An integrated approach to supplier selection using AHP and FUZZY PROMETHEE

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Abstract: Supplier selection has become an important decision problem due to today's competitive environment. The company gets a competitive advantage in long-term relationships with the right suppliers. In the evaluation process both quantitative and qualitative multiple conflicting criteria should be utilized. This requires a systematic multi-criteria decision-making approach to evaluation process. Due to uncertainty in the process and verbal assessment of the decision maker's fuzzy sets are used. In this study, supplier selection carried out via the integrated use of the multi criteria decision making methods, AHP and the Fuzzy-PROMETHEE. Thus, the advantages of both methods were used. Criteria, weighted using AHP, and evaluation of suppliers are carried out by using Fuzzy PROMETHEE. The method is implemented in a company producing medical devices in Ankara. As a result, the most suitable supplier identified for the company.

KeyWords: Supplier Selection, Multi-Criteria Decision Making, AHP, Fuzzy-PROMETHEE

Introduction

As a result of competitive business environment supplier selection became an important multi criteria decision making problem. Working with the right supplier reduces production cost, amount of inventory, and increases production quality. Companies tend to benefit from scientific techniques for supplier selection. Criterias used in determining the supplier selection may vary from company to company (Kahraman et al., 2003).The most widely used criteria such as quality, delivery, price, production capability, service, management, technology, research and development, finance, flexibility, reputation, relationship, risk, safety and environment (Ho et al., 2010).There are several approaches to the problem of supplier selection in the literature, the cluster analysis, case based reasoning systems, statistical models, decision support systems, DEA, a multi-criteria decision-making techniques, activity based costing, artificial intelligence, mathematical programming (Gencer, Gürpınar, 2007). In the scope of work the studies examined that approaches the problem with MCDD techniques. Kılınccı and Önal examined supplier selection problem in a dishwasher factory with Fuzzy AHP. According to various criteria and sub-criteria evaluations was carried out with the help of excel. Amin and Razmi carried out supplier selection with the help of fuzzy SWOT analysis. In addition, how much purchased from each supplier decided by using fuzzy linear programming model. Gencer and Gürpınar studied the problem of supplier selection in an electronic company with the help of ANP. Lin used fuzzy ANP and fuzzy multi-objective linear programming as an integrated model. The supplier and the amount of the order were determined by using the model. Araz and Özkarahan have proposed a new MCDM based on PROMETHEE. In addition, the applicability of the method was showed. Soner and Önüt used ELECTRE and AHP methods. Criterias weighted by using AHP, and the sorting operation carried out using ELECTREE. Dağdeviren and Eraslan used PROEMETHEE method. Özçakar and Demir, determined the supplier by fuzzy-topsis.

In this study, supplier selection was carried out using a combination of AHP and fuzzy PROMETHEE methods. Model implemented in a company that produces medical devices. Criterias weighted using AHP and rank of the alternatives determined by Fuzzy- PROMETHEE.

Methods

AHP

AHP is one of the multi-criteria decision-making techniques developed by Thomas L. Saaty in 1977. AHP is widely studied especially in the last 20 years, and used in almost all MCDM problems due to effectiveness of it (Kahraman et al., 2003).

AHP is applicable for several areas, such as business strategy formulation, customer complaints analysis, product evaluation, supplier selection, choice of location as well as many business decisions, military defence decisions, individual decisions (Ünal, 2010).The study of Saaty, 1980 can be referenced for more information.

PROMETHEE, FUZYY- PROMETHEE

Compared with other MCDM methods PROMETHEE method can be expressed with the actual values and applicable when a large number of criteria available (Ballı, Karasulu, 2007). For the implementation of the method importance of criteria, the values of alternatives according to the criteria must be known (Albadvi et al., 2007).

PROMETHEE steps are as follows:

1. i $(i=1,2,\ldots, m$ and $i \in A)$ alternatives, j $(j=1,2, .., n$ and $j \in C)$ the set of criteria and $g_j(i)$ is the preferred value of alternative i for the criteria j. The value of $g_j(i)$ calculated in the first step, then $F_j(i,i')=g_j(i)-g_j(i') = x_j$ is determined as one of the six different types of generalized functions. (The study of Tuzkaya et al. (2011) can be referenced for generalized functions.) $F_j(i,i')$ indicating the degree of the preference function for alternative i to alternative i'.
2. After the calculation of the preferred values of each alternative, by using these values combined preference functions are calculated for each alternatives pairs. Then $\pi(i, i')$ calculated for all criterias, $\pi(i, i')$ indicated the choice index.
$$\pi(i, i') = \left(\sum_{j=1}^{n} w_j P(x_j)\right) / \left(\sum_{j=1}^{n} w_j\right) \quad (3)$$
3. Positive and negative superlative values for each alternative calculated as in equations 4 and 5.
$$\Phi^{+} = \frac{1}{m-1} \sum_{\substack{i'=1 \\ i' \neq i}}^{m} \pi(i, i') \quad \forall i \in A \quad (4)$$
$$\Phi^{-} = \frac{1}{m-1} \sum_{\substack{i'=1 \\ i' \neq i}}^{m} \pi(i, i') \quad \forall i \in A \quad (5)$$

PROMETHEE I compare the degree of positive and negative superiority values, makes a preliminary ranking of weak and incomparable preferences. Alternative i superior to alternative i', if one of the following equations from (6), (7), and (8), is provided.

$$\Phi^{+}(i) > \Phi^{+}(i') \text{ and } \Phi^{-}(i) < \Phi^{-}(i') \quad (6)$$

$$\Phi^{+}(i) > \Phi^{+}(i') \text{ and } \Phi^{-}(i) = \Phi^{-}(i') \quad (7)$$

$$\Phi^{+}(i) = \Phi^{+}(i') \text{ and } \Phi^{-}(i) < \Phi^{-}(i') \quad (8)$$

If equation (9) is provided, the alternatives are at the same level.

$$\Phi^{+}(i) = \Phi^{+}(i') \text{ and } \Phi^{-}(i) = \Phi^{-}(i') \quad (9)$$

If the equations (10) and (11) provided, the comparison cannot be made.

$$\Phi^{+}(i) > \Phi^{+}(i') \text{ and } \Phi^{-}(i) > \Phi^{-}(i') \quad (10)$$

$$\Phi^{+}(i) < \Phi^{+}(i') \text{ and } \Phi^{-}(i) < \Phi^{-}(i') \quad (11)$$

From the difference of negative and positive flows, the net flow obtained. For the net flow values;

$$\Phi^{net}(i) = \Phi^{+}(i) - \Phi^{-}(i') \quad (12)$$

The rank of the alternatives can be obtained from the comparison of the net flow values.

PROMETHEE method, was developed by Brans et al. (1986), and Fuzzy- PROMETHEE approach was proposed by Wang et al (2008). Verbal expressions were used by the decision makers for assessing alternatives according to the criterias. PROMETHEE is suitable to use with AHP. In generally AHP is used the stage of the weighting the criteria.

Comparison of fuzzy numbers in fuzzy- PROMETHEE is necessary. Center of gravity method that represents the membership functions was proposed by Yager (1981) for the comparison of fuzzy numbers. According to Yager index, a triangular fuzzy number size expressed by the formula *YI=(3*n-a+b)/3*. The notation *F(n, a, b)* is fuzzy triangular number (Tuzkaya et al., 2011).

Evaluation function can be expressed in the following equation for fuzzy- PROMETHEE.

$$\Omega(\alpha,\beta) = \Omega_j(d_j) = \begin{cases} 0 & n - c > q \\ \frac{((n,c,d)-q))}{(p-q)} & q \le n - c \; and \; n + d \le p \\ 1 & n + d > p \end{cases} \qquad (13)$$

In the equation the values of q and p are not fuzzy numbers. The membership functions of fuzzy number c modified to $n\text{-}a \ge 0$ and $n+b \ge 1$. PROMETHEE approach uses the fuzzy PROMETHEE stages. Fuzzy number operators are used for operations on fuzzy numbers.

Application

In a medical device company, due to the difficulties in the supply process, company decided to change the supplier. The supplier is to be decided in a systematic way. Criterias weighted by AHP, and the suitable supplier determined using Fuzzy-PROMETHEE.

In practice, a decision-making team of engineers in the company was first established. Suppliers with a strong set of references were determined. As a result of investigations the number of suppliers reduced to four Criteria, respectively is determined as, the “Cost (C)”, “Quality (Q)”, “Delivery" (D)”, “Technical Support (T)”, “Flexibility (F)”.

The decision hierarchy is as in Figure 1. The hierarchy consists of three levels. First level represents the purpose, second level criterias, and the final level is alternatives.

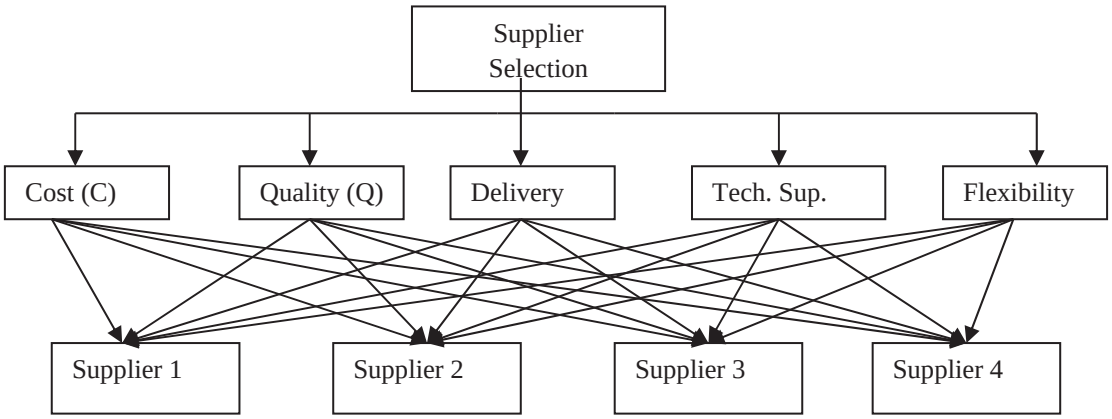

Figure 1. AHP Hierarchy

AHP Calculations

The weights of the each criterias were determined by AHP. 1-9 scale that is proposed by Saaty and pairwise comparison matrices was used (Saaty, 1980). The geometric average of the comparison matrices determined. Pairwise comparison matrix of the criteria established. Table 1shows the pairwise comparison matrices. Table 2 shows the results of AHP.

Table 1. Pairwise Comparison Matrice

Criteria	C	Q	D	T	F
C	1,00	0,28	0,23	0,33	0,23
Q	3,50	1,00	3,55	4,21	3,55
D	4,30	0,28	1,00	1,00	1,44
T	3,03	0,23	1,00	1,00	0,33
F	4,30	0,28	0,69	3,03	1

Table 2. Results of AHP

Criteria	Weights
C	0,09
Q	0,44
D	0,17
T	0,11
F	0,19

The value of λ and CR is respectively 5.5 and 0.08.

F- PROMETHEE Calculations

After weighting the criteria by AHP, for the selection procedure F-PROMETHEE used. Due to the uncertainty of the verbal assessments fuzzy sets were used. Decision makers evaluated the alternatives using verbal statements (Table 3).

Table 3. Evaluation of Alternative Suppliers with Verbal Expressions

	C	Q	D	T	F
Supplier 1	SL	L	VH	E	VH
Supplier 2	VH	L	H	SL	SL
Supplier 3	SH	SL	H	SL	SL
Supplier 4	VL	VH	H	VH	VL

(E: Equal, SL: Slightly Lower, L: Lower, VL: Very Low, SH: Slightly Higher, H: Higher, VH: Very High)

Verbal assessments transformed to triangular fuzzy- numbers (Table–4).

Table4. Verbal Assessments Transformed To Triangular Fuzzy- Numbers

	C			Q			D			T			F		
Supplier 1	0,30	0,15	0,20	0,15	0,15	0,20	1,00	0,20	0,00	0,50	0,20	0,15	1,00	0,20	0,00
Supplier 2	1,00	0,20	0,00	0,15	0,15	0,20	0,80	0,15	0,20	0,30	0,15	0,20	0,30	0,15	0,20
Supplier 3	0,65	0,15	0,15	0,30	0,15	0,20	0,80	0,15	0,20	0,30	0,15	0,20	0,30	0,15	0,20
Supplier 4	0,00	0,00	0,15	1,00	0,20	0,00	0,80	0,15	0,20	1,00	0,20	0,00	0,00	0,00	0,15

The types of preference function determined. There are six type of preference function available. In this study, as a result of interviews with decision makers the third preference function selected. As a result of various experiments function parameters were determined (q = 0 and p = 0.6). Pairwise comparisons of alternatives carried out. In this step, the basic fuzzy operations are used. The results were converted to the comparison values (Table 5)

Table 5. Unweighted Comparison Matrix

	C	Q	D	T	F
1-1	0	0	0	0	0
1-2	0	0	0	0	1
1-3	0	0	0	0	1
1-4	1	0	0	0	1
2-1	1	0	0	0	0
2-2	0	0	0	0	0
2-3	0	0	0	0	0
2-4	1	0	0	0	1
3-1	1	0	0	0	0
3-2	0	0	0	0	0
3-3	0	0	0	0	0
3-4	1	0	0	0	1
4-1	0	1	0	1	0
4-2	0	1	0	1	0
4-3	0	1	0	1	0
4-4	0	0	0	0	0

Matrice, converted to weighted comparison matrice using criteria weights (Table 6).

Table6. Weighted Comparison Matrice

	C	Q	D	T	F
1-1	0,00	0,00	0,00	0,00	0,00
1-2	0,00	0,00	0,00	0,00	0,19
1-3	0,00	0,00	0,00	0,00	0,19
1-4	0,09	0,00	0,00	0,00	0,19
2-1	0,09	0,00	0,00	0,00	0,00
2-2	0,00	0,00	0,00	0,00	0,00
2-3	0,00	0,00	0,00	0,00	0,00
2-4	0,09	0,00	0,00	0,00	0,19
3-1	0,09	0,00	0,00	0,00	0,00
3-2	0,00	0,00	0,00	0,00	0,00
3-3	0,00	0,00	0,00	0,00	0,00
3-4	0,09	0,00	0,00	0,00	0,19
4-1	0,00	0,44	0,00	0,11	0,00
4-2	0,00	0,44	0,00	0,11	0,00
4-3	0,00	0,44	0,00	0,11	0,00
4-4	0,00	0,00	0,00	0,00	0,00

Datas and equation (4) and (5) were used for the calculation of ϕ+ and ϕ- values (Table 7).

Table7. :ϕ^+ and ϕ^-Values

	Sup. 1	Sup. 2	Sup. 3	Sup. 4	ϕ+	ϕnet
Supplier 1	0,00	0,19	0,19	0,28	0,22	-0,02
Supplier 2	0,09	0,00	0,00	0,28	0,12	-0,11
Supplier 3	0,09	0,00	0,00	0,28	0,12	-0,11
Supplier 4	0,55	0,55	0,55	0,00	0,55	0,27
ϕ-	0,24	0,24	0,24	0,28		

From equations 6-7-8-9-10-11 PROMETHEE I calculations was made. As a result, first supplier is better than the second and the third supplier. There was no difference among second supplier and third supplier. Any comparison made with the supplier 4. For the supplier 4 the value of $\phi^-$is bigger than the others but the value of ϕ^+ also bigger than other suppliers' value.

For PROMETHE II the value of the ϕ^{net} was calculated. According to the calculations the Supplier 4 is the best, Supplier 1 is the second, and the Supplier 2 and Supplier 3 the lasted has a same level.

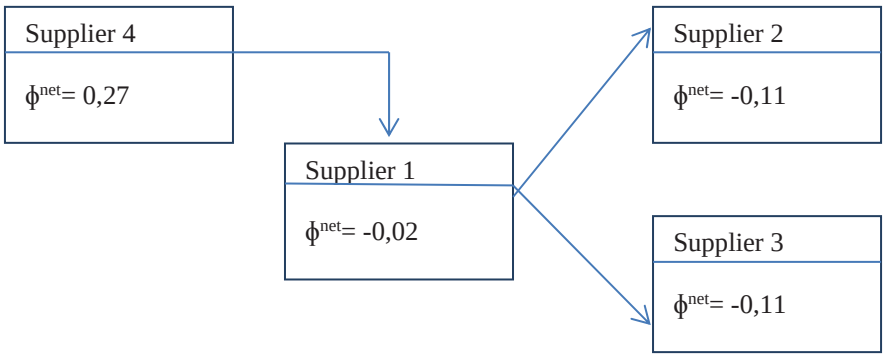

Figure2. PROMETHEE II Assessments

Conclusions

If supplier selection is performed correctly, the efficiency of production systems significantly increased. Decline in product quality, insufficient time for orders, increasing inventories, long durations for supply process may be the results of working with the wrong supplier. As a result, there is a loss of customers, increased cost and waste of time. Long- term relationship with the small number of supplier is possible by working with the right supplier. Multiple conflicting criterias are available for the process of supplier selection. This situation necessitates the use of multi-criteria decision making techniques. In addition verbal assessments that are used for evaluation of alternatives leads to uncertainty. Handling with the uncertainty an integrated method that includes AHP and FUZZY PROMETHEE was used. There has been a lot of studies assigned the weights of the criteria intuitively, we used AHP for the weighting criterias. PROMETHEE was used for the selection of supplier. In addition, the model illustrated with an application. The results of the application were taken into consideration by the authorities.

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