Avrupa Bilim ve Teknoloji Dergisi
Sayı 16, S. 750-757, Ağustos 2019

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
No. 16, pp. 750-757, August 2019

Research Article

A Healthcare Facility Location Selection Problem with Fuzzy TOPSIS Method for a Regional Hospital

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(İlk Geliş Tarihi 28 Haziran 2019 ve Kabul Tarihi 25 Temmuz 2019)

(**DOI:** 10.31590/ejosat.584217)

ATIF/REFERENCE: Miç, P. & Antmen, Z. F. (2019). A Healthcare Facility Location Selection Problem with Fuzzy TOPSIS Method for a Regional Hospital. *Avrupa Bilim ve Teknoloji Dergisi*, (16), 750-757.

Abstract

As being a significant determination for companies, facility location can be regarded as a multi-criteria decision making (MCDM) problem. Nonetheless, facility location is not significant merely in companies, likewise, facility location decisions in healthcare are significant, as well. Furthermore, since human life is the point in healthcare facilities, facility location decisions in this field are vitally important. As are in other facility location problems, there are multiple criteria to be taken into consideration in health care facility location problems and managers in this area should evaluate alternatives under these criteria. Since this process includes uncertainties, it is suitable to integrate fuzzy logic to this process to obtain more accurate results. In line with this, in this study, a fuzzy approach with multi criteria is presented with regard to the evaluation of healthcare facility location. Within the study, in the framework of specified criteria, a fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach is suggested and the proposed approach is performed at a case study for regional hospital location selection in Adana province. The acquired results are expected to be a useful resource to the future decisions in this area for decision makers.

Keywords: Facility Location, Healthcare Facility Location Selection, Multi-criteria Decision Making, Fuzzy Logic, Fuzzy TOPSIS

Bir Bölge Hastanesi için Bulanık TOPSIS Yöntemi ile Sağlık Hizmeti Tesis Yerleşimi Seçimi Problemi

Öz

Şirketler için en önemli kararlardan birisi olarak, tesis yerleşimi çok kriterli bir karar verme (ÇKKV) problemi olarak düşünülebilir. Fakat, tesis yerleşimi sadece şirketler için önemli değildir, aynı şekilde, sağlık hizmetindeki tesis yerleşimi kararları da çok önemlidir. Hatta, sağlık hizmeti tesislerinde insan hayatı söz konusu olduğu için, bu alandaki tesis yerleşimi kararları hayati derecede önemlidir. Diğer tesis yerleşimi problemlerinde olduğu gibi, sağlık hizmeti tesislerinin yerleşimi probleminde de dikkate alınması gereken kriterler vardır ve bu alandaki yöneticilerin bu kriterler altında alternatifleri değerlendirmesi gerekir. Bu süreç belirsizlikleri içerdiğinden dolayı, daha doğru sonuçlara ulaşmak için bu sürece bulanık mantığı ilave etmek uygun olacaktır. Bu doğrultuda, bu çalışmada, sağlık hizmeti tesis yerleşimi değerlendirmesi için çok kriterli bulanık bir yaklaşım sunulmuştur. Çalışma dahilinde, belirlenen kriterler çerçevesinde bulanık bir TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) yaklaşımı sunulmuştur ve önerilen yaklaşım Adana ilindeki bir bölge hastanesi yer seçimi vaka çalışması üzerinde uygulanmıştır. Elde edilen sonuçların, karar vericilere bu alandaki gelecekteki kararları için yararlı bir kaynak olması beklenmektedir.

Anahtar Kelimeler: Tesis Yerleşimi, Sağlık Hizmeti Tesis Yeri Seçimi, Çok Kriterli Karar Verme, Bulanık Mantık, Bulanık TOPSIS

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1. Introduction

Facility location has a great importance in product and service facilities since it helps reducing/removing visible or concealer losses. Furthermore, to be able to operate efficiently a production or service system, not only implementing the most appropriate plan and operational policies are required; also a suitable facility location is necessary (Gülsün, Tuzkaya, & Duman, 2011). Facility location problems may arise in many forms; thus it is crucial to design the facility location in the best manner.

As being both a service facility type but also as the topic of this study; healthcare facilities deliver health service to people. The accuracy of the decisions regarding healthcare facilities impacts the success of the organization directly. It impacts not only the success of healthcare facility; it also effects people's well-being who will be served from that healthcare facility. Particularly nowadays setting up a new facility is a hard decision and taking into account this point, it is obvious that site selection for healthcare facilities requires a large-scaled investment but also it is a troublesome and complicated process. In case that a healthcare facility is set up in a wrong location, it will lead to many troubles and extra costs which will obligate the administrators to deal with these problems. Due to these situations, there will not be positive results in terms of both social expectations and the economic situation of the healthcare facility.

In a broad perspective, there are various studies in literature regarding healthcare facilities. While some studies present a general overview and a review about facility locations in healthcare (Ahmadi-Javid, Seyedi, & Syam, 2017; Hamid Afshari, 2014); some studies focus on a specified field in healthcare facilities, such as intensive care units (Antmen, 2012; Miç & Antmen, 2018), physiotheraphy service (Ogulata, Koyuncu, & Karakas, 2008) or emergency departments (Koyuncu, Araz, Zeger, & Damien, 2017). However, this study's purpose is deciding the most suitable healthcare facility location and for a more detailed literature review, we first focused on decision making problems and then their applications in healthcare facilities.

Decision making can be explained as a technique of making decisions/choices by obtaining information and evaluating alternatives. As in our case, there are a number of criteria to be assessed in this technique, thus it is called "multi criteria decision making (MCDM)". In literature, there are a variety of MCDM methods which are implemented at different sectors. Among the various MCDM techniques, Analytic Hierarchy Process (AHP), Elemination and Choice Translating Reality English (ELECTRE), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) and Preference ranking organization method for enrichment evaluation (PROMETHEE) are the most frequently used methods. A brief summary of some of these technique's area of use are presented thus: AHP technique at educational and vocational guide (Haji, Azmani, & Harzli, 2017), school site selection (Uslu, Kızıloğlu, İşleyen, & Kahya, 2017), determining teaching methods in chemistry education (Yüksel, 2013), hospital facility location selection problem (Wu, Lin, & Chen, 2007; Aydın, Öznehir, & Akçalı, 2009; Vahidnia, Alesheikh, & Alimohammadi, 2009; Datta, 2012; Vafaei, 2014; İnce, Bedir, & Eren, 2016). ELECTRE method for water management (Alvarez-Guerra, Viguri, & Voulvoulis, 2009), ecotourism (Ok, Okan, & Yilmaz, 2011), performance and benchmarking (Bilich & Da Silva, 2008), energy management (Avgelis & Papadopoulos, 2009), risk assessment (Brito, de Almeida, & Mota, 2010), facility layout (Aiello, Enea, & Galante, 2006) and supplier choosing (Montazer, Saremi, & Ramezani, 2009). TOPSIS method at banking and finance (Akyüz, Bozdoğan, & Hantekin, 2011; Amile, Sedaghat, & Poorhossein, 2013), mechanical ventilator selection (Antmen & Miç, 2018), supplier selection (Kumar, Kumar, & Gopal Barman, 2018; Shahroudi & Tonekaboni, 2012), education decisions (Arslan & Yıldız, 2015; Miç, Antmen, & Erdurak, 2019), safety evaluation (Li et al., 2011) and personnel selection (Kelemenis & Askounis, 2010; Şenel, Şenel, & Aydemir, 2017).

However, despite the studies about healthcare facility location in literature; the process of determining healthcare facility location contains uncertainties and it should be better to employ fuzzy logic in this field. In the light of these motives, for the hospital location selection problem, we integrated fuzzy logic and a MCDM method (TOPSIS) in this study since TOPSIS technique is one of the most applied techniques to determine facility locations. Some advantages of this method can be summarized as:

- It has an understandable and logical conception,
- It presents the reasoning of human chocies,
- Computations in this technique are nox complex and they are efficient,
- It permits the decision maker (DM) to assess the best and worst option's relative performance.

In the remainder of this paper, in Section 2, we present an overview about material and method. In Section 3, case study and results are demonstrated. Finally, Section 4 comprises outcomes and suggestions to next studies.

2. Material and Method

In this study, we utilized six criteria for evaluating hospital facility location and adopted fuzzy TOPSIS method for this aim.

2.1. Material

The location of the facility and its location has a significant importance for healthcare facilities. At this point, a decision maker, particularly for healthcare facility location selection problem, should take into account many criteria such as costs and social expectations and then evaluate multiple alternatives (Calvo & Marks, 1973). The quality and efficiency of provided health service increases in healthcare facilities which are built accurately. A healthcare facility location brings some problems together with it if it is not determined properly. For example, there must be factors to bear in mind to ensure patients and hospital staff to reach the hospital within the shortest time. In addition, since hospitals are unmovable, it is crucial to select a feasible location against changing environmental conditions and epidemiological variations.

Therefore, after reviewing related literature and interviewing with hospital head phsycian autrohirites, we specified hospital location selection criteria to be utilized in fuzzy-TOPSIS method in the following:

- Demographic structure (C1) which includes the size of the population, the compound of the population (constitution, birth and death rates), livelihood as well as the distribution of the population and migration;
- Investment costs (C2) which includes hiring purchase, facility arrangement costs and environmental planning costs;
- Travel time and travel costs (C3) which includes the distance of travel (short/long) or direct/indirect transportations;
- Environmental factors (C4) which includes the traffic density, transportation type, closeness to the noise sources and suitability to urban planning;
- Infrastructure (C5) which includes parking areas, the sufficiency of infrastructure and noticeability;
- Location (C6) which includes closeness/distance to the regions that people live commonly.

These six criteria are employed in the utilized Fuzzy TOPSIS technique to decide the best suitable hospital location. In the study, we assumed that the population of candidate counties and investment costs for each alternative location are fixed.

2.2. Fuzzy-TOPSIS Technique

TOPSIS technique was first suggested by Hwang and Yoon (1981) and since that time it is between most utilized techniques for MCDM problems. Nevertheless, at the present time, many real world problems contain uncertainness and they cannot be solved with certain approaches. Thus, it is essential to apply linguistic expressions and fuzzy numbers to solve problems. Since our aim is to obtain most consistent results, we addressed the hospital location selection problem within fuzzy environment which was first raised by Zadeh (1965).

In the following, while Table 1 demonstrates the lingual expressions and their correspondent fuzzy numbers for determination of determination criteria; Table 2 presents lingual expressions and their correspondent fuzzy numbers for evaluating alternatives. A detailed information about fuzzy-TOPSIS method employed in this paper can be found in Chen, Lin, & Huang (2006). In this study, lingual idioms which are presented below are utilized for specifying decision criteria weights and evaluating the alternatives, respectively.

Table 1. Lingual idioms to specify decision criteria weights (Chen, 2000)

Lingual Idioms	Fuzzy Numbers
Very High (VH)	(0.8,1,1)
High (H)	(0.7,0.8,0.9)
Medium High (MH)	(0.5,0.65,0.8)
Medium (M)	(0.4,0.5,0.6)
Medium Low (ML)	(0.2,0.35,0.5)
Low (L)	(0.1,0.2,0.3)
Very Low (VL)	(0,0,0.2

Table 2. Lingual idioms to evaluate the alternatives (Chen, 2000)

Lingual Idioms	Fuzzy Numbers
Very Good (VG)	(8,10,10)
Good (G)	(7,8,9)
Medium Good (MG)	(5,6.5,8)
Medium (M)	(4,5,6)
Medium Poor (MP)	(2,3.5,5)
Poor (P)	(1,2,3)
Very Poor (VP)	(0,0,2)

3. Case Study and Results

For case study, we selected Adana province, which is one of the five biggest cities in Turkey. Total population in the city is 2,220,125 people ("Turkish Statistical Institute," 2019). Adana's location in Turkey map is presented by Figure 1.

Figure 1. Adana Province's Location in Turkey Map

Our purpose is to decide the best location of the new regional city hospital between 4 alternative county locations. These alternatives are:

- Seyhan (A1),
- Yüregir (A2),
- Cukurova (A3),
- Saricam (A4).

The locations of these four candidate locations in Adana province are demonstrated with Figure 2 below.

Figure 2. Locations of four candidate locations in Adana

The populations of these counties are 793,480; 415,198; 365,735 and 173,154 people, respectively ("Turkish Statistical Institute," 2019).

For evaluation of criteria and alternatives, we consulted three hospital head phsycian autrohirity as decision makers. They are notated anonymously as DM1, DM2 and DM3 within the study. After the determination of the criteria, the decision makers evaluated the related hospital facility location criteria according to Table 1. The evaluations of decision makers for each criteria are presented by Table 3.

Table 3. Criteria evaluation according to decision makers

Criteria	Decision Makers		
	DM1	**DM2**	**DM3**
C1	ML	M	M
C2	H	H	VH
C3	H	VH	H
C4	M	MH	M
C5	H	MH	H
C6	VH	H	VH

In line with these criteria evaluations, each criteria's weight is calculated utilizing fuzzy numbers demonstrated with Table 1. Criteria weights which are obtained from DMs' lingual expressions are presented by Table 4. As seen from Table 4, decision makers agreed that the most important criteria for addressed healthcare facility location selection problem is "Location" which is symbolized by "C6" in this study.

Table 4. Criteria weights obtained from lingual expressions

Criteria	**Weights**
C1	(0.33,0.45,0.57)
C2	(0.73,0.87,0.93)
C3	(0.73,0.87,0.93)
C4	(0.43,0.55,0.67)
C5	(0.63,0.75,0.87)
C6	(0.77,0.93,0.97)

Then, each candidate location option is evaluated by DMs for each criterion according to the lingual idioms given at Table 2. These evaluations are given with Table 5.

Table 5. *Alternative evaluations for each criteria*

Criteria	**Alternatives**	**Decision Makers**			**Criteria**	**Alternatives**	**Decision Makers**		
		DM1	**DM2**	**DM3**			**DM1**	**DM2**	**DM3**
C1	A1	VG	G	VG	C4	A1	G	G	G
	A2	G	MG	M		A2	G	MG	MG
	A3	M	M	M		A3	M	M	M
	A4	M	MP	MP		A4	MP	MP	MG
C2	A1	G	MG	G	C5	A1	G	G	VG
	A2	G	MG	MG		A2	MG	MG	MG
	A3	M	M	MG		A3	M	M	MG
	A4	M	M	MP		A4	MP	MP	MP
C3	A1	MG	MG	MG	C6	A1	VG	VG	VG
	A2	G	MG	MP		A2	MG	M	M
	A3	MG	M	MP		A3	M	MG	MP
	A4	MP	P	MP		A4	P	P	MP

Following this step, these evaluations (Table 5) are degraded to a one value and thus fuzzy decision matrix is built. It is demonstrated by Table 6 below.

Table 6. *Fuzzy decision matrix*

	Alternatives			
Criteria	A1	A2	A3	A4
C1	(5.75,7.00,7.25)	(4.00,4.88,5.75)	(3.00,3.75,4.50)	(2.00,3.00,4.00)
C2	(4.75,5.63,6.50)	(4.25,5.25,6.25)	(3.25,4.13,5.00)	(2.50,3.38,4.25)
C3	(3.75,4.88,6.00)	(3.50,4.50,5.50)	(2.75,3.75,4.75)	(1.25,2.25,3.25)
C4	(5.25,6.00,6.75	(4.25,5.25,6.25)	(3.00,3.75,4.50)	(2.25,3.38,4.50)
C5	(5.50,7.00,7.00)	(3.75,4.88,6.00)	(3.25,4.13,5.00)	(1.50,2.63,3.75)
C6	(6.00,7.50,7.50)	(3.25,4.13,5.00)	(2.75,3.75,4.75)	(1.00,1.88,2.75)

Then, fuzzy decision matrix is converted into normalized fuzzy decision matrix. This process is performed for each column by dividing each value in that column to the biggest value in related column. Since our matrix has four alternatives namely columns, we performed this process for all these columns (alternatives). Normalized fuzzy decision matrix is demonstrated with Table 7.

Table 7. Normalized fuzzy decision matrix

	Alternatives			
Criteria	A1	A2	A3	A4
C1	(0.79,0.97,1.00)	(0.55,0.67,0.79)	(0.41,0.52,0.62)	(0.28,0.41,0.55)
C2	(0.73,0.87,1.00)	(0.65,0.81,0.96)	(0.50,0.63,0.77)	(0.38,0.52,0.65)
C3	(0.63,0.81,1.00)	(0.58,0.75,0.92)	(0.46,0.63,0.79)	(0.21,0.38,0.54)
C4	(0.78,0.89,1.00)	(0.63,0.78,0.93)	(0.44,0.56,0.67)	(0.33,0.50,0.67)
C5	(0.79,1.00,1.00)	(0.54,0.70,0.86)	(0.46,0.59,0.71)	(0.21,0.38,0.54)
C6	(0.80,1.00,1.00)	(0.43,0.55,0.67)	(0.37,0.50,0.63)	(0.13,0.25,0.37)

Next, each value in normalized fuzzy decision matrix is multiplied by related criteria's weight which was given by Table 4. In this way, weighted normalized fuzzy decision matrix is acquired and it is presented by Table 8 below.

Table 8. Weighted normalized fuzzy decision matrix

	Alternatives			
Criteria	A1	A2	A3	A4
C1	(0.26,0.43,0.57)	(0.18,0.30,0.45)	(0.14,0.23,0.35)	(0.09,0.19,0.31)
C2	(0.54,0.75,0.93)	(0.48,0.70,0.90)	(0.37,0.55,0.72)	(0.28,0.45,0.61)
C3	(0.46,0.70,0.93)	(0.43,0.65,0.86)	(0.34,0.54,0.74)	(0.15,0.33,0.51)
C4	(0.34,0.49,0.67)	(0.27,0.43,0.62)	(0.19,0.31,0.44)	(0.14,0.28,0.44)
C5	(0.50,0.75,0.87)	(0.34,0.52,0.74)	(0.29,0.44,0.62)	(0.14,0.28,0.46)
C6	(0.61,0.93,0.97)	(0.33,0.51,0.64)	(0.28,0.47,0.61)	(0.10,0.23,0.35)

In the last stage of the method, fuzzy positive ideal solution (FPIS$-A^*$) and fuzzy negative ideal solution (FNIS$-A^-$) are computed for all alternatives. These calculations lead to obtain each alternative city's distance from these solutions denoted as $d_i^*$and d_i^-. In the final, closeness coefficient (C_i) of each candidate city is specified, which are presented with Table 9. The alternative which has higher C_i is the best alternative to locate the city hospital.

Table 9. *Closeness coefficient values of each alternative and rankings*

Alternative	C_i	Ranking
A1	0.76	1
A2	0.66	2
A3	0.59	3
A4	0.50	4

Table 9 shows the closeness coefficient values of each candidate city, also the rankings. As seen from the table, the ranking of alternatives will be: A1 > A2 > A3 > A4. This means that the best location to set up the regional city hospital is A1, namely Seyhan county in Adana, Turkey.

4. Conclusions

Although in the early stages, facility location was based upon only the minimization of transportation costs; later the importance of facility location on service quality is realized and thus its importance is increased. Besides, hospital administration has the opportunity to apply different strategies at different times to raise service quality or decrease costs. On the other hand, due to a built hospital's location cannot be changed later, choosing the right place in the beginning is highly important. Also, hospitals must be located to the most suitable locations to serve patients in the fastest and best way.

Determining the best healthcare facility location is a MCDM problem which contains various criteria. In this decision, personal knowledges are not enough and evaluating the subject from different perspectives should be better. Accordingly, this problem is addressed via a decision making technique in this study. Since TOPSIS is one of the most-utilized methods in MCDM problems and healthcare facility decisions, we adopted this method within the fuzzy environment. The criteria for hospital locations are gained reviewing related literature and consulting hospital head phsycian autrohirities. As a case study, we implemented the proposed method to regional city hospital location selection problem in one of the biggest cities, Adana in Turkey. As a result, Seyhan county is revealed as the best city hospital location.

For further studies, the suitability of other MCDM methods and fuzzy approaches can be examined to healthcare facility location determination question. Also, after the determining of healthcare facility location, the settlement of healthcare facility's departments can be addressed.

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