}$) of Total Relationship Matrix are calculated so that $\tilde{R}$ represents the Prominence value of each criterion on other criteria, and $\tilde{C}$ shows the relation value of each criterion from other criteria. Then values of R + C and R – C that indicate the importance and the relationship between the criteria are calculated. Finally, Defuzzification process of fuzzy numbers R + C and R–C is done by the following formula:

$$A = \frac{a_1+2a_3+a_2}{4} \tag{8}$$

Where, A is the Diffuzified value of fuzzy number $\tilde{A} = (a_1, a_2, a_3)$.

Step 5: Illustrate the cause and effect diagram

In this step, a cause and effect diagram is drawn in which ($\tilde{R} + \tilde{C})^{def}$ and $(\tilde{R} - \tilde{C})^{def}$ are the horizontal and vertical axis, respectively. Finally, if the $(\tilde{R} - \tilde{C})^{def} > 0,$ the criterion is effective, otherwise, if $(\tilde{R} - \tilde{C})^{def} < 0,$ the criterion is impressive. In this way, a hierarchy of criteria is created and the most effective criteria are identified.

3.3 Fuzzy AHP

AHP is a quantitative technique for multi-criteria decision making proposed by Saaty [24] for the first time [25]. The pivoted point is that there are some restrictions in utilizing this method such as reducing the use of definitive decisions, face the confronting unbalanced judgmental measures, being incapable of dealing with the uncertainty and ambiguity of judgment, and selecting and subjective ranking. Therefore, the combination of an AHP technique with a fuzzy theory seems necessary to deal with a vague environment when expert’s opinions are expressed by linguistic variables. Nowadays, FAHP approach attracts many researchers’ attention and it is widely used to solve multi-criteria decision-making problems [26]. Approach proposed by Chang [27] has been used in many studies [28], and its steps are as follows:

Step 1: Convert the linguistic variables used by experts into crisp values

In this way, the linguistic variables used by decision makers (experts) must be converted to its crisp values according to the values shown in Table 2 [29]. Then the comparison matrix will be as follows**:**

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \dots & \tilde{a}_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ \tilde{a}_{21} & \tilde{a}_{21} & \dots & 1 \end{bmatrix} \tag{9}$$

Step 2: Calculate fuzzy synthetic extent value **(S_i)**

Assume that l_i , m_i and u_i are the lower, most promising, and the upper-value limit of criterion i, respectively. Fuzzy synthetic extent value can be expressed as the following relations:

$$S_i = \sum_{j=1}^{n} M_{gi}^{j} \otimes \left[\sum_{i=1}^{m}\sum_{j=1}^{n} M_{gi}^{j}\right]^{-1} \tag{10}$$

$$\sum_{j=1}^{n} M_{gi}^{j} = \left(\sum_{j=1}^{n} l_j, \sum_{j=1}^{n} m_j, \sum_{j=1}^{n} u_j\right) \tag{11}$$

$$\left[\sum_{i=1}^{m}\sum_{j=1}^{n} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{12}$$

Table 3. Linguistic scales of the importance utilized in comparison matrix

Degree of importance	Linguistic variables	Triangular fuzzy number
$\tilde{1}$	Equal or not important (E)	(1,1,1)
$\tilde{3}$	Weak importance (WI)	(1,3,5)
$\tilde{5}$	Moderate importance (MI)	(3,5,7)
$\tilde{7}$	Strong importance (SI)	(5,7,9)
$\tilde{9}$	Extremely important (EI)	(7,9,9)

Step 3: Degree of possibility for two triangular fuzzy numbers

Probability degree of two triangular fuzzy numbers, $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ can be defined as Eq. 13 (see Fig 3)**:**

$$(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \begin{Bmatrix} 1 & m_1 < m_2 \\ 0 & l_1 \geq u_2 \\ \frac{u_1 - l_2}{(u_1 - l_2) - (m_1 - l_1)} & O.W \end{Bmatrix} \tag{13}$$

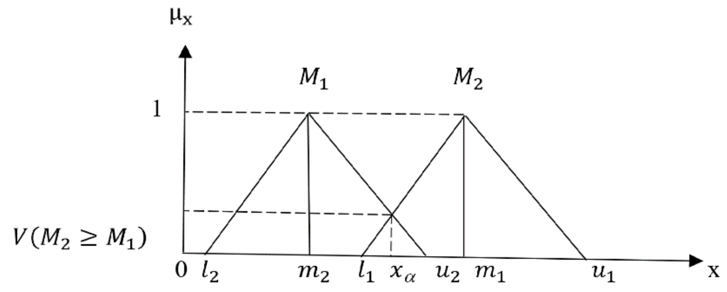

Fig 3. The Possibility degree of two triangular fuzzy numbers

Step 4: Calculate the probability degree of a convex fuzzy number and k Convex fuzzy number

The possibility degree of a convex triangular fuzzy number when it is greater than k convex triangular fuzzy numbers can be expressed as follows:

$$V(M \geq M_1, M_2, \ldots, M_k) = V\big((M \geq M_1), (M \geq M_2), \ldots, (M \geq M_k)\big) \tag{14}$$
$$= \mathrm{Min}\{V(M \geq M_i)\} \qquad i = 1, 2, \ldots, k$$

Step 5: Assessment of compatibility

In order to calculate the consistency and inconsistency ratio, firstly we must obtain the largest Eigen value by following equation:

$$\lambda_i = \frac{Aw}{w_i} \qquad i = 1,2,\dots,m \tag{15}$$

Then, the inconsistency ratio (I.I) for hierarchical structure is estimated by using Eq. 16:

$$\mathrm{I.I} = \frac{\lambda_{max} - n}{n-1} \tag{16}$$

The consistency ratio indicates that comparison matrix is consistent and Eq. 17 can determine it:

$$\mathrm{I.R} = \frac{\mathrm{\bar{I.I}}}{\overline{\mathrm{R.I.I}}} \tag{17}$$

Where, I.R and $\overline{\mathrm{R.I.I}}$ show the consistency index and the random index, respectively (see Table 2).

Step 6: Determine the normalized weight of criteria

To calculate the weight of criteria associated with the comparison matrix, following equation can be used:

$$\mathrm{d}'(\mathrm{A_i}) = \mathrm{Min}\{\mathrm{V}(\mathrm{S_i} \geq \mathrm{S_k})\}, \qquad \mathrm{k} = 1,2,\dots,\mathrm{n} \quad , \quad \mathrm{k} \neq \mathrm{i} \tag{18}$$

Then the normalized weighted vector can be as follows:

$$W' = \left[W'(c_1),\ W'(c_2), \dots, W'(c_n)\right]^T \tag{19}$$

3.5. Fuzzy VIKOR

Fuzzy VIKOR is a decision-making approach developed by Opricovic and Tzeng [30] for the first time to solve the kinds of problem facing uncertainties, ambiguity or opposite criteria and it has utilized in many problems [31- 33]. The term VIKOR refers to "benchmark optimization and reconciliation."

Step 1: Assigning linguistic variables to alternatives:

In this step, language variables are allocated to alternatives due to the given criteria in Table 2 and the structure of the fuzzy matrix can be obtained by the relation.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \dots & \tilde{a}_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ \tilde{a}_{21} & \tilde{a}_{21} & \dots & 1 \end{bmatrix} \tag{20}$$

Step 2: Establish a normalized matrix

In this step, one normalization method is applied to convert the linguistic variables to the equivalent values based on Table 4.

Step 3: Establish the weighted normalized matrix

This step allocating to multiply the weight importance of criteria in normalized values of pervious step.

Table 4. Linguistic variables for alternatives comparison

Verbal variables	Fuzzy Ratings
Very poor (VP)	(0,1,1)
Poor(P)	(0,1,3)
Medium poor(MP)	(1,3,5)
Fair(F)	(3,5,7)
Medium Good (MG)	(5,7,9)
GOOD(G)	(7,9,10)
Very Good (VG)	(9,9,10)

Step 4: Determine the Ideal Positive and Negative solution

The best value of f^*_j and f^-_j for each criterion is calculated in this step. If criteria j has a positive aspect, then f^*_j and f^-_j will be set as best and worst criteria.

$$F^*_j = \text{MAX}\, F_{kj} \tag{21}$$
$$F - j = \text{MIN Fkj} \tag{22}$$

Step 5: Calculate usefulness (S_i) and unfortunate amount (R_i) for each alternative

Utility value (S_i) represents the distance from ideal solution and unfortunate amount (R_i) represents the maximum value of it and they can calculate as follows:

$$\text{SK} = \sum_{J=1}^{M} W_J * \frac{|(F_J^* - F_{KJ})|}{|(F_J^* - F_J^-)|} \tag{23}$$
$$\text{RK} = MAX_{1<j<m} \frac{|(F_J^* - F_{KJ})|}{|(F_J^* - F_J^-)|} \tag{24}$$

Step 6: Calculating the VIKOR Index (Q_i):

$$\text{QK} = \text{V} * \frac{S_K - S^*}{S^- - S^*} + (1 - V) * \frac{R_K - R^*}{R^- - R^*} \tag{25}$$

Where, 0 <V <1 represents the maximum of desirability.

Step 7: Sort the alternatives based on the R_i, S_i, Q_i values in a descending order

The alternative ranking is done by sorting the values of R, S, Q in descending order and obtained results are illustrated in three ranking lists.

Step 8: Propose the comprehensive approach

4. **Prioritizing the hospital nurses of a real case study**

Three approaches described above cannot be used to select and rank the hospital nurses. On one hand, the hospital nurses' selection which is considered as a real problem face the uncertain environment. On the other hand, it is because identifying many effective criteria of mentioned problem is done in a qualitative way and based on experts' judgments according to the linguistic variables, some exact classical method of multi-criteria decision making are not efficient enough. Therefore, proposing a hybrid fuzzy approach to overcome the problems of classical methods seems logical. These problems can be solved by implementing the integrated FDEMATEL, FAHP, and FVIKOR approach to identify the effective criteria of problem, determine the weight importance of criteria in the hospital nurses' selection problem, and rank the selected nurses, respectively.

In this study, one of the most famous hospitals in the north of Iran country has been considered as a real case study for the first time to demonstrate the applicability of the three-stage approach. This hospital namely V. H is located in Qaemshahr city of Mazandaran provinces and plays an essential role in patients' health. Also, presented study tries to investigate considered case study by determining the most effective criteria, calculating the weight importance, and prioritizing the selected hospital nurses by the proposed hybrid approach of FDEMATEL / FAHP / FVIKOR.

In the first stage, a complete list of 10 criteria and 30 sub-criteria was provided as it shown by Fig 1 to a team of 25 experts who were specialized enough to fill out the questionnaires for proposing their opinions based on Table 2. Then, four criteria: administrative discipline, ethical and social obligations, professional and special tasks, and doing extracurricular activities were identified due to Table 5 and Fig. 4 as the most effective and important criteria. In the next step, the weigh importance of the identified criteria in the previous step are determined by FAHP. In other words, four criteria and 14 sub-criteria have been selected as the most important and effective criteria and also the comparison matrix of criteria and the integrated normalized weight obtained according to all experts' opinions are illustrated in Table 6 and Table 7, respectively. It should be noted that the consistency of the comparison matrix is checked by Eq. 15 to Eq. 17 and Expert Choice software and the results indicate that the comparison matrix is consistency (I. R<0.1).

Table 5. Relation and prominence value of criteria

criterion	$R-D$ (Relation)	$R+D$ (Prominence)	Priority
Administrative Discipline	0.157561	0.603808	3
Moral and social obligations	0.270712	0.558322	1
Professional and specialized tasks	0.268852	0.62215	2
Extracurricular activities	0.078841	0.52845	4
Work experience	-0.14111	0.354651	8
Objective factors	-0.12824	0.46753	7
Psychological profile	-0.12139	0.420343	6
Physical features	-0.14607	0.386238	9
Inner Skills	-0.07871	0.451334	5
Individual knowledge	-0.16045	0.424383	10

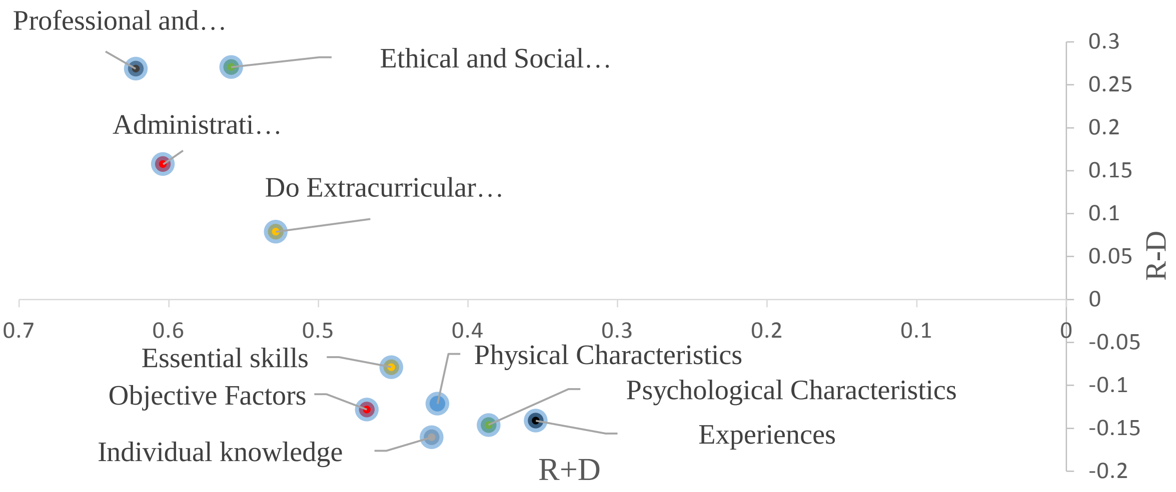

Fig 4. Causal diagram

Table 6. Comparison matrix criteria

Criteria	C_1	C_2	C_3	C_4
C_1	(1,1,1)	(3.4,5.2,7.1)	(1.6,2.2,2.9)	(3.1,5.1,6.8)
C_2	(6,8,9)	(1,1,1)	(1,3,5)	(5.8,7.3,8.8)
C_3	(6.6,8.9,9.1)	(3.5,4,4.8)	(1,1,1)	(7,9,9)
C_4	(2,3.1,3.9)	(1/1,1/4,1.9)	(1,1,1)	(1,1,1)

Table 7. The normalized weight importance of fuzzy criteria

Criteria	C_1	C_2	C_3	C_4
Weight importance(W)	0.24	0.29	0.26	0.21

In the present study, positive triangular fuzzy numbers are used as linguistic variables for evaluating and ranking the alternatives based on the calculated weights of each criterion. In fact, goal of this step is assigning the linguistic variables to the alternatives due to the criteria and then converting these values to their crisp values according to Table 3. For example, the membership function (3, 5, 7) is a positive fuzzy numbers sets that represents a fair decision (F) of criterion 1 (C_1) by expert 1. Therefore, the linguistic variables of alternatives' criteria and the integrated fuzzy number are assigned according to decision maker's point of view that indicates the evaluation of illustrated data in Tables 8 and 9, respectively. At first, best value(f_j^*) and the worst value (f_j^-) for each alternative are calculated. Also, the utility value (S_i) that represents the distance from the ideal solution and the unfortunate amount (R_i) that indicates the maximum value for each selected alternative are determined. After that, VIKOR index (Q_i) is calculated for ranking the alternatives, and after the Defuzzification process of the fuzzy values by Eq. 8, the obtained values are sorted in descending order based on R_i, S_i, Q_i values.

Table 8. Linguistic variables of alternatives' criteria according to DM's opinion (Expert1)

Alternatives	criterion			
	C_1	C_2	C_3	C_4
A_1	G	F	G	P
A_2	VG	G	F	F
A_3	G	F	G	F
A_4	G	F	F	F
A_5	G	F	VG	F
…	…	…	…	…
A_{24}	P	G	P	F
A_{25}	G	G	G	P

Table 9. Integrated normalized fuzzy decision matrix for alternatives

Alternatives	criterion			
	C_1	C_2	C_3	C_4
A_1	(0.7,0.9,1)	(0.4,0.7,1)	(0.7,0.9,1)	(0,0.3,1)
A_2	(0.9,0.9,1)	(0.7,0.9,1)	(0.4,0.7,1)	(0.4,0.7,1)
A_3	(0.7,0.9,1)	(0.4,0.7,1)	(0.7,0.9,1)	(0.4,0.7,1)
A_4	(0.7,0.9,1)	(0.4,0.7,1)	(0.4,0.7,1)	(0.4,0.7,1)
A_5	(0.7,0.9,1)	(0.4,0.7,1)	(0.9,0.9,1)	(0.4,0.7,1)
…	…	…	…	…
A_{24}	(0,0.3,1)	(0.7,0.9,1)	(0,0.3,1)	(0.4,0.7,1)
A_{25}	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.4,0.7,1)

Table 10 shows the final ranking of criteria based on the proposed integrated approach of FDEMATEL / FAHP / FVIKOR. All three indicators, R_i, S_i, Q_i are arranged in descending order in order to rank the alternatives and the best alternative (least Q) should apply two conditions. The first condition is that $Q(A_2)-Q(A_1) > \frac{1}{n-1}$ and the second condition is that alternative A_1 should have the best value at least in R or S. According to these conditions, alternatives 18, 10, 25, 5, and 3 are selected as the best alternatives and similarly, for other alternatives, the ranking results are shown in Table 10. It is worthwhile to mention that the obtained values are the best guideline for hospital experts in hospital nurses' selection process or even other companies in case of selecting the best alternatives based on the most important criteria. On the other word, since the proposed method has been implemented on a real-world problem of health care, the results are practical and reliable to use in similar researches.

Table 10. Final alternatives ranking due to benefit value(S_i), unfortunate value(R_i), and VIKOR index(Q_i)

Alternatives	S_i	R_i	Q_i	Rating
A_{18}	0.107618	0.07225	0.16625	١
A_{10}	0.145696	0.07225	0.2025	٢
A_{25}	0.370069	0.128625	0.31275	٣
A_5	0.544666	0.177625	0.363125	٤
A_3	0.590184	0.177625	0.385417	٥
...	…	…	…	…
A_{14}	1.228275	0.320667	0.827042	٢٤
A_{12}	1.386538	0.347167	0.868667	٢٥

The comparison among the different integration of MCDM methods is shown in Table 11. It is obvious that all integrated methods illustrate that alternatives 18 is the best alternative to choose as a hospital nurse. But, according to DMs' opinion the best ranking satisfied the DMs is produced by an integration of FDEMATEL-AHP-VIKOR methods which is proposed in this paper. On the other hands, FDEMATEL and FAHP are used for weighing the criteria and FVIKOR is utilized for prioritizing the alternatives and it is worthwhile to say that applying each method separately has some demerits. Our results show that integrating these three approaches make it possible to weight the criteria and prioritize the alternatives in a best way and also this integration eliminates the weaknesses of separate usage of each method.

Table 11. Comparative result of different integration of MCDM methods

Methods	Alternatives	Ranking
	A_{18}	1
	A_{10}	2
	A_{25}	3
	A_5	4
FDEMATEL-AHP-VIKOR	A_3	5
	A_{18}	1
	A_{25}	2
	A_5	3
	A_{10}	4
FDEMATEL-AHP	A_3	5
	A_{18}	1
	A_5	2
	A_{25}	3
	A_3	4
FAHP-VIKOR	A_{10}	5

5. Conclusion and future researches

In this paper, we proposed a hospital nurses' selection and ranking model based on an integration of Fuzzy DEMATEL/AHP/VIKOR approach for the first time. At first, the effective indexes of the problem are determined by FDEMATEL approach and then they are weighted by FAHP method to select the most qualified hospital nurses in a year. After that, FVIKOR approach was used for helping DMS to prioritize the hospital nurses based on effective criteria. This paper has illustrated case study for hospital nurses' selection of one of the most prominent hospitals in the north of Iran. It is important to note that the application of the proposed model is not limited to the nurses' selection and it is also applicable to other real-world problems. Therefore, a suggestion for the future studies can be using this model to evaluate other case studies due to the different criteria. In addition, the usage of other multi-criteria decision-making methods such as TOPSIS, ELECTRE or a combination of these methods can be useful.

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