Group Decision Making for Hospital Location Selection Using VIKOR under Fuzzy Environment

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Abstract

Aim: The purpose of this study is to select the best hospital location for a health institution under 10 criteria using multi criteria decision making techniques under fuzzy environment. Another important purpose of this study is to include weights of the members of the board of directors of the institution while making decisions.

Method: Evaluations are done to select the best hospital location for a private health institution. To this aim, fuzzy VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) method is used with the help of members of the board of directors by using group decision making. All members of the board of directors are included in the problem according to the weights in the board of directors. Hence, the results of the study to make the decision of hospital location selection are more objective.

Findings: The results of this study demonstrate the best location for a new hospital. In addition, differences between the locations are clearly seen at the fuzzy results for comparisons. To validate the results of this study and the proposed method, another fuzzy multi criteria decision making method is applied to the problem. Consistency of all results shows applicability, effectiveness and validity of the proposed method for hospital location selection.

Conclusion: Evaluations of all results show that the proposed method is efficient for hospital location selection problem and can also be applicable for other decision making problems of health institutions.

Keywords: Hospital location selection, fuzzy VIKOR, group decision making.

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Bulanık Ortamda VIKOR Kullanarak Hastane Yeri Seçimi için Grup Karar Verme

Öz

Amaç: Bu çalışmanın amacı, bulanık ortamda çok kriterli karar verme teknikleri kullanarak 10 kriter altında, bir sağlık işletmesi için en iyi hastane yerinin seçilmesidir. Bu çalışmanın diğer bir önemli amacı da, hastane işletmesinin Yönetim Kurulu üyelerinin ağırlıklarının karar verme sırasında dâhil edilmesidir.

Yöntem: Değerlendirmeler, özel bir sağlık işletmesi için en iyi hastane yerinin seçimi üzerine gerçekleştirilmiştir. Bu amaç için; grup karar verme kullanarak Yönetim Kurulu üyelerinin de yardımıyla bulanık VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) yöntemi kullanılmıştır. Yönetim Kurulunun tüm üyeleri, Yönetim Kurulundaki ağırlıklarına göre probleme dâhil edilmişlerdir. Bundan dolayı, hastane yeri seçim kararını verme amacında olan bu çalışmanın sonuçları daha objektif olmuştur.

Bulgular: Çalışmanın sonuçları, yeni bir hastane için en iyi yeri göstermiştir. Ayrıca, karşılaştırmalar için, hastane yerleri arasındaki farklar da bulanık sonuçlardan açıkça görülebilir. Bu çalışmayı ve önerilen yöntemi doğrulamak adına, diğer bir bulanık çok kriterli karar verme yöntemi de probleme uygulanmıştır. Tüm sonuçların tutarlılığı, hastane yeri seçimi için önerilen yöntemin uygulanabilirliğini, etkinliğini ve geçerliliğini göstermektedir.

Sonuç: Tüm sonuçların birlikte değerlendirilmesi, önerilen yöntemin hastane yeri seçimi için etkili olduğunu ve sağlık işletmelerinin diğer karar verme problemleri için de uygulanabileceğini göstermektedir.

Anahtar Sözcükler: Hastane yeri seçimi, bulanık VIKOR, grup karar verme.

Introduction

Facility location problem, which is one of the most important vital decisions of companies and industries economically, is firstly introduced by Weber and Friedrich[1]. Facility location selection is the determination of the geographical location of a facility to start, relocate or expand the operations of a firm in order to optimize at least one objective i.e. cost, profit, distance, service etc.[2]. However, facility location selection is not the only important decision to start the operations. Firms implement their manufacturing strategies with the following decisions in their production–distribution system[3].

– Facility Location	– Capacity Acquisition	–Technology Selection
– Production Mix	– Time-phasing of Investments	– Financial Planning

When the decisions given here are analyzed, all of the decisions belongs to the facility location selection and starts after the facility location selection. Because of these, the most important step for companies and institutions to start the operations is the selection of the best facility location. An inappropriately selected facility location increases the other costs cumulatively in association with the facility location. On the contrary, the selection of the best facility location also decreases the other costs both partially and cumulatively in association with the facility location.

In this study, the best hospital location selection for a health institution was aimed by using the evaluations of the members of the board of directors for these locations according to their weights in the board of directors. Obtained results are also validated by using another fuzzy Multi Criteria Decision Making (MCDM) method.

There are many models and methods for facility location selection in the literature. Most of the facility location selection models and methods in the literature are effective. However, most of those effective models and methods have not been applied to hospital location selection problems. In 2006, Lin et al.[4] applied Grey Relational Analysis (GRA) to select hospital locations in Taiwan. They used Porter's diamond model which affects competitive advantages. Önüt et al.[5] proposed an Analytic Network Process (ANP) model for choosing hospital location. They chose potential region for a hospital in Istanbul according to 14 criteria within 6 clusters.

In 2010, Lin et al.[6] introduced a fuzzy additive weighting systems for the location of a health institution. They evaluated 5 alternatives according to 6 criteria by using linguistic variables and fuzzy numbers. Same year, Lin and Tsai[7] applied ANP and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) methods for new investments of hospitals in China. Following year, Shahbandarzadeh and Ghorbanpour[8] combined interpretive structural modeling and fuzzy ANP for health center locations. They selected the best health center location according to 12 criteria within 4 clusters.

In 2013, Chatterjee and Mukherjee[9] applied analytic Hierarchy Process (AHP) to select the potential locations of hospitals in India. They evaluated the alternatives according to 11 criteria. Same year, another AHP model was applied to select the best potential services at hospital location by Chiu and Tsai[10].

Şen and Demiral[11] proposed a grey system theory model for hospital location selection in 2016. They combined GRA and AHP based on grey systems during the selection process. A fuzzy TOPSIS model with hesitant fuzzy sets was introduced for hospital location selection by Senvar et al[12]. They selected one of four alternatives according to 7 criteria with the proposed model. In 2017, Şen[13] applied additive ratio assessment method by using grey numbers to select the best hospital location. 3 potential hospital locations are evaluated by using 6 criteria in the study.

Material and Method

An integrated fuzzy VIKOR approach by using group decision making is proposed for hospital location selection in this study. In the following sections, proposed fuzzy VIKOR approach and group decision making process is introduced step by step.

Fuzzy VIKOR

VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) method was firstly introduced by Opricovic[14] for MCDM of complex systems. The method ranks a set of alternatives according to the ideal solution. At the end, compromise solutions are generated between the maximum group utility of the majority and the minimum of the individual regret of the opponents. There are some different fuzzy VIKOR approaches in the literature.

Amiri et al.[15] applied a fuzzy VIKOR approach with group decision making process for car parts supplier selection. Authors used linguistic variables which were defined as triangular fuzzy numbers in the study. Farsi et al.[16] rank the cell phone alternatives by using fuzzy VIKOR. They used triangular fuzzy numbers defined as linguistic words in VIKOR calculations. Kuo and Liang[17] applied a fuzzy VIKOR approach with interval–valued fuzzy numbers and Euclidean distance to evaluate intercity bus companies. Su et al.[18] proposed a hybrid fuzzy multi criteria decision making approach by using fuzzy DEMATEL (The Decision Making Trial and Evaluation Laboratory), fuzzy ANP and fuzzy VIKOR. They determined the weights with fuzzy DEMATEL and fuzzy ANP. Fuzzy

VIKOR was then used to evaluate the performance of computing applications. They used triangular fuzzy numbers in the application and obtained fuzzy results.

Mohaghar et al.[19] proposed an integrated approach by using fuzzy VIKOR and assurance region–data envelopment analysis. They applied the proposed approach with triangular fuzzy numbers to evaluate the best supplier alternative for a manufacturing company. Liao and Xu[20] applied VIKOR method with hesitant fuzzy sets. They used hesitant normalized Manhattan distance to calculate the group utility measure, the individual regret measure and the compromise solution. In this study, they evaluated the service quality of domestic airlines with the proposed approach and obtained hesitant fuzzy group utility measures, hesitant fuzzy individual regrets and hesitant fuzzy compromise solutions for alternatives. Bashiri[21] presented a hybrid model which uses the fuzzy VIKOR results in genetic algorithm solution. They applied fuzzy VIKOR to evaluate the candidate hub locations in their study. Kim and Chung[22] introduced a fuzzy VIKOR method which uses normalized fuzzy difference calculations in the methodology. The vulnerability of the water supply to climate change was evaluated with the proposed fuzzy VIKOR method.

Chang[23] evaluated the hospital service quality with fuzzy VIKOR method. Triangular fuzzy numbers were used and the utility measures, the regret measures and the compromise solutions were obtained with fuzzy numbers at the end of the study. Afful–Dadzie et al.[24] proposed a fuzzy VIKOR approach with triangular fuzzy numbers and normalized fuzzy differences. Quality of internet health information was evaluated by the proposed fuzzy VIKOR approach and the results were also obtained as fuzzy numbers in the study. Kavitha and Vijayalakshmi[25] introduced an integrated fuzzy multi objective linear programming model. Fuzzy VIKOR method was applied to rank the alternatives to be used in the fuzzy multi objective linear programming. They applied the proposed approach to a facility location selection problem. In their study, factors were separated as quantitative and qualitative. The qualitative factors were obtained by using fuzzy VIKOR and both of the factors were used in fuzzy multi objective linear program to evaluate the optimal location.

Adhikary et al.[26] applied fuzzy VIKOR and fuzzy TOPSIS to small hydropower projects and compared the results. They did all of the calculations with triangular fuzzy numbers and used defuzzified crisp values to rank the alternatives. Arunachalam et al.[27]

ranked polishing tools with traditional AHP and fuzzy VIKOR. The results for alternatives obtained from these two methods were compared and showed that the results were almost the same. The fuzzy VIKOR results were obtained as triangular fuzzy numbers and rankings were done with defuzzified values. Leeet et al.[28] proposed an improved group decision making approach combined with fuzzy VIKOR.

Büyüközkan and Göçer[29] used fuzzy VIKOR to select the best smart medical device. They also used group decision making process and intuitionistic fuzzy VIKOR in their study. Zain[30] applied fuzzy VIKOR to evaluate the quality of internet breast cancer information. Linguistic variables are used in the study to solve uncertainties and subjectivities.

In this study, we propose a fuzzy VIKOR method is derived as the combination of different fuzzy approaches in the literature[31,32,33,34]. The computational steps of the proposed fuzzy VIKOR are as follows.

Step 1: Defining the problem, alternatives and criteria: First step of the method is defining problem with the alternatives and criteria. In this study, the problem is the selection of the best location for a hospital.

Step 2: Generation of the decision matrix: $D = [\tilde{d}_{ij}]_{m\times n}$ represents the decision matrix for the alternatives vector $A = [A_i]_m$ and criteria vector $W = [W_j]_n$.

Step 3: Calculation of the normalized decision matrix: $\tilde{d}_{ij} = (d_{ij}^1, d_{ij}^2, d_{ij}^3)$ is a triangular fuzzy number of decision matrix. It is normalized by using the Eq. (1) for benefit attributes and normalized decision matrix $X = [\tilde{x}_{ij}]_{m\times n}$ is obtained.

$$\tilde{x}_{ij} = \left(\frac{d_{ij}^1}{\max_i(d_{ij}^3)}, \frac{d_{ij}^2}{\max_i(d_{ij}^3)}, \frac{d_{ij}^3}{\max_i(d_{ij}^3)}\right) \quad (1)$$

Step 4: Calculation of the weighted regret matrix: After the normalization of decision matrix, ideal solution for each criterion is $(1,1,1)$. So, weighted fuzzy regret matrix $R = [\tilde{r}_{ij}]_{m\times n}$ is calculated by using Eq. (2).

$$\tilde{r}_{ij} = W_j\left(1 - x_{ij}^3, 1 - x_{ij}^2, 1 - x_{ij}^1\right) \quad (2)$$

Step 5: Calculation of the utility measures and the regret measures: The utility and regret measures are calculated by using Eq. (3)–(4) for each alternative.

$$\tilde{S}_i = \sum_{j=1}^{n} \tilde{r}_{ij} = \left(\sum_{j=1}^{n} r_{ij}^1, \sum_{j=1}^{n} r_{ij}^2, \sum_{j=1}^{n} r_{ij}^3\right) \quad (3)$$

$$\tilde{R}_i = \max_j\left(\tilde{r}_{ij}\right) = \left(\max_j\left(r_{ij}^1\right), \max_j\left(r_{ij}^2\right), \max_j\left(r_{ij}^3\right)\right) \quad (4)$$

Step 6: Calculation of the compromise solutions: The compromise solutions $\tilde{Q}_i = \left(q_{ij}^1, q_{ij}^2, q_{ij}^3\right)$ are calculated as normalization given in Eq. (5). In this step, v value, which is for compromised solution, is mostly taken 0.5 in the literature. It can be between [0,1] according to preferences.

$$q_{ij}^k = v\left(\frac{\tilde{S}_i^k - \min_i\left(\tilde{S}_i^1\right)}{\max_i\left(\tilde{S}_i^3\right) - \min_i\left(\tilde{S}_i^1\right)}\right) + (1 - v)\left(\frac{\tilde{R}_i^k - \min_i\left(\tilde{R}_i^1\right)}{\max_i\left(\tilde{R}_i^3\right) - \min_i\left(\tilde{R}_i^1\right)}\right) \quad (5)$$

Step 7: Defuzzification of the utility measures, the regret measures and the compromise solutions: The fuzzy values of $\tilde{S}_i$, $\tilde{R}_i$ and $\tilde{Q}_i$ are defuzzified by using Converting Fuzzy data into Crisp Scores (CFCS) introduced by Opricovic and Tzeng[35]. The proposed defuzzification is given in the following equations for the defuzzified values as S_i, R_i and Q_i. The following equations for $\tilde{Q}_i$ are applied for $\tilde{S}_i$ and $\tilde{R}_i$ as the same way.

$$\tilde{Q}_{i(1)}^k = \frac{\tilde{Q}_i^k - \min_i\left(\tilde{Q}_i^1\right)}{\max_i\left(\tilde{Q}_i^3\right) - \min_i\left(\tilde{Q}_i^1\right)} \qquad k \in \{1,2,3\} \quad (6)$$

$$\tilde{Q}_{i(2)}^{k} = \frac{\tilde{Q}_{i(1)}^{k+1}}{1 + \tilde{Q}_{i(1)}^{k+1} - \tilde{Q}_{i(1)}^{k}} \qquad k \in \{1,2\} \tag{7}$$

$$\tilde{Q}_{i(3)} = \frac{\tilde{Q}_{i(2)}^{1}\left(1 - \tilde{Q}_{i(2)}^{1}\right) + \tilde{Q}_{i(2)}^{2}\tilde{Q}_{i(2)}^{2}}{1 - \tilde{Q}_{i(2)}^{1} + \tilde{Q}_{i(2)}^{2}} \tag{8}$$

$$Q_i = \min_i\left(\tilde{Q}_i^1\right) + \tilde{Q}_{i(3)}\left(\max_i\left(\tilde{Q}_i^3\right) - \min_i\left(\tilde{Q}_i^1\right)\right) \tag{9}$$

Step 8: Ranking and evaluation of the alternatives: S_i, R_i and Q_i values are ranked from minimum to maximum respectively. The ranked lists are the utility measure list, the regret measure list and the compromise solution list. The minimum value of Q_i list is the best alternative to compromise between the maximum group utility and the minimum individual regret.

Group Decision Making

Group decision making process is used to decrease the subjectivity of the decision makers by using their weights in the decision process. In this study, decision makers are the members of the board of directors. The weights, sum of which is 1, are determined according to weight of the vote of the board of directors. Then, weighted average method is applied to decision matrices of all the board of directors to obtain only one decision matrix, which is more objective and weighted according to the members.

Hospital Location Selection

In this section, details of hospital location selection done in the study are given. Selecting the best location of 5 alternatives under 10 criteria for a new hospital of a private health institution is carried out in this study. The evaluations are done by 7 members of the board of directors. All of the evaluations done by the members of the board of directors are done according to the scales given in Table 1.

Table 1: Linguistic scales for the evaluations

Linguistic Scale	Representation	Fuzzy Number
Equally Important	EI	(1,1,2)
Weakly Important	WI	(2,3,4)
Important	I	(4,5,6)
Strongly Important	SI	(6,7,8)
Absolutely Important	AI	(8,9,9)

As the first step of the process, evaluations are done for the criteria weights. All of the members of the board of directors evaluated criteria given in Table 2 according to the scale given in Table 1. Then, all evaluations are aggregated by using the weights of the members as a group decision making. Final fuzzy weights and defuzzified values of the weights used in fuzzy VIKOR calculations are given in Table 2.

Table 2: Criteria and weights of the criteria done by the members of the board of directors

Symbol	Criteria	Fuzzy criteria weights	Defuzzified weights
C1	Building Cost	(7.268,8.277,8.653)	0.1400
C2	Population Density	(5.769,6.804,7.560)	0.1153
C3	Prospective Population	(6.952,7.958,8.653)	0.1349
C4	Distance to Social Centers	(3.634,4.718,5.769)	0.0811
C5	Distance to Medical Suppliers	(1.587,2.080,3.175)	0.0378
C6	Distance to Other Institutions	(2.520,3.557,4.579)	0.0618
C7	Easy Access for Ambulances	(4.160,5.278,6.350)	0.0904
C8	Easy Access to Transportation	(6.604,7.612,8.320)	0.1290
C9	Hospital Demand at the Location	(8.000,9.000,9.000)	0.1529
C10	Availability of Parking Lot	(2.714,3.107,4.380)	0.0566

After obtaining the weights of the criteria, next step is generation of the decision matrix. Aggregated decision matrix obtained by the evaluations of 7 members of the board of directors is given in Table 3.

Table 3: Fuzzy decision matrix of hospital location selection problem

	C1	C2	C3	C4	C5
A1	(5.56,6.58,7.60)	(6.37,7.40,8.05)	(5.23,6.26,7.17)	(6.37,7.40,8.05)	(3.07,3.78,4.94)
A2	(3.20,4.36,5.37)	(3.04,3.90,5.14)	(2.29,3.14,4.31)	(4.92,6.03,6.99)	(2.06,3.22,4.30)
A3	(5.36,6.39,7.19)	(5.18,6.20,7.21)	(5.98,7.01,7.79)	(2.97,4.23,5.21)	(4.39,5.05,6.30)
A4	(3.80,5.14,6.13)	(4.31,5.01,6.09)	(2.55,3.35,4.50)	(3.52,4.30,5.46)	(3.80,4.99,5.92)
A5	(5.32,6.33,7.35)	(6.20,7.21,8.09)	(5.65,6.68,7.47)	(2.28,3.41,4.47)	(2.29,3.16,4.34)
	C6	C7	C8	C9	C10
A1	(4.07,4.78,5.94)	(2.33,3.58,4.64)	(5.23,6.26,7.17)	(4.37,5.38,6.39)	(2.90,3.74,4.95)
A2	(2.79,4.12,5.21)	(4.43,5.55,6.53)	(3.69,4.45,5.61)	(2.84,3.66,4.86)	(4.75,5.83,6.78)
A3	(2.68,3.59,4.76)	(4.33,5.61,6.46)	(2.88,3.74,4.90)	(2.82,3.63,4.82)	(2.41,3.52,4.59)
A4	(2.74,3.32,4.64)	(4.22,5.26,6.28)	(2.84,4.07,5.20)	(2.33,2.87,4.03)	(2.82,3.65,4.77)
A5	(3.55,4.74,5.75)	(4.12,5.32,6.33)	(5.52,6.53,7.53)	(5.62,6.66,7.46)	(5.61,6.63,7.64)

Normalized fuzzy decision matrix calculated by using Eq. (1) is given in Table 4.

Table 4: Normalized fuzzy decision matrix of hospital location selection problem

	C1	C2	C3	C4	C5
A1	(0.73,0.86,1.00)	(0.78,0.91,0.99)	(0.67,0.80,0.92)	(0.79,0.91,1.00)	(0.48,0.60,0.78)
A2	(0.42,0.57,0.70)	(0.37,0.48,0.63)	(0.29,0.40,0.55)	(0.61,0.74,0.86)	(0.32,0.51,0.68)
A3	(0.70,0.84,0.94)	(0.64,0.76,0.89)	(0.76,0.90,1.00)	(0.36,0.52,0.64)	(0.69,0.80,1.00)
A4	(0.50,0.67,0.80)	(0.53,0.61,0.75)	(0.32,0.43,0.57)	(0.43,0.53,0.67)	(0.60,0.79,0.93)
A5	(0.69,0.83,0.96)	(0.76,0.89,1.00)	(0.72,0.85,0.95)	(0.28,0.42,0.55)	(0.36,0.50,0.68)
	C6	C7	C8	C9	C10
A1	(0.68,0.80,1.00)	(0.35,0.54,0.71)	(0.69,0.83,0.95)	(0.58,0.72,0.85)	(0.37,0.48,0.64)
A2	(0.47,0.69,0.87)	(0.67,0.85,1.00)	(0.49,0.59,0.74)	(0.38,0.49,0.65)	(0.62,0.76,0.88)
A3	(0.45,0.60,0.80)	(0.66,0.85,0.98)	(0.38,0.49,0.65)	(0.37,0.48,0.64)	(0.31,0.46,0.60)
A4	(0.46,0.55,0.78)	(0.64,0.80,0.96)	(0.37,0.54,0.69)	(0.31,0.38,0.54)	(0.36,0.47,0.62)
A5	(0.59,0.79,0.96)	(0.63,0.81,0.96)	(0.73,0.86,1.00)	(0.75,0.89,1.00)	(0.73,0.86,1.00)

Weighted regret fuzzy decision matrix calculated by using Eq. (2) is given in Table 4.

Table 5: Weighted regret fuzzy decision matrix of hospital location selection problem

	C1	C2	C3	C4	C5
A1	(0.00,0.01,0.03)	(0.00,0.00,0.02)	(0.01,0.02,0.04)	(0.00,0.00,0.01)	(0.00,0.01,0.01)
A2	(0.04,0.05,0.08)	(0.04,0.05,0.07)	(0.06,0.08,0.09)	(0.01,0.02,0.03)	(0.01,0.01,0.02)
A3	(0.00,0.02,0.04)	(0.01,0.02,0.04)	(0.00,0.01,0.03)	(0.02,0.03,0.05)	(0.00,0.00,0.01)
A4	(0.02,0.04,0.06)	(0.02,0.04,0.05)	(0.05,0.07,0.09)	(0.02,0.03,0.04)	(0.00,0.00,0.01)
A5	(0.00,0.02,0.04)	(0.00,0.01,0.02)	(0.00,0.01,0.03)	(0.03,0.04,0.05)	(0.01,0.01,0.02)
	C6	C7	C8	C9	C10
A1	(0.00,0.01,0.01)	(0.02,0.04,0.05)	(0.00,0.02,0.03)	(0.02,0.04,0.06)	(0.01,0.02,0.03)
A2	(0.00,0.01,0.03)	(0.00,0.01,0.02)	(0.03,0.05,0.06)	(0.05,0.07,0.09)	(0.00,0.01,0.02)
A3	(0.01,0.02,0.03)	(0.00,0.01,0.03)	(0.04,0.06,0.07)	(0.05,0.07,0.09)	(0.02,0.03,0.03)
A4	(0.01,0.02,0.03)	(0.00,0.01,0.03)	(0.03,0.05,0.08)	(0.07,0.09,0.10)	(0.02,0.02,0.03)
A5	(0.00,0.01,0.02)	(0.00,0.01,0.03)	(0.00,0.01,0.03)	(0.00,0.01,0.03)	(0.00,0.00,0.01)

After step 4, calculation of the normalized decision matrix, utility measures, regret measures and compromise solutions for each alternative are calculated by using Eq. (3)–(5). Calculated fuzzy utility measures, regret measures and compromise solutions are given in Table 6.

Table 6: Fuzzy utility measures and fuzzy regret measures of the alternatives

	The utility measures $(\tilde{S}_i)$	The regret measures $(\tilde{R}_i)$	The compromise solutions $(\tilde{Q}_i)$
A1	(0.093,0.222,0.357)	(0.026,0.042,0.063)	(0.031,0.264,0.531)
A2	(0.266,0.415,0.548)	(0.060,0.080,0.095)	(0.420,0.698,0.925)
A3	(0.183,0.319,0.454)	(0.054,0.078,0.094)	(0.298,0.589,0.829)
A4	(0.289,0.439,0.561)	(0.070,0.093,0.104)	(0.507,0.808,1.000)
A5	(0.062,0.190,0.333)	(0.036,0.046,0.058)	(0.063,0.259,0.474)

The calculated fuzzy compromise solutions of the alternatives are defuzzified by using Eq. (6)–(9). According to the defuzzified results, the best hospital location is Alternative 5 with the lowest Q_i value of 0.276. Fuzzy decision matrix given in Table 3 with the weights given in Table 2 for the hospital location selection is also analyzed by using fuzzy AHP proposed by Çelikbilek et al.[36] for comparison and validation of the results obtained in this study. The defuzzified compromise solution results of fuzzy

VIKOR with the results of fuzzy AHP[36] for comparison and validation is given in Table 7.

Table 7: Defuzzified compromise solutions of fuzzy VIKOR with the results of fuzzy AHP

	Defuzzified compromise solutions (Q_i)	Ranking	Fuzzy priority weights of F–AHP	Defuzzified results priority weights of F–AHP	Ranking
A1	0.2875	2	(0.685,0.829,0.966)	0.8211	2
A2	0.6769	4	(0.481,0.623,0.782)	0.6354	4
A3	0.5746	3	(0.582,0.725,0.870)	0.7266	3
A4	0.7715	5	(0.468,0.598,0.758)	0.6132	5
A5	0.2761	1	(0.711,0.863,1.000)	0.8509	1

Findings

According to the results shown in Table 7, ranking of the alternatives decreasing from the best is Alternative 5, Alternative 1, Alternative 3, Alternative 2 and Alternative 4, respectively. Alternative 5 is the best location for the new hospital of the health institution; on the contrary, Alternative 4 is the worst location for the new hospital of the health institution. Final ranking results of the proposed approach were validated with the fuzzy AHP. Besides these, fuzzy compromise solutions show that the intersection of the fuzzy results of the first and the second alternatives (A5–A1) is large. Namely, we should evaluate the first and second alternative carefully for the final decision. According to these fuzzy results, ranking of the first and the second alternative can be changed even if the conditions are changed slightly. In addition, the ranking can be changed according to the defuzzification technique chosen during the evaluation process. To avoid making wrong decision in this situation, results can be validated by using other MCDM techniques as done in this study for confirmation.

Discussions and Conclusion

This study introduced a fuzzy VIKOR approach for the hospital location selection under group decision making conditions. Possible hospital locations are evaluated by the members of the board of the directors according to their weights in the board of the directors. This enables a more objective evaluation of the hospital locations in a group decision making process. The proposed approach also facilitates the evaluation of the hospital locations according to the results of each criterion separately.

A literature review of the studies focusing on the hospital location selection shows that there are limited studies focusing on the hospital location selection using MCDM techniques as well as for fuzzy systems. This study proves the applicability of the fuzzy MCDM techniques for the hospital location selection problems. The proposed approach was used for the evaluations of the possible new hospital locations of a health institution in order to demonstrate its efficiency and feasibility.

For further researches, the proposed approach can be used for the other MCDM problems of health sciences as medical devices selection, hospital manager selection and medical supplier selection. It can also be integrated with other fuzzy MCDM methods to improve its results and methodology.

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