Comparison of Two Fuzzy Multi Criteria Decision Methods for Potential Airport Location Selection

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Abstract: Facility location selection is a very important multi criteria decision problem for many companies. As other strategic decisions, any failure in facility location selection has also irreversible consequences that affect the future of a company. Multi criteria decision methods (MCDM) are widely used in comparison related problems. These methodologies give more obvious and rational solutions in decision process. This study is proposed fuzzy TOPSIS and fuzzy ELECTRE I to overcome facility location selection problem. We combine fuzzy sets theory with two different multi criteria decision methods to eliminate the vagueness of linguistic factors that stem from the uncertain and imprecise assessment of decision-makers. The proposed methods have been applied to a facility location selection problem that determines a potential second airport in Ankara, Turkey.

1 INTRODUCTION

Strategic decisions are usually evaluated as irreversible decisions that affect the future of a company. The reason behind this situation is the risky nature of strategic decisions. Any mistaken decision may cause terrible consequences that will threat the existence of the company. Facility location selection may be the most important decision among strategic decisions. The aim of facility location is determining the optimal location for a company. Facility location selection requires sizable financial investment and can affect operating costs and revenues. So, poor location selection causes high distribution costs, expensive or incapable labor, inadequate raw materials, financial loss and low competitive advantage (Reid and Sanders, 2011). On the one hand, facility location selection aims to keep variable costs as low as possible in order to reach customer zones; on the other hand, facility location selection causes high fixed costs.

Several papers attempt to find the best solution for facility location problem from past to present. Many papers aim to find an optimal solution with mathematical programming methods. Spath (1984) tried to minimize weighted sum of distances to their minimum location centre. Aikens (1985), Owen and Daskin (1998), and Melo et al., (2009) reviewed vast number of papers in which several mathematical models were developed in order to find the best facility location for different requirements. Nevertheless, mathematical programming models take into consideration only quantitative factors, qualitative factors such as linguistic factors are not always considered. On the other hand, multi criteria decision methods (MCDM) usually merge both quantitative and qualitative factors. Thus, decision-maker (DM) takes into account both type of factors that affect facility location selection. Mostly, the values for the qualitative criteria are not accurately defined for decision-makers. Moreover, value and importance weight of criteria are usually defined e.g. “very low”, “low”, “medium”, “high”, “very high". So, it is very hard to accurately quantify the rating of each alternative location.

To select best facility location, different multi criteria decision methods have been suggested in various papers. Yang and Lee (1997) used analytical hierarchy process (AHP) to select facility location from the view of organizations which contemplate locations of a new facility or a relocation of existing facilities. Market, transportation, labor and community were determined as main factors, and then every factor is divided into three sub-factors. Badri (1999) tried to combine AHP and goal

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programming in order to minimize the overall deviations in the objective function. Proposed model aims to solve facility location-allocation problem for Biochemical Company. Yang et al., (2008) developed AHP-ANP approach for evaluating location characteristics in order to help managers to realize the advantages and disadvantages of potential location. To establish a location selection model, this study suggested three-step procedure. It consists of building initial criteria, modifying dimensions and detailed criteria, and building an evaluation model, respectively. In study of Erden and Cosgun (2010), AHP and geographic information systems (GIS) combination used to find optimal site location among pre-selected fire stations. GIS has been used for supporting spatial decision-making. After the determination of possible locations, decision maker decides main criteria for AHP procedure. Deluka-Tibljas et al., (2010) proposed an AHP approach to solve the problem of selecting a location for the garage-parking facility in a town.

Except AHP related models, other MCDM have also been used for facility selection problems. Gundogdu (2011) suggested an ELECTRE I method for selecting facility location of industrial plants when considering environmental priorities. Huang et al. (2011) formulated potential influence location ranking theory. Authors offered a nearest location circle algorithm and a voronoi diagram based algorithm to process the query. Zhang (2011) used two stage procedure GIS model in order to select facility location for biofuel production company. When the first stage revealed potential locations related to railroads, roads, and other transportation channels, the second stage was detected facility exact location by using a total transportation cost model. Combining Bayesian Networks and Total Cost of Ownership (TCO), Dogan (2012) analyzed facility location problem for an international manufacturing plant. With suggested model, decision maker selects the facility that has minimum total cost when considering multiple criteria.

In real world, the evaluation of decision process can rarely be given precisely because of the uncertain structure of linguistic terms. In fact, defining linguistic terms without losing the meaning can be extremely challenging issue for researchers. To eliminate the vagueness of linguistic terms, fuzzy sets have been integrated with several MCDM. Liang and Wang’s (1991) study is one of the first attempts to combine a MCDM and fuzzy sets into a model. The model helps decision maker to assess precisely the weighting criteria and the determination of facility location. Chen (2001) solved the location selection problem of distribution center by using a fuzzy approach that express the ratings of alternatives and the weights of criteria in triangular fuzzy numbers. After that, all potential locations were ranked in a fuzzy manner. Kaboli et al. (2008) and Tabari et al. (2008) were both combining fuzzy sets and AHP method to select facility location. Proposed models insert AHP method into the fuzzy sets. As a result of that, interval judgments become much more reliable than fixed value judgments during the process of facility location selection.

Chu (2002), developed a fuzzy TOPSIS model in which the ratings and weights of each alternative location could be aggregated by interval arithmetic and α-cuts of fuzzy numbers. Moreover, Hu et al. (2009) applied fuzzy sets into TOPSIS method in order to select best distribution center for a manufacturer. Ulukan and Kop (2009) used fuzzy TOPSIS method in two step procedure. Firstly, candidate locations were defined by a trapezoidal membership function. Then, this trapezoidal numbers embedded into criteria and alternatives in TOPSIS. Finally, suitable facility location selected for waste disposal company. Kahraman (2003) compared four different multi criteria decision methods (Blin's Fuzzy Method, Fuzzy Synthetic Evaluation, Yager's Weighted Goals, Fuzzy AHP) and showed basic differences among them. In this context, fuzzy AHP applied to motor vehicle manufacturer for facility location selection. Ertugrul and Kasapoglu (2008) presented another compression study between fuzzy AHP and fuzzy TOPSIS. Each approach was used to select the best facility location for a textile company. In a recent study, Ozdagoglu (2011) proposed fuzzy ANP method to overcome the problem of facility location selection. First step of fuzzy ANP includes the determination of fuzzy AHP solution. Next step focused on integrating fuzzy AHP solution into ANP approach. Kaya and Cinar (2007) investigated three different preference models to explain fuzzy outranking methods with the application of facility location selection for motors manufacture company. To select facility location for a high tech company, Chou et al., (2008) integrated fuzzy set theory, factor rating system and simple additive weighting into Fuzzy Simple Additive Weighting System. Momeni et al., (2011) attempted to extend VIKOR method by adding fuzzy sets into it. Fuzzy VIKOR solved facility location problem in eight consecutive steps when taking into account all criteria and alternatives.

Literature review shows that although several MCDM have been developed to solve different facility location problems, there is a huge gap about potential facility location selection for an airport. This study aims to fill this gap with suggested fuzzy TOPSIS and fuzzy ELECTRE I method. The criteria that belong to airport location selection are determined by structured interview with several experts from public and private sectors. After interviews, not only are criteria determined but also potential locations for airport are decided by the views of interviewees. The population of Ankara, the capital of Turkey, grows in each year because of immigration from rural regions. Also, these condense population give rise to growth in air transportation. Even though, Esenboğa, the only airport in Ankara, is the main stream of air transportation, lack of capacity makes air traffic more crowded as time progressed. We compare the solutions of two different MCDM in facility location selection for a second airport in Ankara. In section 2, we give brief information about fuzzy TOPSIS and fuzzy ELECTRE I methods. In section 3, we illustrate findings that are related to the application of airport location selection. In section 4, we sum up with our conclusions and future research directions.

2 METHODOLOGY

In this study we select two different MCDM in order to compare and comment the findings of these MCDM. Moreover, fuzzy TOPSIS and fuzzy ELECTRE use different way to make pairwise comparison between alternatives. Fuzzy TOPSIS ranks each alternative from the best to the worst by considering different criteria. On the other hand, fuzzy ELECTRE I outranks each alternatives by the aid of concordance and discordance matrices. These reasons take our attention when the determination process of MCDM selection among other MCDM. Below, we give some basic information about fuzzy TOPSIS and fuzzy ELECTRE I.

3 FUZZY TOPSIS

TOPSIS method was firstly introduced in 1981 by Hwang and Yoon. In TOPSIS, the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from negative ideal solution. Then, alternatives have ranked from the best to the worst one. Positive ideal solution maximizes the benefit criteria and minimizes the cost criteria (Chen, 2000). On the other hand, negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. Fuzzy TOPSIS emerges the adaptation of fuzzy sets into TOPSIS method in which linguistic variables are represented by fuzzy numbers and evaluated by the weights of criteria and the ratings of alternatives. Fuzzy TOPSIS algorithm consists of several steps and follows a hierarchical way as shown below;

Step 1: Form "n" number of decision-maker, decide "k" number of evaluation criteria and "m" number of alternatives. (n=3, k=34, m=5).

Step 2: Choose the appropriate linguistic variables for the importance weight of the criteria and the linguistic ratings for alternatives with respect to criteria. The linguistic variables used for determining the criteria weights, the significance degrees of the alternatives and the related fuzzy numbers are indicated in Table 1.

Table 1: Linguistic variables and Fuzzy Numbers.

Linguistic variables for the importance weight of each criterion		Linguistic variables for the ratings of each alternatives	
Linguistic variables	Fuzzy Numbers	Linguistic variables	Fuzzy Numbers
Very Low	(0, 0, 0.1)	Very Poor	(0, 0, 1)
Low	(0, 0.1, 0.3)	Poor	(0, 1, 3)
Medium Low	(0.1, 0.3, 0.5)	Medium Poor	(1, 3, 5)
Medium	(0.3, 0.5, 0.7)	Fair	(3, 5, 7)
Medium High	(0.5, 0.7, 0.9)	Medium Good	(5, 7, 9)
High	(0.7, 0.9, 1)	Good	(7, 9, 10)
Very High	(0.9, 1, 1)	Very Good	(9, 10, 10)

(Chen, 2000; 5)

Step 3: Calculate the fuzzy weight of each criteria and alternatives.

Step 4: Construct the fuzzy decision matrix and the normalized fuzzy decision matrix, the weighted normalized fuzzy decision matrix.

Step 5: Construct the normalized fuzzy decision matrix.

Step 6: Construct the weighted normalized fuzzy decision matrix.

Step 7: Calculate the distance of each alternative from fuzzy positive-ideal solution (FPIS, A^*) and fuzzy negative-ideal solution (FNIS, A^-), respectively.

Step 8: Calculate the closeness coefficient of each alternative.

Step 9: Rank alternatives according to their closeness coefficient that are between 0 and 1, then choose the alternative whose closeness coefficient is adjacent to 1.

4 FUZZY ELECTRE I

By using binary outranking relations *S* (means at least as good as), ELECTRE I models preferences. Considering two actions a and b, four situations may happen; a*S*b and not b*S*a (a is the strictly preferred to b), b*S*a and not a*S*b (b is the strictly preferred to a), a*S*b and not b*S*a (a is indifferent to b) or not a*S*b and not b*S*a (a is incomparable to b). ELECTRE I can build one or several (crisp, fuzzy or embedded) outranking relations (Figueira et al., 2005). The fuzzy ELECTRE I method uses concordance and discordance indexes to analyze the outranking relations among the alternatives (Rouyendegh and Erkan, 2012). The fuzzy ELECTRE I method proposed here can be described in 4 steps;

Step 1: Form "n" number of decision-maker, decide "k" number of evaluation criteria and "m" number of alternatives.

Step 2: Choose the appropriate linguistic variables for the importance weight of the criteria and the linguistic ratings for alternatives with respect to criteria.

Step 3: Calculate the fuzzy weight of each criteria and alternatives.

Step 4: Construct the fuzzy decision matrix and the normalized fuzzy decision matrix, the weighted normalized fuzzy decision matrix.

Step 5: The distance between two alternatives p and r with respect to each criterion (Construct to concordance and discordance sets)

Step 6: Form concordance and discordance matrices.

Step 7: Calculate the average of matrices.

Step 8: Determine the superiority among alternatives by comparing the averages of matrices.

Step 9: Create a global matrix and a decision graph that indicates the superiority of alternatives, and then rank the alternatives from best to worst.

Although linguistic variables and the evaluation of weighting are same in both MCDM, there are several differences between fuzzy TOPSIS and fuzzy ELECTRE I (Hatami-Marbini and Tavana, 2011). The main difference between two methodologies is the ranking technique. Fuzzy ELECTRE I method focuses on the selection a single action among a small set of good actions, on the contrary fuzzy TOPSIS method purposes the selection of a complete or partial order of the actions. In other words; TOPSIS makes the decision of alternative selection and want the best alternative should be farther from the negative-ideal solution and closer to the positive-ideal solution than other alternatives. However, ELECTRE I outranks unsuitable alternative with help of concordance and discordance matrices.

In this study, both fuzzy TOPSIS and fuzzy ELECTRE I take into account uncertain and imprecise linguistic assessments provided by decision makers. We aim to select and compare alternative airport locations in the city of Ankara with two fuzzy MCDM. It is desired to select a suitable location for a second airport in Ankara among five candidate region. By the result of the interviews with decision-makers and comprehensive literature review, nine main criteria (geographical specifications, climatic conditions, infrastructure conditions, costs, transportation, the possibility of extension, legal restrictions and regulations, potential demand, environmental and social effects) are determined to analyze with fuzzy TOPSIS and fuzzy ELECTRE I, comparatively. These main criteria have divided into 34 sub-criteria in order to evaluate each alternative more precisely.

5 FINDINGS

Table 2: The Importance Fuzzy Weights of Decision Criteria.

Decision Criteria	(wj)			
Crt.	l	m	u	Ranking
16	0,9	1	1	1
12	0,83	0,97	1	2
29	0,83	0,97	1	2
1	0,77	0,93	1	3
14	0,77	0,93	1	3
15	0,77	0,9	0,97	4
9	0,7	0,9	1	5
26	0,7	0,9	1	5
30	0,7	0,9	1	5
32	0,7	0,9	1	5
13	0,63	0,8	0,93	6
3	0,63	0,8	0,9	7
5	0,63	0,8	0,9	7
28	0,57	0,77	0,9	8
34	0,57	0,73	0,87	9
27	0,5	0,7	0,87	10
2	0,5	0,7	0,83	11
4	0,43	0,63	0,8	12
8	0,47	0,63	0,77	12
31	0,47	0,6	0,73	13
7	0,4	0,57	0,73	14
10	0,3	0,5	0,7	15
33	0,3	0,5	0,7	15
6	0,27	0,43	0,63	16
11	0,23	0,43	0,63	17
17	0,17	0,37	0,57	18
18	0,17	0,37	0,57	18
19	0,17	0,37	0,57	18
20	0,17	0,37	0,57	18
21	0,13	0,3	0,5	19
22	0,13	0,3	0,5	19
23	0,13	0,3	0,5	19
25	0,13	0,3	0,5	19
24	0,1	0,3	0,5	20

This study aims to determine potential facility location for a second airport within Ankara territory, the capital city of Turkey, by using fuzzy TOPSIS and fuzzy ELECTRE I, separately. Alternatives are determined after the interview with aviation experts who have worked in public and private sectors. We made a structural interview with the experts, and then final decision for potential airport locations has been concluded. To eliminate the vagueness of linguistic values, it is decided to use fuzzy triangular numbers. The importance weights of the nine main criteria and thirty-four are sub-criteria are described using the following linguistic terms: very low, low, medium low, medium, medium high, high and very high. Table 2 shows the importance fuzzy weights of decision criteria and the ranking of each criterion.

Note 1: C16: Capacity rate, C12: Connection with urban or rural areas, C29: Contribution to regional economy, C1: The topography of landscape, C14: Transportation to downtown and residential area, C15: Extension potential, C9: Condition of transportation network, C26: Expectations related to future demand, C30: Effects on social life in the region, C32: Security risk, C13: The density of traffic, C3: The risk of freeze, fog, hurricane or flood, C5: Wind speed, C28: The condition of wastes and effects on environment, C34: Regional residents attitudes towards second airport, C27: The impact on ecological balance of region, C2: The geological and tectonic pattern of landscape, C4: The average annual pressure, temperature and moisture, C8: The condition of energy network, C31: The potential risk for regional residents, C7: The condition of communication network, C10: The cost of land, C33: The risk and density of traffic, C6: The sewer system condition, C11: Construction costs, C17: Value-added tax exemption, C18: Tariffs exemption, C19: Tax discounts, C20: The support of social insurance (employer ration), C21: The discount of income tax stoppage, C22: The support of social insurance, C23: Support for interest payment, C25: The repayment of value-added tax

Note 2: Crt.: Criteria, w_j: fuzzy weights, Triangular Membership Function defined by three main parameters. l, u and m mean the lower bound, the upper bound and mean, respectively (Tavakkoli-Moghaddam, 2008).

The results related to fuzzy TOPSIS method are presented in Table 3. The distance of each alternative to Fuzzy Positive Ideal Solution (d*) and Fuzzy Negative Ideal Solution (d^-) and closure coefficients of the alternatives (CC) are indicated that A_1 is the best location for a possible second airport in Ankara. Alternatives are ranked from the best to worst A_1, A_2, A_5, A_3, and A_4 respectively for the selection of potential airport.

Table 3: The Result of Fuzzy TOPSIS Method.

Alternatives	d*	d^-	CC	Ranking
A_1	12,805	15,215	0,543	1
A_2	13,516	14,54	0,518	2
A_3	16,346	11,399	0,411	4
A_4	16,648	11,205	0,402	5
A_5	16,206	11,648	0,418	3

Table 4 indicates that the result of fuzzy ELECTRE I method has as same ranking as the result of fuzzy TOPSIS method. Considering concordance and discordance values, alternatives are ranked from the best to the worst. Likewise, we can conclude that A_1 is the best location for second airport; on the other hand, A_2, A_3, A_4 and A_5 are less suitable locations than A_1. Finally, decision graph of fuzzy ELECTRE I method is depicted in figure 1.

Table 4: The Result of Fuzzy ELECTRE I Method.

Fuzzy ELECTRE I		
Alternatives		Ranking
A_1	4	1
A_2	3	2
A_3	1	3
A_4	0	4
A_5	0	4

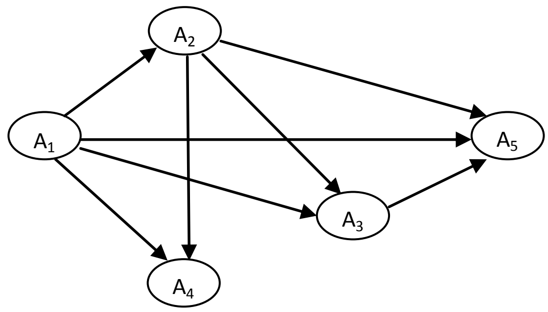

Figure 1: Decision Graph of fuzzy ELECTRE I.

6 CONCLUSIONS

Facility location selection problem is the one of the most important decision among strategic decisions for a company. Generally, a mistaken investment decision about facility location can cause much more loss than expectations. Not only does it affect financial structure of a company but also future investment opportunities may be affected by this failure. Therefore, a vast number of methods have been developed to solve facility location selection problem. Subjective factors usually give rise to uncertainty and vagueness in decision making process. MCDM can help decision-makers to overcome the uncertainty and the vagueness of subjective factors.

In this study, we present fuzzy TOPSIS and fuzzy ELECTRE I methods to cope with facility location selection problem for a possible second airport in Ankara. With the view of experts in aviation sector and comprehensive literature review, nine main criteria (geographical specifications, climatic conditions, infrastructure conditions, costs, transportation, possibility of extension, legal restrictions and regulations, potential demand, environmental and social effects) are determined to analyze with fuzzy TOPSIS and fuzzy ELECTRE I. Fuzzy TOPSIS and fuzzy ELECTRE I resemble each other when converting linguistic values into performance ratings and evaluating the weight of criteria. On the other hand, fuzzy ELECTRE I aims to select a single action among a small set of good actions, fuzzy TOPSIS purposes the selection of a complete or partial order of the actions. According to fuzzy TOPSIS method, location A_1 was determined as the top compromising solution. In this context, it can be proposed that selecting location A_1 is the best decision for fuzzy TOPSIS method. According to the ranking order of other alternatives is $A_1>A_2>A_5>A_3>A_4$. Both fuzzy TOPSIS and fuzzy ELECTRE I methods suggest very similar solution to facility location problem for second airport in Ankara. According to fuzzy ELECTRE I method, alternatives are ranked as $A_1>A_2>A_3>A_4=A_5$.

Even though facility location selection problem is so crucial investment decision for a company, there are a few numbers of studies about aviation sector. Therefore, this study aims to indicate how fuzzy TOPSIS and fuzzy ELECTRE I can be used for facility location selection problem in aviation sector. Indeed, both methods can be applied in other sectors like textile, electronics, manufacturing, retail, logistics etc. in future studies. Also, other MCDM (fuzzy AHP, fuzzy ANP, fuzzy PROMETHEE etc.) can be used to solve facility location selection problems.

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