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An Innovative Fuzzy TOPSIS Method to Determine the Location of A New Hospital

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Abstract: The optimal facility location choosing is very necessary action for newly established facilities. There are many phases for building the new hospital. Firstly, hospital's location must be determined for the new one. While choosing the most appropriate location; a number of criteria is taking into account by facility managers who are in the case of deciding and they evaluate alternatives under the criteria. And also location of healthcare buildings are extremely important. In this study, six experts' opinions help us to decide the best place for new hospital in Eskişehir. The assessments are decision makers' subjective assessments. Most commonly used methods in this kinds of problem is fuzzy logic. So in this study it is used for determining methods for multi-criteria problems. 5 candidates are evaluated and the fuzzy TOPSIS method is used to sequence the options for new hospital location. Objective of this study is selecting the best location for new hospital in Eskişehir.

Keywords Facility location, Fuzzy TOPSIS, Multi-criteria decision making, Fuzzy logic.

1. Introduction

The people who serve in the health sector in our country are in interaction with some factors. While some factors can be controlled by sector managers, the other part can be checked from time to time. Some of them are developing completely out of control of management. By going out of here; the starting point for improving the quality of service in the health sector is to optimize the controllable factors as much as possible. Taking this optimization into consideration at the initial stage of the health care facility means that the position of the establishment is determine correctly. While many improvements can be made in the service phase, changing the location of the organization is a difficult and often undesirable process. The most basic methods that can be applied choosing a location are multi-criteria quantitative decision making methods. These methods are aimed at optimizing multiple objectives at the same time.

There are many methods used in location selection. TOPSIS is one of these methods that allows us to make the best choice[1]. Especially in recent years it has been frequently observed that the health institution that have entered the service that are not planned by analytical methods can not achieve their goals. For this reason, in the following years, the health managers have heard the need to use analytical methods in planning and service processes. As a result, decisions were made more robust and accurate and faster solutions were started to be produced as far as possible from personal comments.

2. Literature Review

Numerical methods are generally used in mathematical programming and multi-criteria methods in recent years studies on selection of location of establishment. In one study, the solution was investigated by dual-mode linear mathematical programming[2]. Goemans et al. used the fuzzy AHP method for these kind of problems[3]. Deng et al. has analysed the problem of establishment place in leather sector with Analytic Hierarchy Process[4]. On the other hand, Padberg et al. examined the problem of establishment place in furniture sector with Analytic Hierarchy Process[5]. Balinski studied the same problem with the help of fuzzy TOPSIS[6]. Chudak used fuzzy AHP and fuzzy TOPSIS methods together and compared these two methods[7]. And Baran et al. used AHP and linear mathematical model together to determine the order quantity for suppliers[8]. Also Baran used linear mathematical programming to schedule the work shifts, it has some similarities with this studies problem[9].

In this study, a decision model is proposed to determine the most suitable candidate region for hospital location selection. Selection of branch locations in the health sector is a process in which many factors are active and factors affecting this process may vary for each hospital. In other words, selection of criteria can be determined differently for each hospital because the decision process is different. The segment is different and different location preferences for different hospitals can be seen as a result.

For the selection of an effective hospital location, candidates with the best criteria should be identified by evaluating candidate hospital locations based on appropriate criteria. However, in some cases, numerical values may be insufficient when evaluating. In other words, linguistic variables such as medium, little and more can be used. The fuzzy TOPSIS model developed by Chen et al. which is one of the models based on the fuzzy set theory, can make such evaluations meaningful[10]. In the fuzzy TOPSIS model, evaluation of decision criteria and existing alternatives is done with linguistic variables. In the third part of the study, the algorithm of the fuzzy TOPSIS model is introduced. In the fourth part of the study, 5 different regions in Eskişehir were evaluated by fuzzy TOPSIS method for hospital location.

3. Fuzzy Logic and Fuzzy TOPSIS

Barany, who presented the packing and covering tree, stated that it is necessary to use linguistic expressions rather than numerical expression[11]. While fuzzy set theory models the linguistic uncertainty associated with human perception and special judgments, it ensures that this ambiguity is expressed mathematically with fuzzy numbers.

One of the most common methods in multi-criteria decision making problems is the TOPSIS method[12]. The most important feature of the TOPSIS method, which is a linear weighting technique is to determine the most appropriate solution in which the positive ideal solution is the closest and the negative ideal solution is the farthest. With these distances being bi-directional, not only minimized sitiuations but also minimized situations are considered and the most appropriate choice made accordingly[13]. From this point of view, the method can be used as an alternative method that can be used in hospital location selection. However, when evaluating many cases in real life, numerical values may be insufficient because human preferences and judgments, especially preferences, often include uncertainty. The fuzzy TOPSIS method developed by Chen et al. was used in the decision support model developed for the hospital location which constitutes the subject of this study[10]. In the first step of this method, a jury composed of expert decision makers(DM) is formed. The set of N decision-makers is expressed as E={€1, €2,…., €N}. After the jury is formed, the existing alternatives A={A1, A2,…,Am} and the criteria C={C1, C2,…,Cn} to be used in evaluating these alternatives are determined. Following this, they evaluate alternatives and criteria with the help of verbal variables to be used in evaluating the alternatives and determining the importance of the criteria. The expression of these evaluations as fuzzy numbers is shown in Table1 and Table2.

Very Good (VG)	(0.7, 1, 1)
Good	(0.65, 0.75, 0.80)
Slightly Good (SG)	(0.45, 0.55, 0.75)
Average (A)	(0.35, 0.45, 0.65)
Slightly Bad (SB)	(0.25, 0.45, 0.6)
Bad (B)	(0.15, 0.3, 0.45)
Very Bad (VB)	(0, 0, 0.3)

Table 1. Determining the Weight of Criteria

Very Good (VG)	(7, 9, 10)
Good	(7, 8, 9)
Slightly Good (SG)	(5, 6.5, 8)
Average (A)	(4, 5, 6)
Slightly Bad (SB)	(2, 3.5, 5)
Bad (B)	(1, 2, 3)
Very Bad (VB)	(0, 0, 2)

Table 2. Determining the Weight of Alternatives

4. Application

In this study, the optimal hospital setting for Eskişehir is determined. For this purpose, the opinions of the specialists of the hospital management were taken and the most appropriate settlement plan was created in the light of these opinions. As the optimal settlement alternatives, the regions in different geographical locations of Eskişehir were discussed. When determining the regions, the socio-economic level, the geographical position of the region and the transportation possibilities were taken into consideration and the regions of Sumer(A1), Kırmızı Toprak(A2), 71 Evler(A3), Batikent(A4) and Sazova(A5) districts were investigated. From these regions, optimal hospital setting was obtained by appropriate quantitative decision method and the best solution was tried to be achieved.

In this study, it was aimed to select the best place for a new hospital planned to open in Eskişehir. For this purpose, expert opinion was taken to carry out the investment project; as a result, AHP was selected as the analysis method. A team of hospital managers, architects, finance specialists and academicians were asked to review the alternatives. Alternatives in the problem were chosen from different socio-economic levels of Eskişehir. The total number of private and state hospitals and health centers in Eskişehir is 25. However, a new state hospital has to be built to meet the health needs of this growing city. The locations of these health centers on the map and the candidate locations of the new hospitals are given below in Figure1.

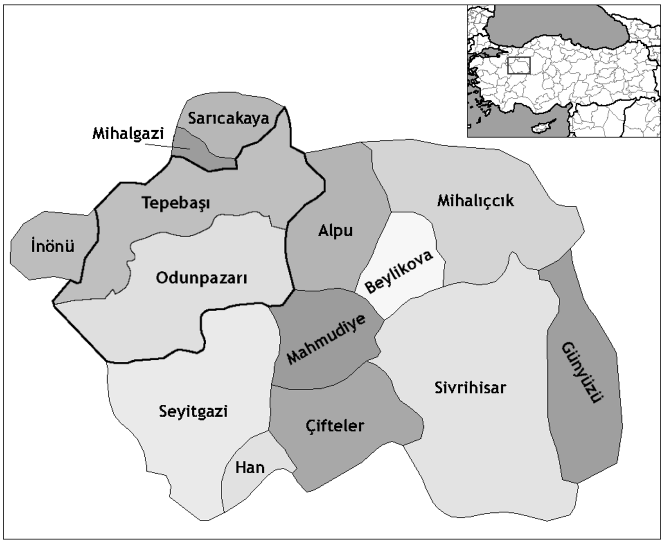

Figure 1. Map of Eskişehir

The 5 criteria for this problem are investment costs(C1), demographic structure(C2), environmental factors(C3), building location factors(C4) and building properties(C5). In table 3, evaluation of criteria weights by decision makers is given below.

	DM1	DM2	DM3	DM4	DM5	DM6
C1	VG	VG	VG	VG	VG	VG
C2	G	VG	VG	G	VG	VG
C3	VG	G	G	VG	G	G
C4	SG	G	SG	SG	G	SG
C5	G	G	G	G	G	G

Table 3. Evaluation of Criteria Weights

The evaluations of alternatives by each criterion by each criterion were transformed into triangular fuzzy numbers using Table 1 and Table 2. The fuzzy decision matrix is shown in Table 4. Criteria weights are given in Table 5.

	C1	C2	C3	C4	C5
A1	(6, 8.30, 10)	(6, 7.65, 10)	(4, 7.83, 10)	(6, 7.65, 9)	(8, 7.65, 10)
A2	(6, 7.50, 9)	(5, 7.5, 9)	(6, 8.50, 10)	(6, 8.5, 10)	(6, 8, 8)
A3	(6.50, 8, 9.50)	(6, 6, 7)	(6, 8, 9.50)	(6, 8, 9.50)	(6, 8.50, 9.50)
A4	(6, 7, 8)	(6, 7.5, 9)	(6, 7, 8)	(6, 8., 9.50)	(6, 8, 9.50)
A5	(6, 7.5, 9)	(3, 4, 5)	(5, 7, 8)	(3, 5, 7)	(5, 6, 8.50)

Table 4. Fuzzy Decision Matrix

Criteria	Weights
C1	(0.8, 1, 1)
C2	(0.75, 0.93, 1)
C3	(0.75, 0.87, 1)
C4	(0.5, 0.8, 1)
C5	(0.8, 0.8, 0.9)

Table 5. Criteria Weights

By using the Table 4, normalized decision matrix is determined and it is shown in Table 6.

	C1	C2	C3	C4	C5
A1	(0.7, 0.93, 1)	(0.7, 0.87, 1)	(0.5, 0.78, 1)	(0.7, 0.87, 1)	(0.7, 8.7, 1)
A2	(0.7, 0.87, 1)	(0.4, 0.65, 0.9)	(0.7, 0.93, 1)	(0.5, 0.75, 0.9)	(0.5, 0.75, 0.9)
A3	(0.6, 0.75, 0.8)	(0.6, 0.75, 0.8)	(0.6, 0.75, 0.9)	(0.6, 0.75, 0.8)	(0.6, 0.75, 0.8)
A4	(0.6, 0.7, 0.9)	(0.6, 0.75, 0.8)	(0.6, 0.85, 0.9)	(0.6, 0.75, 0.8)	(0.6, 0.75, 0.8)
A5	(0.6, 0.75, 0.8)	(0.3, 0.65, 0.8)	(0.5, 0.6, 0.8)	(0.5, 0.6, 0.7)	(0.5, 0.6, 0.75)

Table 6. Normalized Fuzzy Decision Matrix

Each of the values in the normalized fuzzy decision matrix is weighted normalized by multiplying by the corresponding criterial weights given in Table 5. And it is shown in Table 7.

	C1	C2	C3	C4	C5
A1	(036, 0.94, 1)	(0.45, 0.81, 1)	(0.4, 0.74, 1)	(0.52, 0.7, 0.9)	(05, 0.61, 0.8)
A2	(0.36, 0.77, 1)	(0.25, 0.75, 0.84)	(0.45, 0.78, 1)	(0.3, 0.5, 0.8)	(0.4, 0.62, 0.74)
A3	(0.6, 0.8, 0.9)	(0.45, 0.55, 0.74)	(0.4, 0.65, 0.81)	(0.3, 0.53, 0.77)	(0.5, 0.62, 0.78)
A4	(0.46, 0.7, 0.9)	(0.45, 0.75, 0.9)	(0.5, 0.6, 0.8)	(0.3, 0.53, 0.75)	(0.45, 0.6, 0.77)
A5	(0.45, 0.75, 0.9)	(0.21, 0.45, 0.7)	(0.32, 0.47, 0.75)	(0.33, 0.45, 0.63)	(0.3, 0.51, 0.78)

Table 7. Weighted Normalized Fuzzy Decision Matrix

By using these tables and equations, proximity coefficients is determined and it is shown in Table 8 below.

Alternatives	CC_n
A1	0.618
A2	0.549
A3	0.460
A4	0.502
A5	0.388

Table 8. Proximity Coefficients

When we analyze the table 8, it is contributed from it that proximity coefficients' sequence from the best to worst is A1>A2>A4>A3>A5. In other words, the best candidate in this problem is Sogut. And the sequence should be Sogut, Kırmızı Toprak, Batikent, 71 Evler, Sazova.

5. Conclusion

When the results of this study for determining the most suitable city for the opening of a new branch are examined, it is seen that the most important criteria together with the criterial values are the investment costs which is foregrounded in many other studies in the literature. The

Sogut score is the highest in the direction of criteria and hospital administrators' branch opening is considered to be the most suitable candidate. It is also possible to observe that this region is rated higher than the other candidate regions for the criteria used in the study.

The fuzzy TOPSIS method is method to help group decision in fuzzy environments. In this study, linguistic expressions are transformed into triangular fuzzy numbers. The fuzzy TOPSIS method, which is based decision making methods, has been very successfully in the solution of such models. The fact that fewer makers have the advantages of being sufficient and easy to implement, as well as the correct determination of criteria and weights this method, depends on the objective attitude of decision makers.

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