Quality Function Deployment-ELECTRE in Supplier Evaluation

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Abstract—**The decision of supplier selection is becoming a dominant strategy in the success of the quality of the outsourcing and for process effective supply chain management in severe competitive environment in number of sectors of services, products or manufacturing in addition to the customers' needs that are becoming increasingly as well. In this paper, we applied a multi-criteria group decision-making approach that makes use of quality function deployment (QFD) by using "House of Quality" charts, fusion of information of ELECTRE model for supplier selection. The proposed methodology seeks to establish the relevant supplier assessment criteria. The proposed framework is used to analyse a case study of an outsourcing in road transport.**

Index Terms—**outsourcing, supplier selection, quality function deployment, supplier criteria**

I. Introduction

Outsourcing strategies have become an important element in the success of companies [1]. Because the primary goal of most companies is to achieve competitive advantage in the field in which they operate, whether services or manufacturing. The process of selecting suppliers is one of the most difficult outsourcing tasks because the company relies on its suppliers to provide services or products that meet customer needs, wherefore the supplier must therefore meet the required standards [2] [3]. Since customer satisfaction depends largely on the quality of the final services provided, this means that customers are linked to what the suppliers' service [4]. There is many of methods that address the problem of supplier selection and evaluation, because of the key role of provider's performance on quality of service in achieving the objectives of outsourcing, considered provider selection is one of the most critical activities in supply chain and outsourcing. QFD is used to develop better products and services responsive to customer requirements (CRs). QFD provides the importance of weighting the evaluation criteria, which are derived from the importance ratings of stakeholder requirements together.

II. Literature Review

Because of the key role of provider's performance on quality of service in achieving the objectives of outsourcing, considered provider selection is one of the most critical activities in supply chain and outsourcing. The supplier selection problem is needing to be conducted a trade-off between conflicting tangible and intangible factors to find the most appropriate supplier for this reason it is characterized as a multi-criteria decision-making (MCDM) problem which is affected by several conflicting factors [5]. Literature review shows rich collection of work on supplier selection. Researchers used various methods such as analytic hierarchy process (AHP), multi-objective programming (MOP), data envelopment analysis (DEA), mixed integer programming (MIP), goal programming (GP), genetic algorithm (GA), analytic network process (ANP), case-based reasoning (CBR), data mining (DM), cluster analysis (CA), activity-based costing (ABC), technique for order preference by similarity to ideal solution (TOPSIS), rough sets theory (RST), quality function deployment (QFD), neural network (NN), and multi attribute utility theory (MAUT). Some researchers combined at least two of the above technique for supplier selection. Some of the examples are AHP-GP, AHP-LP, DEA-AHP, DEA-MOP, etc. In this regard, Table I. shows various techniques for single sourcing and multiple sourcing supplier selection.

Quality function deployment is a strategic tool to help companies in developing products/ services that satisfy the desires of customers. QFD is used to develop better products and services responsive to customer requirements (CRs). QFD ensures a higher quality level that meets customer expectations throughout each stage of product planning. House of quality (HOQ) is the main part of the QFD where consumer requirements and technical requirements evaluate together in a common matrix.

Building a matrix HOQ requires the formation of the following key elements [6] [7]:

1- Customer requirements (CRs) (WHATs), also known as the voice of the customer or customer attributes, are considered the basic step in the matrix HOQ.

2- Technical requirements (TRs) (HOWs), also known as quality characteristics or engineering attributes, through which the extent to which the company meets customer requirements is determined.

3- Importance of customer requirements (CRs); through this step, the matrix to classify CRs by importance is formed and its goal is to neutralize relatively unimportant requirements.

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4- Internal relationship between the requirements and standards indicate the extent of impact between CRs and TRs.

5- Internal adoption of TRs. The objective is to determine the extent to which a change in a product or service characteristic affects other features.

6- TR rankings to determine the most important criteria and final order of HOWs. [8] applied the methodology of QFD-ANP in selecting sustainable suppliers to determine the weights of the standards and then used AHP to determine the weights of the suppliers through technical standards then using MOORAS and WASPAS for supplier classification. [9] addressed the relationship among the criteria for supplier selection in decision making QFD-AHP techniques; subsequently, the proposed integrated hierarchical methodology for supplier selection was delineated.

ELECTRE stands for [10] : ELimination Et Choix Traduisant la REalite´ (ELimination and Choice Expressing the REality) is a popular approach to multiple-criteria decision-making (MCDM) and has been widely used in the literature [11] [12]. The ELECTRE methods are based on the evaluation of a range of indicators the concordance index and the discordance index for each pair of alternatives [13].

In this study, we integrate a case-focused model where these objectives are attained through an integrated MCDM model and quality function deployment (QFD) by using "House of Quality" [14] [15] [16], we used two of hybrid and modular methods, which are based on ELECTRE by using the Entropy weighting method [17] [18] [19].

TABLE I. SUPPLIER SELECTION METHODS

Method	Author(s)
Agency Theory	Zu and Kaynak (2012)
AHP	Hou and Su (2007), Liu and Hai (2005), Chan and Chan (2004), Akarte et al. (2001)
ANP	Gencer and Gürpinar (2007), Bayazit (2006), Sarkis and Talluri (2002), Nydick and Hill (1992)
Case-based reasoning	Choy and Lee (2002), Cook (1997) Cluster analysis Zenz (1981)
Conjoint analysis	Boer, Labro, and Morlacchi (2001)
DEA	Braglia and Petroni (2000), Forker and Mendez (2001), Karpak, Kumcu and Kasuganti (2001, 2001), Talluri, Narasimhan, and Nair (2006), Talluri and Baker (2002)
Decision Analysis	Friedl and Wagner (2012)
e-constraint method	Buffa and Jackson (1983)
Expert Systems	Wei, Zhang, and Li (1997)
Fuzzy set theory	Sarkar and Mohapatra (2006), Florez-Lopez (2007), Chen, Lin, and Huang (2006), Shu and Wu (2009)
Genetic algorithm	Vokurka, Choobineh, and Vadi (1996)
Goal programming	Karpak, Kumcu, and Kasuganti (2001)
Linear programming	Talluri and Narasimhan (2003), Ng (2008)
Mathematical programming	Talluri, Wadhwa and Ravindran (2007)
Mixed integer linear programming	Hong et al. (2005)
Mixed integer nonlinear programming	Ghodsypour and O'Brien (2001)
Multi-objective programming	Narasimhan, Talluri, and Mahapatra (2006)
Neural networks	Ding, Benyoucef, and Xie (2003)
Outranking	Mummalaneni, Dubas, and Chao (1996), de Boer, van der Wegen, and Telgen (1998)
Path analysis	Lo, Sculli, and Yeung (2006), Li et al. (2012)
Simple weighting	Dobler and Burt (1996)
Six sigma	Wang, Du, and Li (2004)
SMART	Barla (2003)
Total Cost of Ownership	Monczka and Trecha (1988), Smytka and Clemens (1993), Degraeve and Roodhooft (1999), Roodhooft and Konings (1996)
Uncertainty analysis	Hinkle, Green, and Green (1969)

III. METHOLOGY

A. *Introduction of Case Study (Shipping Company MSC)*

The Decision Makers in this case have experience in transport and selection supplier. For MSC Company the DM1 is company manager, DM2 has experience in road transport and DM3 is responsible for customer attributes and has been consulting the company for the last 10 years. The questionnaire is developed to assess the degree of importance of criteria. In decision-making processes the provider that were evaluated are ranked and the results are presented from a company perspective. We identified from the literature survey in addition to the criteria added by the respondents 13 customer requirements (CR) and 16 technical requirements (TR).

For our objective, we determined the customer requirements in thirteen needs as follows: CR1 transport cost, CR2 Delivery time, CR3 Financial solidity, CR4 Chronology, CR5 Quality of service, CR6 Flexibility, CR7 Customization of the service, CR8 Customer satisfaction, CR9 Effective problem solving, CR10 Reactivity, CR11 assurance, CR12 Green image, CR13 Quotation Capacity. For the technical requirements (TR): TR1 Quality, TR2 Delivery, TR3 Increase customer satisfaction, TR4 Cooperation with customers, TR5 Cost, TR6 Excellent reputation, TR7 Optimization capability, TR8 financial situation, TR9 business excellence, TR10 reliability, TR11 stability, TR12 responsibility, TR13 solve the problem, TR14 safety and security, TR15 reactivity, TR16 information sharing.

B. *QFD Model*

The second part of this research includes an application of the process of QFD

2.1. A central relationship matrix is constructed that exhibits the effects and relationships between each pair of

CR and the corresponding supplier selection criteria, and the matrix shows how supplier selection criteria can satisfy each CR.

Using the central relationship matrix and weights of CRs, the weights of each supplier selection criteria is computed. The normalized weights of all criteria are obtained which shows that the TR1 is the most important supplier evaluation criterion among the others.

With respect to each evaluation criterion, suppliers are now rated using pairwise comparisons as stated previously. Thus, seven pairwise comparisons are performed for ten alternative suppliers. For instance, Tables II show the pairwise comparison matrices for alternative suppliers regarding ENRC and GD criteria, respectively. For the remaining criteria, the same procedure is followed. At the end of this step, the performance ratings of alternative suppliers and criteria weights are integrated to comprise the initial decision matrix, as shown in Table III.

From the initial decision matrix, suppliers S3 and S2 outperformed most of the other alternative suppliers with respect to higher values of TR1 and TR11 and to a lower value of TR15 criteria. On the other hand, the main reason behind the underperformance of S5 supplier is its very low TR1 value, although it has amazingly attractive values for TR5 criteria.

TABLE II. PAIRWISE COMPARISON MATRIX OF SUPPLIERS FOR THE TR1 CRITERION

TR1	S1	S2	S3	S4	S5	Weights
S1	1.0000	1.0000	6.0000	6.0000	9.0000	0.3644
S2	1.0000	1.0000	9.0000	9.0000	9.0000	0.4595
S3	0.1700	0.1100	1.0000	1.0000	3.0000	0.0837
S4	0.1700	0.1100	1.0000	1.0000	1.0000	0.0520
S5	0.1100	0.1100	0.3300	1.0000	1.0000	0.0404

TABLE III. INITIAL DECISION MATRIX FOR SUPPLIER SELECTION

	0,1012 TR1	0,2059 TR2	0,0938 TR3	0,0447 TR4	0,0595 TR5	0,0312 TR6	0,0692 TR7	0,0510 TR8	0,0137 TR9	0,0759 TR10	0,0385 TR11	0,0385 TR12	0,0676 TR13	0,0539 TR14	0,0386 TR15	0,0169 TR16
S1	0,1012	0,2059	0,0938	0,0447	0,0595	0,0312	0,0692	0,0510	0,0137	0,0759	0,0385	0,0385	0,0676	0,0539	0,0386	0,0769
S2	0,3644	0,2000	0,1738	0,1552	0,1416	0,2000	0,2000	0,2000	0,2000	0,2000	0,1067	0,2000	0,2000	0,2000	0,2289	0,2289
S3	0,4595	0,2000	0,1809	0,2104	0,1968	0,2000	0,2000	0,2000	0,2000	0,2000	0,3011	0,2000	0,2000	0,2000	0,1808	0,2531
S4	0,0837	0,2000	0,0568	0,0586	0,3138	0,2000	0,2000	0,2000	0,2000	0,2000	0,1067	0,2000	0,2000	0,2000	0,1565	0,1808
S5	0,0520	0,2000	0,1204	0,0586	0,3138	0,2000	0,2000	0,2000	0,2000	0,2000	0,1067	0,2000	0,2000	0,2000	0,1808	0,1808

C. Ranking by ELECTRE Method

Step 1. In this step, values of decision-making matrix will be descaled using norm. this matrix is named *N*

$$N = [n_{ij}],\ n_{ij} = a_{ij}/\left[\sum_{i=1}^{m} a_{ij^2}\right] \frac{1}{2} \quad (1)$$

Step 2 In this step, using matrix *W* and following descaled relation and obtain descaled balanced is named *N*

$$V = N \times W_{n\times n} \quad (2)$$

where V is descaled balanced matrix, $W_{n\times n}$ is weights diagonal matrix obtained for indices. However, weights can be calculated by judgement or based on methods provided in previous section and use it for calculations of next steps.

Step 3 In this step, all items proportionate to all indices will be evaluated and a set of consistent and inconsistent matrices will be formed. A consistent set of K and I named as $S_{K,I}$ containing all indices within which A_K is more favourable than A_I .

For finding this favourability, the positive or negative decision making indices, that is to say that:
If the index is of positive aspect:

$$S_{K,I} = \{j|V_{kj} \geq V_{ij}\}, j = 1, \dots, m \quad (3)$$

If the index is of negative aspect:

$$S_{K,I} = \{j|V_{kj} \leq V_{ij}\}, j = 1, \dots, m \quad (4)$$

The inconsistent matrix $D_{K,I}$ *also contains indices within which* A_K *is less favourable than* A_I *. That is:*

$$D_{K,I} = \{j|V_{kj} < V_{Ij}\},\ j = 1, \dots, m \quad (5)$$

This formula is for positive indices and for negative one as follows:

$$D_{K,I} = \{j|V_{kj} > V_{Ij}\},\ j = 1, \dots, m \quad (6)$$

Step 4 In this step, the consistent matrix is obtained from abovementioned data. This matrix is $m\ x\ m$ whose diagonal is without element. Other elements of this matrix are obtained summing weights of indices. That is:

$$I_{KI} = \sum W_j,\quad j \in A_{K,I} \quad (7)$$

TABLE IV. THE CONSISTENT MATRIX I

S1	S2	S3	S4	S5
Nan	0,00	0,857	0,857	0,4334
0,9762	Nan	0,857	0,857	0,4334
0,2572	0,131	Nan	0,8049	0,4334
0,2572	0,131	0,6857	Nan	0,4334
0,5427	0,5427	0,5427	0,5427	Nan

Step 5 In this step, the effective consistent matrix is calculated. This matrix is indicated with H. for creating this matrix, so a threshold should be determined and if each element of matrix I is equal or bigger than that the element will take value of 1 in matrix H otherwise 0. For determining the threshold, the previous data and decision maker's idea was used. A general criterion for determining this threshold includes average of values of matrix:

$$\bar{I} = \sum_{I=1}^{m} \sum_{K=1}^{m} I_{KI} / m_{(m-1)} \quad (8)$$

Step 6 In this step, effective inconsistent matrix G was developed which is obtained as consistent one. The threshold of this matrix is calculated as:

$$\overline{NI} = \sum_{I=1}^{m} \sum_{K=1}^{m} NI_{KI} / m_{(m-1)} \quad (9)$$

Step 7 In this step, combining H and G the general effective matrix F is obtained. It is calculated as:

$$F_{KI} = H_{KI} \times G_{KI}$$

In the third stage, matrix QG is obtained by specifying the weights of criteria (W). Each element of the QG matrix is equal to

$$q/_{it} = \sum_{j=1}^{n} \pi itj \,.\, w_j \qquad (10)$$

If option i is in the ranking t in the criterion , then

$$\pi\, itj = 1. \qquad (11)$$

TABLE V. THE WEIGHT MATRIX OF THE NUMBER OF RANKING ALTERNATIVES

Areas	First rank	Second rank	Third rank	Forth rank	Fifth rank
1	0,6068	0,1182	0	0	0,275
2	0,2162	0,7838	0	0	0
3	0,1771	0,0981	0,725	0	0
4	0	0	0,1427	0,8573	0
5	0	0	0,1323	0,1473	0,725

The results shown in the alternatives scoring Table VI, the rank of suppliers is calculated by taking a value of 1 per line and considering the accompanying order in the first line of Table VI. We get the best supplier ranking, which is supplier 1 and the order of the rankings alternatives by ELECTRE and linear assignment method.

TABLE VI. THE RANKINGS ALTERNATIVES BY ELECTRE AND LINEAR ASSIGNMENT METHOD

Areas	Ranking
1	1
2	2
3	3
4	4
5	5

IV. CONCLUSION

Supplier's selection has a key role on quality, cost, delivery and service in achieving the objectives of a supply chain and in outsourcing decision in the transportation service and improves corporate competitiveness. An advantage of the ELECTRE method is that a significantly weak criterion value of an alternative cannot directly be compensated by other good criteria values [20]. This feature allows setting strong criteria in selecting suppliers. By applying HOQ-ELECTRE in the resource, selection problem demonstrates. We obtain the best supplier ranking, which is supplier 1 and the order of the rankings alternatives by ELECTRE and linear assignment method in Table VI. The number one supplier has a strong standard of delivery time and quality of service that distinguishes it from other suppliers. The strength of the delivery time standard requires other suppliers to improve this standard to reach the required level of quality.

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