

# A Decision Support Model for Bank Branch Location Selection

Nihan Cinar\*

**Abstract**—Location selection is one of the most important decision making process which requires to consider several criteria based on the mission and the strategy. This study's object is to provide a decision support model in order to help the bank selecting the most appropriate location for a bank's branch considering a case study in Turkey. The object of the bank is to select the most appropriate city for opening a branch among six alternatives in the South-Eastern of Turkey. The model in this study was consisted of five main criteria which are Demographic, Socio-Economic, Sectoral Employment, Banking and Trade Potential and twenty one sub-criteria which represent the bank's mission and strategy. Because of the multi-criteria structure of the problem and the fuzziness in the comparisons of the criteria, fuzzy AHP is used and for the ranking of the alternatives, TOPSIS method is used.

**Keywords**—MCDM, bank branch location, fuzzy AHP, TOPSIS.

## I. INTRODUCTION

LOCATION selection has a strategic importance for many companies. The general procedure for making location decisions usually consists of the following steps: Decide on the criteria that will be used to evaluate location alternatives; select the criteria that are important; develop location alternatives and select the alternatives evaluated. [22] Selecting a location is very important decision for firms because they are costly and difficult to reverse. A poor choice of location might result in excessive transportation costs, loss of qualified labor, competitive advantage or some similar condition that would be detrimental to operations.[22]. Each organization should consider meaningful criteria for location selection suitable to its mission and strategy in order to make an efficient and effective strategic decision. The location decision may differ with regard to type of business. Thus, the factors considered vary from business to business but it is emphasized that the objective of the decision is to maximize the benefit of location of the firm [10].

Location selection is a multi-criteria decision because it requires to take into consideration both qualitative and quantitative factors.

The literature including bank branch location has also shown that that the selection process is a multi-staged process having different criteria in each level. In the literature, several approaches can be seen to handle multi-criteria problem.

The analytic hierarchy process (AHP) developed by Saaty [21] is used methodology for his type of problems [14],[17].

AHP allows to structure multi criteria problem hierarchically and to combine the results obtained at each level of the hierarchy but cannot reflect the human thinking style which is uncertain and imprecise. Therefore, fuzzy AHP is used to obtain the judgments for the decision making process. In the literature, different approaches to fuzzy AHP such as Laarhoven and Pedrycz [15], Buckley[5], Chang[9], Leung and Cao[16] and Buckley et al.[6] can be found. In this study, Chang's extent analysis method is used to compare the criteria. The authors have used this fuzzy approach to compare the catering services companies in Turkey[13], to develop a framework for quality function deployment (QFD) planning process using analytic network approach[14], to evaluate machine tool alternatives [1], for the selection among computer integrated manufacturing systems [4], for the operating system selection using fuzzy replacement analysis and analytic hierarchy process[23].

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was firstly proposed by Hwang and Yoon [11]. According to this technique, the best alternative would be one that is nearest to the positive ideal solution and farthest from the negative ideal solution [2]. The positive ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria [42].

The remainder of this study is organized as follows: In the second section Chang's extent analysis on FAHP is summarized. In the third section TOPSIS method is tried to be explained. The fourth section introduces the decision support model for the branch location selection and the application process. And finally, in section five results of the application are presented and this section concludes this study.

## II. EXTENT ANALYSIS METHOD ON FUZZY AHP

In this study, Chang's[9] extent analysis method on fuzzy AHP, therefore triangular fuzzy numbers (TFN) are used. Triangular fuzzy numbers are represented as  $l/m/u$ , (or  $(l, m, u)$  in which  $l$ ,  $m$  and  $u$  refer to, respectively, the lower value, modal value and upper value.

Let  $X = \{x_1, x_2, x_3, \dots, x_n\}$ ,  $G = \{g_1, g_2, g_3, \dots, g_n\}$  be an object set and a goal set respectively. Then each object is taken and extent analysis for each goal is performed respectively. Therefore,  $m$  extent analysis values for each object can be obtained, with the following signs:

\*Nihan Cinar is with Yildiz Technical University, Department of Mathematical Engineering, Davutpasa Kampus, Esenler ISTANBUL (e-mail: ntirmik@yildiz.edu.tr)

$$M_{gi}^1, M_{gi}^2, \dots, M_{gi}^m, \quad i=1,2,\dots,n$$

Where  $M_{gi}^j$  ( $j=1,2,\dots,m$ ) all are TFNs. The steps of Chang's [9] extent analysis can be given as following:

*Step 1:* The value of fuzzy synthetic extent with respect to the  $i$ th object is defined

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

To obtain  $\sum_{j=1}^m M_{gi}^j$ , the fuzzy addition operation of  $m$  extent analysis values for a particular matrix is performed such as:

$$\sum_{j=1}^m M_{gi}^j = \left( \sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j \right) \quad (2)$$

and to obtain  $\left[ \sum_{j=1}^m M_{gi}^j \right]^{-1}$ , the fuzzy addition operation

of  $M_{gi}^j$  ( $j=1,2,\dots,m$ ) values is performed such as :

$$\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j = \left( \sum_{i=1}^n l_i, \sum_{i=1}^n m_i, \sum_{i=1}^n u_i \right) \quad (3)$$

And then inverse of the vector above is computed, such as:

$$\left[ \sum_{i=1}^n \sum_{j=1}^m M_{gi}^j \right]^{-1} = \left( \frac{1}{\sum_{i=1}^n u_i}, \frac{1}{\sum_{i=1}^n m_i}, \frac{1}{\sum_{i=1}^n l_i} \right) \quad (4)$$

*Step 2:* As  $M_1 = (l_1, m_1, u_1)$  and  $M_2 = (l_2, m_2, u_2)$  are two triangular fuzzy numbers, the degree of possibility of  $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$  is defined as  $V(M_2 \geq M_1) = \sup_{y \geq x} [\min(\mu_{M_1}(x), \mu_{M_2}(y))]$  (5)

and can be expressed as follows:

$$V(M_2 \geq M_1) = \text{hgt}(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1 & , \text{if } m_2 \geq m_1 \\ 0 & , \text{if } l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & , \text{if } \text{otherwise} \end{cases}$$

Where  $d$  is the ordinate of the highest intersection point  $D$  between  $\mu_{M_1}$  and  $\mu_{M_2}$ . To compare  $M_1$  and  $M_2$ , we need both the values of  $V(M_1 \geq M_2)$  and  $V(M_2 \geq M_1)$ .

*Step3:* The degree possibility for a convex fuzzy number to be greater than  $k$  convex fuzzy  $M_i$  ( $i=1,2,\dots,k$ ) numbers can be defined by ( $i=1,2,\dots,k$ )

$$V(M \geq M_1, M_2, \dots, M_K) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \dots \text{ and } (M \geq M_K)] = \min V(M \geq M_i) \quad (7)$$

Assume that  $d(A_i) = \min V(S_i \geq S_k)$  for  $k=1,2,\dots,n$ ;

$k \neq i$ . Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^T \quad (8)$$

where  $A_i$  ( $i=1,2,\dots,n$ ) are  $n$  elements.

*Step 4:* Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T \quad (9)$$

where  $W$  is a non fuzzy number.

### III. TOPSIS METHOD

In this study, TOPSIS method is used for determining the final ranking of the alternatives.

*Step1:* Decision matrix is normalized via Eq.(10):

$$r_{ij} = \frac{w_{ij}}{\sqrt{\sum_{j=1}^J w_{ij}^2}}, \quad j=1,2,3,\dots,J \quad i=1,\dots,n \quad (10)$$

*Step2 :* Weighted normalized decision matrix is formed:

$$v_{ij} = w_i * r_{ij} \quad j=1,2,3,\dots,J, \quad i=1,\dots,n \quad (11)$$

*Step3:* Positive ideal solution (PIS) and negative ideal solution (NIS) are determined :

$$A^* = \{v_1^*, v_2^*, \dots, v_n^*\} \text{ maximum values} \quad (12)$$

$$A^- = \{v_1^-, v_2^-, \dots, v_n^-\} \text{ minimum values} \quad (13)$$

*Step4 :* The distance of each alternative from PIS and NIS are calculated

$$d_i^* = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^*)^2}, \quad j=1,2,\dots,J \quad (14)$$

$$d_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2}, \quad i=1,2,\dots,J \quad (15)$$

*Step5 :* The closeness coefficient of each alternative is calculated

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \quad (16)$$

*Step6:* By comparing  $CC_i$  values, the ranking of alternatives are determined.

#### IV. DEVELOPING A DECISION SUPPORT MODEL FOR BANK BRANCH LOCATION SELECTION

##### A. Evaluation of the criteria

TABLE I THE HIERARCHICAL STRUCTURE

Main criteria		Demographic(D)
		Socio-economic(SE)
		Sectoral employment(E)
		Banking(B)
		Trade Potential(T)
Sub-criteria	Demographic	Total Population(D1)
		Urbanization rate(D2)
		Annual Population Growth Rate(D3)
	Socio-Economic	Gross National Product Per Capita(TL)*(S1)
		Literacy Rate(S2)
		Rate of Population with Higher Education(S3)
		Average Household Size(S4)
		Employee rate(S5)
		Employer rate(S6)
	Sectoral employment	Agricultural employment rate(E1)
		Manufacturing employment rate(E2)
		Construction employment rate(E3)
		Services employment rate(E4)
	Banking	Number of bank(B1)
		Number of branch(B2)
		Bank deposit per branch (TL)*(B3)
		Credit per branch(TL)*(B4)
		Bank deposit per capita(TL)*(B5)
		Credit per capita(TL)*(B6)
	Trade potential	Number of firms(T1)
		Number of organized (T2)industrial zone

\* Turkish currency

As mentioned above, the aim of this study is to select the best bank branch location among the alternatives using fuzzy AHP to determine the weights of main and sub-criteria and TOPSIS method to evaluate the potential locations considering weights of the criteria and to rank them. The object of the bank is to decide which city among six alternatives in the South-eastern part of Turkey a branch should be opened based on its vision and strategy.

Firstly, the criteria for the selection decision were identified. Considering the studies in the literature which are [3],[18],[19], [20],[25] and the discussions with the bank's managers in different areas, many criteria were determined, selected, eliminated and the hierarchical structure which was illustrated in Table I was constructed.

As shown in the Table I, the model contain five main criteria: "demographic", "socio-economic", "banking", "sectoral employment" and "trade potential" which are decomposed twenty one sub-criteria. Once the model was constructed, a questionnaire form was established to obtain the bank managers' pair wise comparisons for the main criteria and sub-criteria for evaluating the candidate cities. In the form, six bankers indicated their pair wise comparisons to obtain the weights of the main criteria and the sub-criteria using the linguistic scale [14] which is presented in Table II.

TABLE II LINGUISTIC SCALE FOR IMPORTANCE

Linguistic scale	Triangular Fuzzy Numbers
Absolutely more important	(5/2,3,7/2)
Very strongly more important	(2,5/2,3)
Strongly more important	(3/2,2,5/2)
Weakly more important	(1,3/2,2)
Equally important	(1/2,1,3/2)
Just equal	(1,1,1)

Using the tables II&III, the values of fuzzy synthetic extent with respect to each main criterion is calculated as follows :

$$\begin{aligned}
 S_D &= (4.57, 6.3, 8.33) \otimes \left( \frac{1}{37.08}, \frac{1}{28.54}, \frac{1}{21.92} \right) \\
 &= (0.12, 0.22, 0.38) \\
 S_S &= (3.12, 4.01, 5.30) \otimes \left( \frac{1}{37.08}, \frac{1}{28.54}, \frac{1}{21.92} \right) \\
 &= (0.08, 0.14, 0.24) \\
 S_E &= (2.90, 3.56, 5.07) \otimes \left( \frac{1}{37.08}, \frac{1}{28.54}, \frac{1}{21.92} \right) \\
 &= (0.08, 0.12, 0.23) \\
 S_B &= (7.00, 9.00, 11.00) \otimes \left( \frac{1}{37.08}, \frac{1}{28.54}, \frac{1}{21.92} \right) \\
 &= (0.19, 0.32, 0.50) \\
 S_T &= (4.31, 5.65, 7.36) \otimes \left( \frac{1}{37.08}, \frac{1}{28.54}, \frac{1}{21.92} \right) \\
 &= (0.12, 0.20, 0.34)
 \end{aligned}$$

The fuzzy values are compared and the following values are obtained :

TABLE III FUZZY PAIRWISE COMPARISONS

	Demographic	Socio-economic	Sect.Employment	Banking	Trade Potential
Demographic	(1,1,1)	(0.75,1.25,1.75)	(1.5,2,2.5)	(0.57,0.80,1.33)	(0.75,1.25,1.75)
Socio-economic	(0.57,0.80,1.33)	(1,1,1)	(0.83,1.33,1.83)	(0.36,0.44,0.57)	(0.36,0.44,0.57)
Sect.Employment	(0.40,0.50,0.67)	(0.55,0.75,1.20)	(1,1,1)	(0.32,0.39,0.48)	(0.63,0.93,0.72)
Banking	(0.75,1.25,1.75)	(1.75,2.25,2.75)	(2.08,2.58,3.08)	(1,1,1)	(1.42,1.92,2.42)
Trade Potential	(0.57,0.80,1.33)	(1.75,2.25,2.75)	(0.58,1.08,1.58)	(0.41,0.52,0.70)	(1,1,1)

$$V(S_D \geq S_S) = 1 \quad V(S_S \geq S_D) = 0.60$$

$$V(S_D \geq S_E) = 1 \quad V(S_S \geq S_E) = 1$$

$$V(S_D \geq S_B) = 0.67 \quad V(S_S \geq S_B) = 0.23$$

$$V(S_D \geq S_T) = 1 \quad V(S_S \geq S_T) = 0.69$$

$$V(S_B \geq S_D) = 1 \quad V(S_T \geq S_D) = 0.90$$

$$V(S_B \geq S_S) = 1 \quad V(S_T \geq S_S) = 1$$

$$V(S_B \geq S_E) = 1 \quad V(S_T \geq S_E) = 1$$

$$V(S_B \geq S_T) = 1 \quad V(S_T \geq S_B) = 0.56$$

$$V(S_E \geq S_D) = 0.53$$

$$V(S_E \geq S_S) = 0.90$$

$$V(S_E \geq S_B) = 0.18$$

$$V(S_E \geq S_T) = 0.61$$

The priority weights are :

$$d'(D) = \min(1, 1, 0.67, 1) = 0.67$$

$$d'(S) = \min(0.60, 1, 0.23, 0.69) = 0.23$$

$$d'(E) = \min(0.53, 0.90, 0.18, 0.61) = 0.18$$

$$d'(B) = \min(1, 1, 1, 1) = 1$$

$$d'(T) = \min(0.90, 1, 1, 0.56) = 0.56$$

The weight vector is obtained as

$$W' = (0.67, 0.23, 0.18, 1, 0.56)^T$$

an the vector of priority of weight is found by normalization :

$$W = (0.254, 0.087, 0.068, 0.379, 0.212)^T$$

The result indicates that “banking criterion” is the most important main criterion with the priority of 0.379 for the branch location selection. The criterion is followed by the “Demographic” which has the priority of 0.254, “trade potential” with the priority of 0.212 and “socio-economic with “0.087”. The lowest priority belongs to the criterion “sectoral employment” in the decision makers’ judgments.

The same method was used to obtain the weights for the sub-criteria. With the decision makers’ pair wise comparisons of the sub-criteria with respect to main criteria, the following weight vectors are obtained:

$$W_D = (0.599, 0.353, 0.048)^T$$

$$W_S = (0.248, 0.127, 0.139, 0.103, 0.199, 0.184)^T$$

$$W_E = (0.293, 0.267, 0.185, 0.255)^T$$

$$W_B = (0.08, 0.182, 0.182, 0.148, 0.212, 0.195)^T$$

$$W_T = (0.684, 0.316)^T$$

It's shown that the most important sub-criterion for the “demographic” is “total population” with the weight of 0.599 and it's followed by “urbanization rate” with the weight of 0.353 and “annual population growth rate” with the weight of 0.048. For the “socio-economic”, the “gross national product per capita” has the highest weight which is 0.248. In the sectoral employment criterion, agricultural employment rate has the highest weight of 0.293. In the “banking” criterion, it is obviously seen that bank deposit per capita has the highest weight and is followed by credit per capita. From the vector of the trade potential, the number of firms is more important sub-criterion with the weight of 0.684.

#### B. Evaluation of the alternatives

After determining the weights of the criteria with fuzzy AHP, the next step is to rank each candidate city with respect to each sub-criteria and main criteria using their weights. The data of the sub-criteria for candidate cities which were obtained from Bank Association of Turkey, State Institute of Statistics and Union of Chambers and Commodity Exchanges of Turkey can be seen in Tables IV,V,VI,VII,VII.

TABLE IV DEMOGRAPHIC SUB-CRITERIA FOR THE CANDIDATE CITIES

	D1	D2(%)	D3(%)
C1	623.811	54	35
C2	1.362.708	60	42
C3	1.002.384	53	25
C4	853.658	58	32
C5	705.098	55	17
C6	1.443.422	58	34

TABLEV SOCIOECONOMIC SUB-CRITERIA FOR THE CANDIDATE CITIES

	S1(TL)	S2(%)	S3(%)	S4	S5(%)	S6(%)
C1	1112,3	80	3	6	25	28
C2	1591	70	3	6	35	22
C3	1918,7	83	4	5	30	25
C4	1716	85	5	5	30	24
C5	1190	71	3	7	25	20
C6	1220	68	2	7	24	24

TABLEVI SECTORAL EMPLOYMENT SUB-CRITERIA FOR THE CANDIDATE CITIES

	E1(%)	E2(%)	E3(%)	E4(%)
C1	73	4	2	21
C2	64	4	4	24
C3	67	1	5	21
C4	64	6	3	27
C5	70	3	3	24
C6	73	4	3	20

TABLEVII BANKING SUB-CRITERIA FOR THE CANDIDATE CITIES

	B1	B2	B3(TL)	B4(TL)	B5(TL)	B6(TL)
C1	14	30	14.391	20.110	738	1031,2
C2	16	66	18.160	22.002	803,2	972,8
C3	15	50	22.903	31.599	1112,6	1535
C4	14	40	32.667	26.436	1780,7	1441,1
C5	11	33	11.601	17.263	510	758,9
C6	15	45	15.686	25895	477	740,2

TABLEVIII TRADE POTENTIAL SUB-CRITERIA FOR THE CANDIDATE CITIES

	T1	T2
City1	203	3
City2	331	2
City3	305	1
City4	522	3
City5	171	1
City6	411	4

After the data are obtained, normalization of these values is made via Eq.(10). Then weighted normalized matrix is formed by multiplying each value of sub-criteria with their weights to form TableIX

TABLE IX TOTAL VALUES OF MAIN CRITERIA

	D	S	E	B	T
C1	0,3052	0,3788	0,3425	0,3197	0,3142
C2	0,4977	0,4176	0,3839	0,4028	0,3678
C3	0,3855	0,4525	0,5163	0,4819	0,2968
C4	0,3677	0,4522	0,4141	0,5368	0,5723
C5	0,3159	0,3493	0,3533	0,1211	0,1883
C6	0,5069	0,3506	0,3598	0,3224	0,5325

Then the values in Table IX and the weights of each main criterion are multiplied to form TableX.

TABLE X TOTAL WEIGHTED VALUES OF MAIN CRITERIA

	D	S	E	B	T
C1	0,079	0,033	0,020	0,125	0,068
C2	0,128	0,033	0,023	0,157	0,079
C3	0,099	0,035	0,030	0,188	0,064
C4	0,095	0,035	0,024	0,210	0,123
C5	0,082	0,028	0,021	0,047	0,040
C6	0,131	0,027	0,021	0,126	0,114

Positive and negative ideal solutions are determined by taking the maximum and minimum values for each criterion:

$$A^* = \{0.131, 0.035, 0.030, 0.210, 0.123\}$$

$$A^- = \{0.079, 0.027, 0.020, 0.047, 0.040\}$$

Then the distance of each candidate city from PIS and NIS with respect to each criterion are calculated with help of Eqs.(14) and (15). Then closeness coefficient of each candidate city is calculated by Eq.(16) and the ranking of the cities are determined according to these values. The ranking of these cities are shown in Table XI

TABLEXI RANKINGS OF CITIES

Candidate s	$CC_i$
C4	0,834
C3	0,672
C2	0,646
C6	0,585
C1	0,420
C5	0,017

After the ranking the candidate cities for bank branch location selection by taking into consideration their data obtained from official foundations, the order of the cities are found as in TableXI.

Beside the data, the decision makers' priorities also affect this ranking. If there will be a difference in the priority of decision makers, the ranking may change. For this reason, decision maker should know his priority properly and then determine the weights of the criteria.

## IV. CONCLUSION

Branches have a strategic importance on a bank's performance and competitiveness [12],[18],[19] and the banks must identify meaningful criteria for their location selection considering their missions and strategies.

In this study, FAHP and TOPSIS methods are used together. FAHP is utilized for determining the weights of the criteria and TOPSIS method for determining the ranking of the cities. In the application, the ranking result of the candidate cities is reached by considering their data obtained Bank Association of Turkey, State Institute of Statistics and Union of Chambers and Commodity Exchanges of Turkey. As the weights of the criteria are determined by bank managers from different areas, the result indicates an overall performance ranking.

In summary, this study indicates that both fuzzy AHP and TOPSIS can be used a decision support system by the organizations in order to make effective decision on the bank branch location selection.

## REFERENCES

- [1] Ayağ, Z., & Özdemir, R.G., "A fuzzy AHP approach to valuating machine tool alternatives," *Journal of Intelligent Manufacturing*, 17, 179-190, 2006.
- [2] Benitez, J.M., Martin, J.C., & Roman, C.(2007). "Using fuzzy number for measuring quality of service in the otel industry". *Tourism Management*, 28(2), 544-555, 2007.
- [3] Boufounou, P.V., "Evaluating bank branch location and performance : A case study," *European Journal of Operational Research*, 87, 389-402,1995.
- [4] Bozdağ, C.E., Kahraman, C., & Ruan, D. (2003). "Fuzzy group decision making for selection among computer integrated manufacturing systems. *Computer in Industry*, 51, 13-29
- [5] Buckley, J.J., "Fuzzy hierarchical analysis", *Fuzzy Sets and Systems*, 17(3), 233-247,1985.
- [6] Buckley, J.J., t.Feuring and Y.Hayashi "Fuzzy hierarchical analysis revisited, " *European Journal of Operational Research*, 129, 48-64, 2001.
- [7] Buyukozkan, G., C.Kahraman and D.Ruan, "A fuzzy multi-criteria decision approach for software development strategy selection", *International Journal of General Systems* 33 (2-3), 259-280, 2004.
- [8] Chan, F. T. S., & Kumar, N. (2007). "Global supplier development considering risk factors using fuzzy extended AHP-based approach. *Omega International Journal of Management Science*, 35.
- [9] Chang, D.Y., "Applications of the extent analysis method on fuzzy AHP", *European Journal of Operational Research*, 95, 649-655, 1996
- [10] Heizer, J. And B.Render; *Production and Prentice-Hall*, 2001.
- [11] Hwang, C.L., & Yoon, K. (1981). *Multiple attributes decision making methods and applications*: Berlin: Springer.
- [12] Iannou, G. A. Karakerezi and M.Mavri, "Branch network and modular service optimization for community banking", *International Transactions in Operational Research*, 9, 531-547, 2002.
- [13] Kahraman, C., U.Cebeci and D.Ruan," Multi attribute comparison of catering service companies using fuzzy AHP; The case of Turkey," *International Journal of Production Economics*, 87(2), 171-184, 2004.
- [14] Kahraman, C., T. Ertay and G. Buyukozkan," A fuzzy optimization model for QFD planning process using analytic network approach", *European Journal of Operational Research*, 171, 390-411, 2006.
- [15] Laarhoven, P.J.M and W. Pedrcyz, "A fuzzy extension of Saaty's priority theory," *Fuzzy Sets and Systems* 11 (3), 229-241, 1983.
- [16] Leung, L., & Cao, D. (2000). On consistency and ranking alternatives in fuzzy AHP. *European Journal of Operational Research*, 124,102-113
- [17] Liu, F.H. and Hai,L.H., "The voting analytic hierarchy process method for selecting supplier", *International Journal of Production Economics*, 97, 308-317, 2005.
- [18] Miliotis, P. M. Dimopoulou and I.Giannikos " Ahierarchical location model for locating bank branches in a competitive environment," *International Transactions in Operational Research*, 9-5, 549-565, 2002.
- [19] Min, H., "A model based decision support system for locating banks", *Information and Management*, 17-4, 207-215, 1989.
- [20] Ravallion, M. And Q.Wodon ,"Banking on the poor? Branch location and nonfarm rural development in Bangladesh," *Review of Development Economics*, 4(2), 121-139, 2000.
- [21] Saaty, T. L., *The Analytic Hierarchy Process*, New York: Mc Graw-Hill, 1980.
- [22] Stevenson WJ (1993) *Production/ Operations Management*, 4thEdition, Richard D.Irwin.,Homewood.
- [23] Tolga E, Demircan M, Kahraman C ," Operating system selection using fuzzy replacement analysis and analytic hierarchy process", *International Journal of Production Economics*, 97:89-117.
- [24] Wang, Y.M., & Elhag, T.M.S (2006). Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment. *Expert Systems with Applications*, 31, 309-319.
- [25] Zhao, L.,B.Garner and B.Parolin, "Branch bank closures in Sydney : A geographical perspective and analysis,"12th International Conference on Geoformatics, Sweden, 2004.