An Integrated DEMATEL-QFD Model for Medical Supplier Selection

Mehtap Dursun, Zeynep Şener

Abstract**—**Supplier selection is considered as one of the most critical issues encountered by operations and purchasing managers to sharpen the company's competitive advantage. In this paper, a novel fuzzy multi-criteria group decision making approach integrating quality function deployment (QFD) and decision making trial and evaluation laboratory (DEMATEL) method is proposed for supplier selection. The proposed methodology enables to consider the impacts of inner dependence among supplier assessment criteria. A house of quality (HOQ) which translates purchased product features into supplier assessment criteria is built using the weights obtained by DEMATEL approach to determine the desired levels of supplier assessment criteria. Supplier alternatives are ranked by a distance-based method.

Keywords**—**DEMATEL, Group decision making, QFD, Supplier selection.

I. Introduction

Considering the global challenges in manufacturing environment, organizations are forced to optimize their business processes to remain competitive. To reach this aim, firms must work with its supply chain partners to improve the chain's total performance. As the key process in the upstream chain and affecting all areas of an organization, the purchasing function is increasingly seen as a strategic issue in supply chain hierarchy. Selecting the right suppliers significantly reduces the purchasing cost and improves corporate competitiveness. Supplier selection problem requires considering multiple conflicting criteria incorporating vagueness and imprecision with the involvement of a group of experts, is an important multi-criteria group decision making problem. The inherent imprecision and vagueness in criteria values justify the use of fuzzy set theory. In the literature, there are a number of studies that use different fuzzy decision making techniques for evaluating suppliers. Several authors have used fuzzy mathematical programming approaches [1]-[3]. A number of studies have focused on the use of fuzzy multi-attribute decision making (MADM) techniques for supplier selection process [4]-[6]. Lately, few researchers have employed the quality function deployment (QFD) in supplier selection [7]-[9].

The objective of this study is to propose a fuzzy multi-criteria group decision making methodology integrating quality function deployment (QFD) and decision making trial and evaluation laboratory (DEMATEL) method. A house of quality (HOQ) which translates purchased product features into supplier assessment criteria is built using the weights obtained by DEMATEL approach to determine the desired levels of supplier assessment criteria. Supplier alternatives are ranked by a distance-based method.

The rest of the paper is organized as follows. Section II and Section III delineate QFD and DEMATEL method, respectively. In Section IV, the fuzzy multi-criteria decision making (MCDM) framework is introduced. Section V presents the application of the proposed methodology to medical device supplier selection problem. The concluding remarks are given in the final section.

II. Quality Function Deployment

Quality function deployment is a crucial product development method dedicated to translate customer requirements into activities to develop products and services [10]. QFD is a customer oriented design tool for developing new products to increase customer satisfaction. QFD is also a tool for analyzing and improving manufacturing systems. The reported benefits of QFD include better products or services that are highly focused and responsive to the customer needs, developed in a shorter period of time with fewer resources. The basic concept of QFD is to translate the desires of customers into design requirements, and subsequently into parts characteristics, process plans and production requirements [11]. In order to establish these relationships, QFD usually requires four matrices, each corresponding to a stage of the product development cycle. These are product planning, part deployment, process planning, and production/operation planning matrices, respectively.

In this paper, we focus on the first of the four matrices, also called the house of quality (HOQ). HOQ translates customer needs into design requirements. It contains seven elements as shown in Fig. 1.

III. DEMATEL Method

The DEMATEL method was intended to study and resolve the complicated and intertwined problem group. This method could improve understanding of the specific problem, the cluster of intertwined problems, and contribute to identification of workable solutions by a hierarchical structure. Four major steps of DEMATEL method can be summarized as follows [12].

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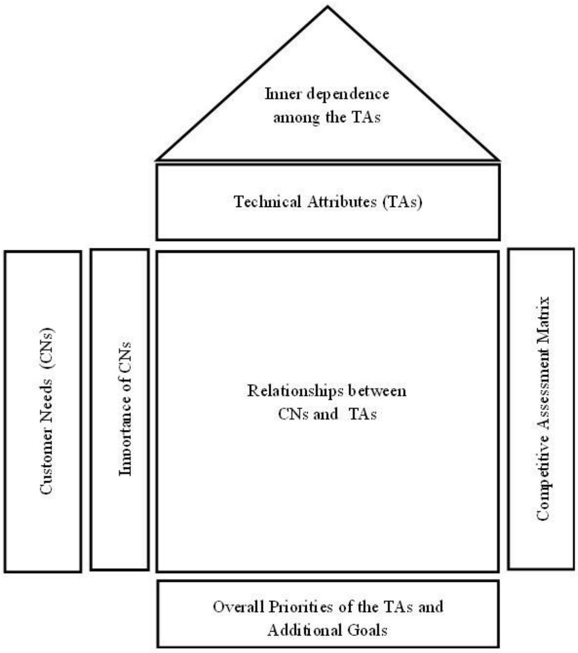

Fig. 1 House of quality

Step 1. Compute the average matrix.

Respondents are asked to indicate the direct influence that they believe each factor i exerts on each factor j of the others, as indicated by a_{ij}. From any group of direct matrices of respondents, it is possible to derive an average matrix $\boldsymbol{A}$.

Step 2. Calculate the normalized initial direct-relation matrix.

The normalize initial direct-relation matrix $\boldsymbol{D}$ can be obtained as $\boldsymbol{D}=s.\boldsymbol{A}$, where

$$s = \min\left[\frac{1}{\max_{1\le i\le n}\sum_{j=1}^{n}\left|a_{ij}\right|},\frac{1}{\max_{1\le i\le n}\sum_{i=1}^{n}\left|a_{ij}\right|}\right] \quad (1)$$

Step 3. Calculate the total relation matrix.

The total relation matrix $\boldsymbol{T}$ is defined as $T = D(I-D)^{-1}$, where $\boldsymbol{I}$ is the identity matrix. Define r and c be n x 1 and 1 x n vectors representing the sum of rows and sum of columns of the total relation matrix $\boldsymbol{T}$, respectively. Suppose r_i be the sum of ith row in matrix T, then r_i summarizes both direct and indirect effects given by factor i to the other factors. If c_j denotes the sum of jth column in matrix T, then c_j shows both direct and indirect effects by factor j from the other factors. When $j = i$, the sum $(r_i + c_j)$ shows the total effects given and received by factor i. Thus, $(r_i + c_j)$ indicates the degree of importance for factor i in the entire system. On the contrary, the difference $(r_i - c_j)$ represents the net effect that factor i contributes to the system. Specifically, if $(r_i - c_j)$ is positive, factor i is a net cause, while factor i is a net receiver or result if $(r_i - c_j)$ is negative.

Step 4. Set up a threshold value to obtain the digraph.

IV. MCDM Model for Supplier Selection

In this section, a fuzzy multi-criteria group decision making approach based on QFD and DEMATEL method is proposed. In traditional QFD applications, the company has to identify its customers' expectations and their relative importance to determine the design characteristics for which resources should be allocated. When the HOQ is used in supplier selection, the company starts with the features that the outsourced product/service must possess to meet certain requirements that the company has established, and then tries to identify which of the suppliers' attributes have the greatest impact on the achievement of its established objectives. The stepwise representation of the fuzzy MCDM framework is as follows:

Step 1. Construct a decision-makers committee of Z (z=1,2,…,Z) experts. Identify the characteristics that the product being purchased must possess (CNs) in order to meet the company's needs and the criteria relevant to supplier assessment (TAs).

Step 2. Construct the decision matrices for each decision-maker that denote the direct influence matrix among CNs, the fuzzy assessment to determine the CN-TA relationship scores, the degree of dependencies among TAs, and the ratings of each potential supplier with respect to each TA.

Step 3. Let the value assigned as the CN e exerts on CN i (i=1,2,…,m) , relationship score between the ith CN and jth TA (j=1,2,…,n), degree of dependence of the kth TA on the jth TA, and and rating of the lth supplier (l=1,2,...,L) with respect to the jth TA for the zth decision-maker be w_{eiz}, $\tilde{x}_{ijz} = (x^1_{ijz}, x^2_{ijz}, x^3_{ijz})$, $\tilde{r}_{kjz} = \left(r^1_{kjz}, r^2_{kjz}, r^3_{kjz}\right)$, and $\tilde{y}_{ljz} = \left(y^1_{ljz}, y^2_{ljz}, y^3_{ljz}\right)$, respectively. Aggregate w_{eiz}, $\tilde{x}_{ijz}$, $\tilde{r}_{kjz}$, and $\tilde{y}_{ljz}$ using arithmetic mean operator.

Step 4. Calculate the importance weights of CNs by employing DEMATEL method.

Step 5. Calculate the normalized fuzzy relationships as

$$\left(\tilde{X}'_{ij}\right)^L_\alpha = \min\sum_{k=1}^{n} z_{ik}\left(r_{kj}\right)^L_\alpha$$

subject to

$$\sum_{k=1}^{n} z_{ik}\left(\left(r_{kj}\right)^L_\alpha + \sum_{\substack{l=1\\ l\neq j}}^{n}\left(r_{kl}\right)^U_\alpha\right) = 1$$
$$\left(X_{ik}\right)^L_\alpha t \le z_{ik} \le \left(X_{ik}\right)^U_\alpha t, \quad k=1,2,...,n \quad (2)$$
$$t > 0$$

$$\left(\tilde{X}'_{ij}\right)^U_\alpha = \max \sum_{k=1}^{n} u_{ik} \left(r_{kj}\right)^U_\alpha$$

subject to

$$\sum_{k=1}^{n} u_{ik} \left(\left(r_{kj}\right)^U_\alpha + \sum_{\substack{l=1 \\ l \neq j}}^{n} \left(r_{kl}\right)^L_\alpha \right) = 1$$

$$\left(X_{ik}\right)^L_\alpha s \le u_{ik} \le \left(X_{ik}\right)^U_\alpha s, \quad k = 1,2,...,n$$

$$s > 0 \qquad (3)$$

Step 6. Calculate the weight of each criteria $\tilde{\psi}_j = \left(\psi^1_j, \psi^2_j, \psi^3_j\right)$ using

$$\left(\psi_j\right)^U_\alpha = \max \sum_{i=1}^{m} v_i \left(X'_{ij}\right)^U_\alpha$$

subject to

$$z\left(W_i\right)^L_\alpha \le v_i \le z\left(W_i\right)^U_\alpha, \quad i = 1,2,...,m$$

$$\sum_{i=1}^{m} v_i = 1$$

$$z, v_i \ge 0 \qquad (4)$$

$$\left(\psi_j\right)^L_\alpha = \min \sum_{i=1}^{m} v_i \left(X'_{ij}\right)^L_\alpha$$

subject to

$$z\left(W_i\right)^L_\alpha \le v_i \le z\left(W_i\right)^U_\alpha, \quad i = 1,2,...,m$$

$$\sum_{i=1}^{m} v_i = 1$$

$$z, v_i \ge 0 \qquad (5)$$

Step 7. Compute the distances from the ideal and the anti-ideal solutions (D_l^* and D_l^-, respectively) for each alternative as

$$D_l^* = \sum_{j=1}^{n} \frac{1}{2} \left\{ \max\left(\psi_j^1 \left| y_{lj}^1 - 1 \right|, \psi_j^3 \left| y_{lj}^3 - 1 \right| \right) + \psi_j^2 \left| y_{lj}^2 - 1 \right| \right\} \qquad (6)$$

$$D_l^- = \sum_{j=1}^{n} \frac{1}{2} \left\{ \max\left(\psi_j^1 \left| y_{lj}^1 - 0 \right|, \psi_j^3 \left| y_{lj}^3 - 0 \right| \right) + \psi_j^2 \left| y_{lj}^2 - 0 \right| \right\} \qquad (7)$$

Step 8. Calculate the ranking index (*RI*) of alternative *l* as follows:

$$RI_l = \frac{D_l^-}{D_l^- + D_l^+} \qquad (8)$$

Step 9. Rank the alternatives according to RI_l values in descending order. Identify the alternative with the highest RI_l as the best alternative.

V. Illustrative Medical Device Supplier Selection Problem

In order to illustrate the application of the proposed decision making method to medical device supplier selection problem, an evaluation for epidural catheter suppliers is presented. The case study is conducted in a private hospital on the Asian side of Istanbul is presented. The hospital operates with all major departments, and also includes facilities such as clinical laboratories, emergency service, intensive care units and operating room.

As a result of discussions with experts from the purchasing department of the hospital, nine fundamental characteristics required of products purchased from medical supplies (CNs) are determined. These can be listed as “cost (CN_1)”, “kink resistant (CN_2)”, “friction (CN_3)”, “high tensile strength (CN_4)”, “a traumatic tip design (CN_5)”, “easy to thread and remove (CN_6)”, Easy to anchor with the catheter connector (CN_7)”, “good flow characteristics (CN_8)”, and “Shear resistant (CN_9)”.

Nine criteria relevant to supplier assessment are identified as “product volume (TA_1)” delivery (TA_2)” payment method (TA_3)” supply variety (TA_4)” reliability (TA_5)” experience in the sector (TA_6)” earlier business relationship (TA_7)” management (TA_8)”, and “geographical location (TA_9)”. There are 12 suppliers who are in contact with the hospital.

The evaluation is conducted by a committee of three decision-makers (DM_1, DM_2, DM_3). The experts used the linguistic scale given in Table I, to determine the direct influence matrix among CNs, whereas they utilized the linguistic term set depicted in Fig. 2 to denote the impact of each TA on each CN, the inner dependencies of TAs, and the ratings of suppliers with respect to each TA.

TABLE I
LINGUISTIC SCALE FOR DETERMINING THE DIRECT INFLUENCE MATRIX AMONG CNS [11]

No influence	0
Low influence	1
Moderate influence	2
Strong influence	3
Extreme strong influence	4

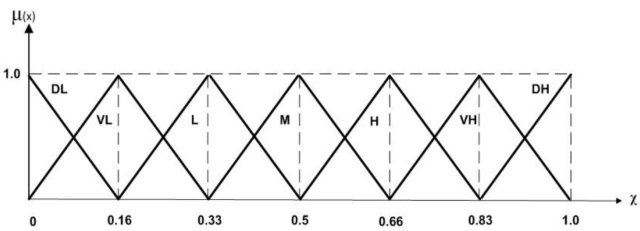

Fig. 2 Linguistic term set where DL: (0, 0, 0.16), VL: (0, 0.16, 0.33), L: (0.16, 0.33, 0.50), M: (0.33, 0.50, 0.66), H: (0.50, 0.66, 0.83), VH: (0.66, 0.83, 1), DH: (0.83, 1, 1)

The average matrix ***A*** is calculated as in Table II.

By employing DEMATEL method and setting the threshold value as 0.03, the weights of CNs are determined as CN_1=0.1220, CN_2=0.0738, CN_3=0.0327, CN_4=0.1151, CN_5=0.0410, CN_8=0.2987, CN_9=0.3167.

Using (2) and (3) the normalized fuzzy relationships are calculated. Then, employing (4) and (5), the weights of each TA are calculated as in Table III.

TABLE II
AVERAGE MATRIX

	CN_1	CN_2	CN_3	CN_4	CN_5	CN_6	CN_7	CN_8	CN_9
CN_1	0,00	3,67	3,33	3,33	3,00	3,67	3,67	3,33	4,00
CN_2	3,67	0,00	3,67	3,67	3,00	3,67	0,67	2,33	3,67
CN_3	4,00	4,00	0,00	2,67	3,33	4,00	0,67	1,00	3,33
CN_4	4,00	3,67	2,33	0,00	1,67	2,33	0,00	3,67	4,00
CN_5	3,67	2,67	2,67	1,33	0,00	4,00	2,00	1,00	3,67
CN_6	4,00	4,00	2,67	2,00	3,00	0,00	1,33	0,33	3,00
CN_7	3,67	0,00	0,67	0,00	1,67	2,33	0,00	0,33	3,00
CN_8	4,00	2,33	1,00	3,67	2,00	0,00	0,33	0,00	2,00
CN_9	4,00	3,67	3,33	4,00	3,00	3,00	3,00	2,33	0,00

TABLE III
IMPORTANCE WEIGHTS FOR EACH TA

TAs	Importance Weights
TA_1	(0.0072, 0.0089, 0.0100)
TA_2	(0.0107, 0.0129, 0.0129)
TA_3	(0.0091, 0.0111, 0.0118)
TA_4	(0.0093, 0.0115, 0.0130)
TA_5	(0.0812, 0.1012, 0.1140)
TA_6	(0.1014, 0.1245, 0.1341)
TA_7	(0.0122, 0.0149, 0.0158)
TA_8	(0.0207, 0.0406, 0.0654)
TA_9	(0.0046, 0.0060, 0.0074)

The distances from the ideal and the anti-ideal solutions for each alternative are computed using (6) and (7). Finally, the ranking index for each alternative is computed using (8). Table IV summarizes the results obtained using the fuzzy decision framework. According to the results of the analysis, supplier 1 is determined as the most suitable supplier, which is followed by supplier 7, and then by supplier 2 and supplier 4. Suppliers 12 and 5 are ranked at the bottom due to late delivery time, inadequate experience in the sector, unsatisfactory earlier business relationships, and improper geographical location.

TABLE IV
RANKING OF SUPPLIERS

Suppliers	D_i^*	D_i^-	RI_i	Rank
S_1	0.0809	0.3541	0.8139	1
S_2	0.1076	0.3279	0.7529	3
S_3	0.1483	0.2849	0.6577	5
S_4	0.1200	0.3161	0.7248	4
S_5	0.2109	0.2155	0.5054	12
S_6	0.1621	0.2680	0.6232	6
S_7	0.0891	0.3502	0.7971	2
S_8	0.1844	0.2446	0.5703	8
S_9	0.1790	0.2506	0.5833	7
S_{10}	0.1958	0.2321	0.5424	10
S_{11}	0.1890	0.2388	0.5583	9
S_{12}	0.2106	0.3541	0.5091	11

VI. CONCLUDING REMARKS

Supplier's performance has a key role on cost, quality, delivery and service in achieving the objectives of a supply chain. Hence, supplier selection is considered as one of the most critical activities of purchasing management in a supply chain. Selecting the right suppliers significantly reduces the purchasing cost and improves corporate competitiveness [13]. Supplier selection problem, which considers several individual attributes exhibiting vagueness and imprecision, may be regarded as a highly important group decision-making problem. The classical MCDM methods that consider deterministic or random processes cannot effectively handle group decision-making problems including imprecise and linguistic information. In this paper, a fuzzy multi-criteria decision making algorithm is proposed to rectify the problems encountered when using classical decision making methods in group decision making problems. The decision making approach set forth in this paper disregards the troublesome fuzzy number ranking process, which may yield inconsistent results for different ranking methods, and as a result improves the quality of decision. Future research might focus on applying the decision frameworks presented in here to real-world group decision making problems in diverse disciplines that can be represented in HOQ structures.

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