# QFD-MCDM Integrated for supplier selection in outsourcing of transport

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**Abstract :** In today's severe competitive environment in the global market whether in services, products or manufacturing, the decision to select suppliers is an important step in the success of the quality of the outsourcing and for process effective supply chain management. This decision gives the opportunity to enhance the competitiveness of companies; In addition to meeting, the customers' needs that are becoming increasingly as well as they may be conflicting with some of the company's capabilities. In order to achieve these objectives, it is necessary to choose the suppliers who fulfills requirements customers at the same time succeed in achieving the standards of the company.

In this paper, we applied a multi-criteria group decision-making approach that makes use of quality function deployment (QFD), fusion of information between DEMATEL and ELECTRE model each separately and both of MOORA and COPRAS method for supplier selection. The proposed methodology seeks to establish the relevant supplier assessment criteria while also considering the impacts of inner dependence among them and customers' requirements$CR_s$. The study establishes the weights of $CR_s$ through the Decision Making Trial and Evaluation Laboratory (DEMATEL) method and ELimination and Choice Expressing Reality (ELECTRE) method, which considers the influences of inconformity and causal relationship between customers' needs. For supplier selection and evaluation, this paper employs quality function deployment to integrate the voice of outside consumers $CR_s$ and supplier criteria $TR_s$ by using "House of Quality" charts. Finally, for achieving the object of this paper, which is ranking the supplier and choose the best one and the alternatives we compare between multi-objective optimization based on ratio analysis method (MOORA) and (COPRAS) .The proposed framework is used to analyse a case study of an outsourcing in road transport.

**Keywords:** Outsourcing, Supplier selection, Quality function deployment, Customers' requirements, Supplier criteria.

## 1. Introduction

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 characterised as a multi-criteria decision-making (MCDM) problem which is affected by several conflicting factors (Chan et al. 2008).

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). It employs a cross functional team to identify the needs of customer and translate them into design characteristics to plan new or improved products. QFD ensures a higher quality level that meets customer expectations throughout each stage of product planning.

DEMATEL project was first conducted by Battelle Memorial Institute through its Geneva research center (Wu and Lee, 2007). This method is best suited for analyzing complex structural models involving a causal relationship between complex factors (Wu and Lee, 2007a). The basic concept of DEMATEL is a diagraph theory, which enables us to realize the cause and effect of the system by dividing and relating the issues, which bind with it.

ELECTRE stands for (Roy 1985): 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 (Papadopoulos and Karagiannidisa 2008, Wang and Triantaphyllou 2008). 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 (Wang and Trintanphyllou, 2006).

In this study, we integrate a case-focused model where these objectives are attained through an integrated MCDM model, we used two of hybrid and modular methods, which are based on DEMATEL and ELECTRE by using the Entropy weighting method, then compare it by COPRAS and MOORA methods.

## 2. Materials and Methods

### 2.1. 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.

### 2.2. DEMATEL method for weighting customers (Tamura and Akazawa, 2005; Tzeng et al., 2007; Ranjan et al., 2014 ; Yazdani, M., et al., 2017).

Step 1. Generation of the direct-relation matrix (A)

At first, the goal of decision makers is to refer to the relationship the relationship between the sets of paired criteria to indicate the direct effect that they believe each ith criterion exerts on each jth criterion, as indicated by an integer scale (score) ranging from 0 to 4 The comparison scale consists of the following levels (Büyüközkan and Öztürkcan, 2010), representing no influence (0), low influence (1), medium influence (2), high influence (3) and very high influence (4). DMs are asked to compare the criteria pair-wise in terms of influence and direction. These evaluations are used for constructing a matrix with the dimensions of $n$ x $n$, called the direct-relation matrix $A$. Here, a_$ij$ stands for the degree to which the criteria $i$ affects the criteria $j$.

Then, as a result of these evaluations, the initial data is obtained as a direct-relation matrix ($A$) which is in the form of an $n$×$n$ matrix, in which the individual element ($a_{ij}$) denotes the degree to which $ith$ criterion affects $jth$ criterion and n denotes the total number of criteria.

Normalize the direct-relation matrix: The direct-relation matrix $A$ is used to calculate the normalized direct relation matrix $A$, using the formulae (1), (2).

$$\begin{bmatrix} 0 & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ a_{21} & 0 & \cdots & a_{2j} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & & \cdots & \cdots \\ \cdots & \cdots & \cdots & & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nj} & \cdots & 0 \end{bmatrix} \quad (1)$$

After the interrelationships are measured, the initial direct-relation matrix (A) is produced, as shown in Table 2. The matrix A is an 13× 13 matrix, obtained by pair-wise comparisons in terms of influences and directions between the CRs.

| | CR1 | CR2 | CR3 | CR4 | CR5 | CR6 | CR7 | CR8 | CR9 | CR10 | CR11 | CR12 | CR13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CR1 | 0 | 3 | 0 | 3 | 0 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 |
| CR2 | 0 | 0 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 3 | 2 | 2 | 2 |
| CR3 | 3 | 0 | 0 | 3 | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 3 | 2 |
| CR4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CR5 | 3 | 0 | 0 | 3 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 2 |
| CR6 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 2 | 2 | 0 | 0 |
| CR7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CR8 | 0 | 0 | 2 | 3 | 0 | 0 | 3 | 0 | 3 | 3 | 3 | 3 | 3 |
| CR9 | 0 | 0 | 2 | 2 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 2 |
| CR10 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 |
| CR11 | 0 | 0 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| CR12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CR13 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 0 | 0 | 3 | 3 | 3 | 0 |

*Table 1: The direct-relation matrix A*

Step 2. Formation of the normalized direct-relation matrix ($X$):

After the generation of the direct-relation matrix ($A$), the normalized matrix ($X$) is obtained through formulas $\left(\sum_{j=1}^{n} a_{ij}\right) \max_{1 \le i \le n}$

$X = k.A$ (2)

$k = \frac{1}{\max_{1\le i\le n}\left(\sum_{j=1}^{n} a_{ij}\right)}, i,j = 1,2,\dots\dots,n$ (3)

K= 0.0370

Step 3. The total-relation matrix $T$

We can Obtain the total-relation matrix $T$ , after calculated the normalized direct-relation matrix $X$ , the total relation matrix $T$ can be acquired by using the following equation, in which the $I$ is identity matrix, and the matrix T reveals the total relationship between each pair of decision variables.

$$T = \left[t_{ij}\right]_{n\times n}$$

$$T = X + X^2 + X^3 + \cdots + X^k$$

$$T = X + (I + X + X^2 + X^3 + \cdots + X^{k-1})[(I - X)\,(I - X)^{-1}]$$

$$T = X(I - X^k)(I - X)^{-1}$$

$$T = X(I - X)^{-1}T \text{ , when } k \to \infty, X^k = [0]_{n\times n}$$

$$T = X(I - X)^{-1} \qquad (4)$$

The total-influence matrix ($T$) is derived as shown in Table 4, in which denotes each element ($t_{ij}$) of this matrix symbolizes the indirect influences that $i_{th}$ criterion imparts on $j_{th}$ criterion.

Step 4. Determination the sum of rows and columns of matrix $T$

This step is represented by vectors $D$ and $R$ by calculated the sums of rows and columns as represented by vectors D and R respectively are computed and are shown in Table 5. As derived using Eqs. (5), (6) respectively.

$$D_i = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = [t_i]_{n\times 1} \ , i = 1,2 \cdots\cdots, n \quad (5)$$

$$R_i = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} = \left[t_j\right]_{n\times 1} \ , j = 1,2 \cdots\cdots, n \quad (6)$$

| | $D_k$ | $R_k$ |
|---|---|---|
| CR1 | 1.5330 | 0.3211 |
| CR2 | 1.4372 | 0.1468 |
| CR3 | 1.0886 | 0.6243 |
| CR4 | 0 | 1.3667 |
| CR5 | 1.1873 | 0.2654 |
| CR6 | 0.2963 | 0.9198 |
| CR7 | 0 | 1.0500 |
| CR8 | 1.1825 | 0.3966 |
| CR9 | 0.7334 | 0.4806 |
| CR10 | 0.4092 | 0.9596 |
| CR11 | 0.4359 | 0.8712 |
| CR12 | 0 | 0.9110 |
| CR13 | 0.6714 | 0.6617 |

*Table 2: The computation of vectors D and R*

Calculate dispatcher and receiver groups. The dispatcher is calculated from the $D - R$ which have positive values and higher influence on one another.

They are assumed to exhibit higher priority and are called dispatcher groups, where $R$ is the sum of columns and $D$ is the sum of rows in matrix $T$, as indicated in the formulae (4), (5), (6). The other values with negative values of $D - R$ receiving more influence from another are considered to have a lower priority and are called receiver groups. The value of $D + R$ here shows the relation degree between each criterion with others. Those criteria that are exhibiting higher $D + R$ values mean having more relationship with another and those having lower $D + R$ values mean having less of a relationship with others.

Set a threshold value and construct the impact diagraph map: By mapping the dataset of the $(D + R, D - R)$, the impact-diagraph map is obtained. Here, the horizontal axis indicates $D + R$ and the vertical axis indicates $D - R$. In order to have an appropriate diagram, DMs must set an influence level threshold value. As the influence level in matrix $T$ is higher than the threshold value, it can be converted into the impact-diagraph map.

Step 5. Use of threshold values helped in identifying the critical set of risks and helped generate powerful insights on the cause-effect linkage between the risks. Generally this threshold value is determined by experts in order to set up the minimum value of influence level. It thus becomes essential for the DM to set a threshold value (α) for elucidating the structural relation among criteria while simultaneously keeping the intricacy of the entire system to a convenient level.
The threshold value is calculated by the mean of elements in matrix $T$ by using Eq. (7) where $N$ is the total number of elements in matrix $T$ which provides information on how one factor affects another, . An influence relationship between two elements is excluded from the map if their correlation value in matrix $T$ is smaller than α and only the effects greater than the set α value are chosen and shown in the digraph.

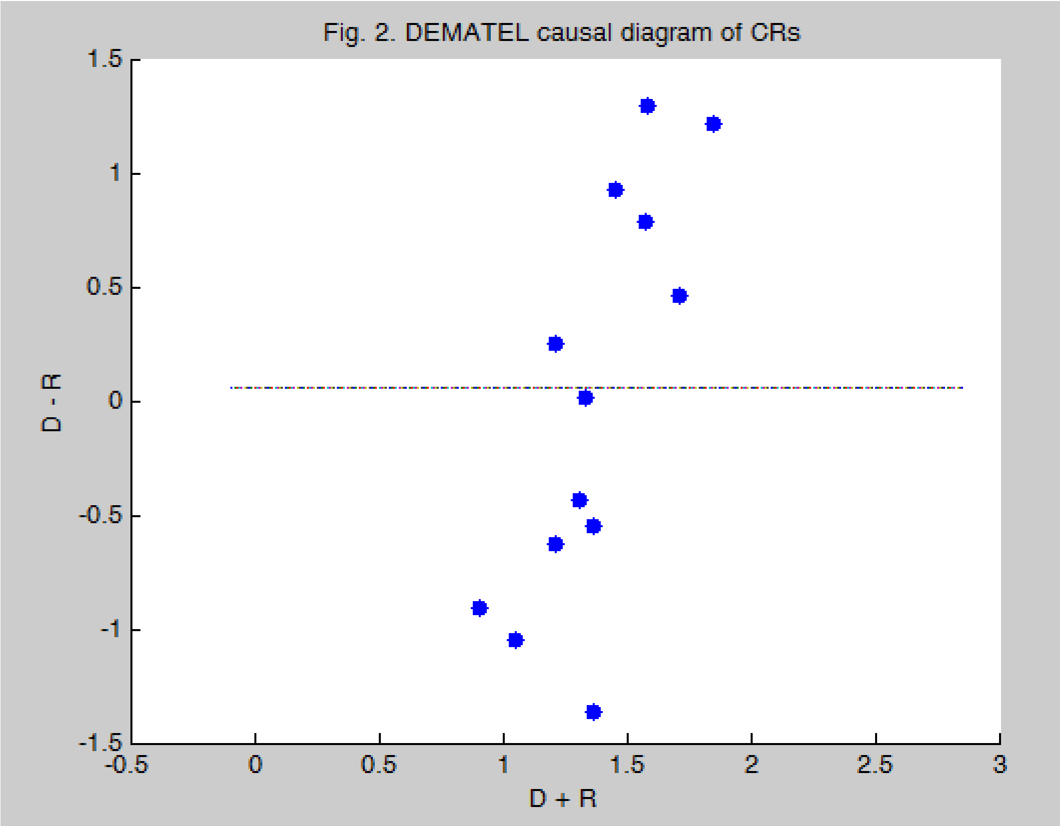


*Figure 1: DEMATEL causal diagram of green CRs*

According to Figure 1 and Table 6, CR1 is the most influential factor and CR4 is the most important factor in the whole system.

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}[t_{ij}]}{N} \quad (7)$$

*The threshold alpha,* $\alpha =$ 0.0531

By normalizing the values of prominence vector (D + R) of Table 6 and are shown in Table 7 in order to calculate the weights of the CRs we find that CR1 is the most influencing factor and it has the highest weight among other CRs.

| Criteria | CR1 | CR2 | CR3 | CR4 | CR5 | CR6 | CR7 | CR8 | CR9 | CR10 | CR11 | CR12 | CR13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Criteria weights | 0.1033 | 0.0882 | 0.0954 | 0.0761 | 0.0809 | 0.0678 | 0.0585 | 0.0880 | 0.0676 | 0.0763 | 0.0728 | 0.0508 | 0.0734 |

*Table 3 : The criteria weights (Ci) of CRs*

| | 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 |

*Table 4: Initial decision matrix for supplier selection*

From the initial decision matrix of Table 11, it is observed that supplier S3 and S2 outperforms most of the other alternative suppliers with respect to higher values of TR1 and TR11, and 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.

**2.3 Ranking by ELECTRE method (Momeni, 2015, Tavassoli, 2018)**

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

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

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

$$V = N \times W_{n\times n}$$

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:

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

$$If\ the\ index\ is\ of\ negative\ aspect:$$

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

$$The\ inconsistent\ matrix\ D_{K,I} also\ contains\ indices\ within\ which\ A_K$$

$$is\ less\ favourable\ than\ A_I\ .That\ is:$$

$$D_{K,I} = \{j | V_{kj} < V_{Ij}\}, \qquad j = 1, \dots, m$$

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

$$D_{K,I} = \{j | V_{kj} > V_{Ij}\}, \qquad j = 1, \dots, m$$

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:

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

| 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 |

*Table 5 : The consistent matrix I*

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:

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

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:

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

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

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

| Areas | Number of dominance | Number of defeats | Difference |
|---|---|---|---|
| 1 | 2 | 3 | -1 |
| 2 | 3 | 2 | 1 |
| 3 | 1 | 4 | -3 |

| | | | |
|---|---|---|---|
| 4 | 1 | 4 | -3 |
| 5 | 2 | 3 | -1 |

*Table 6 : The number of dominance, effect and difference*

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

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

If option $i$ is in the ranking $t$ in the criterion , then $\pi\ itj = 1$.

| 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 |

*Table 7 : The weight matrix of the number of ranking alternatives*

The results shown in the alternatives scoring table, 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 23. We get the best supplier ranking, which is supplier 1 and the order of the rankings alternatives by ELECTRE and linear assignment method.

| Areas | Ranking |
|---|---|
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |
| 4 | 4 |
| 5 | 5 |

*Table 8 : The rankings alternatives by ELECTRE and linear assignment method*

**2.4. COPRAS method (Zavadskas et al., 1994 ; Yazdani, M., et al., 2017)**

The computational steps as involved in COPRAS method-based analysis are now presented below (Zavadskas et al., 1994):

**Step 1** Normalize the decision matrix using

$$r_{ij} = \frac{x_{ij}}{\sum_{j=1}^{m} x_{ij}}, j = 1,2, \cdots\cdots, m; i = 1,2, \cdots\cdots, n$$

**Step 2** Calculate the weighted normalized decision matrix as follows: where $wi$ includes the weights of criteria and given by

$$\sum_{i=1}^{n} w_i = 1;$$

$$v_{ij} = w_i \times r_{ij}, j = 1,2, \cdots\cdots, m; i = 1,2, \cdots\cdots, n$$

***The vector of indexes of non-beneficial (cost/negative) criteria is = 5***

**Step 3** Calculate the sums of weighted normalized values for both the beneficial ($Pj$) and non-beneficial attributes ($Rj$) using the following equations:

$$P_j = \sum_{i=1}^{k} v_{ij}$$

**Step 4** Determine the relative significances or priorities of the alternatives as follows:

$$Q_j = P_j + \frac{\sum_{j=1}^{m} R_j}{R_j + \sum_{j=1}^{m} \frac{1}{R_j}}$$

**Step 5** Calculate the quantitative utility (Nj) for *j*th alternative.

$$N_j = \frac{Q_j}{Q_{max}} \times 100\%$$

| | $Pj$ | $Rj$ | $Oj$ | $Nj$ | Rank |
|---|---|---|---|---|---|
| S1 | 0.1983 | 0.0084 | 0.2071 | 80.8876 | 3 |
| S2 | 0.2171 | 0.0117 | 0.2234 | 87.2691 | 2 |
| S3 | 0.1510 | 0.0187 | 0.1549 | 60.5233 | 5 |
| S4 | 0.1547 | 0.0187 | 0.1586 | 61.9655 | 4 |
| S5 | 0.2195 | 0.0020 | 0.2560 | 100.000 | 1 |

*Table 9: $Pj, Rj, Oj, Nj$ and rank values COPRAS method*

For the application of COPRAS method, the candidate suppliers are their arranged in descending order of $Nj$ values. The best choice of supplier for the Iranian dairy company is S5. S2 is the second choice and the last choice is supplier S3.

### 2.5. MOORA method (Brauers and Zavadskas, 2006; Yazdani, M., et al., 2017)

The step by step application procedure of MOORA (Brauers and Zavadskas, 2006) method is explained below:

**Step 1**

$$r_{ij} = \frac{x_{ij}}{\sum_{j=1}^{m} x_{ij}^2}$$

**Step2** Determine the weighted normalized matrix as:

$$v_{ij} = w_i \times r_{ij}$$

**Step3** Compute the overall rating of benefit and cost criteria for all alternatives implementing the following equations:

$$S_j^+ = \sum_{i=1}^{n} v_{ij} \ , i \in J^{Max}$$

$$S_j^- = \sum_{i=1}^{n} v_{ij} \ , i \in J^{Min}$$

**Step 4** Obtain the overall performance index by mutually subtracting the overall ratings for beneficial and cost criteria using the following formula:

$$S_{j=} S_j^+ - S_j^-$$

**Step 5** The ranking for each alternative is obtained by arranging the $S_j$ values in descending order. It means higher values of $S_j$ exhibit better priority order and would be preferred.

| | TR1 | TR2 | TR3 | TR4 | TR5 | TR6 | TR7 | TR8 | TR9 | TR10 | TR11 | TR12 | TR13 | TR14 | TR15 | TR16 | $S_j^+$ | $S_j^-$ | $S_j$ | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 0.7692 | 0.2059 | 0.1346 | 0.0610 | 0.1397 | 0.0312 | 0.0692 | 0.0510 | 0.0137 | 0.0759 | 0.0143 | 0.0385 | 0.0676 | 0.0539 | 0.0746 | 0.0327 | 1.6950 | 0.1397 | 1.553 | 3 |
| S2 | 1.2158 | 0.2059 | 0.2598 | 0.0893 | 0.1737 | 0.0312 | 0.0692 | 0.0510 | 0.0137 | 0.0759 | 0.1252 | 0.0385 | 0.0676 | 0.0539 | 0.0308 | 0.0351 | 2.3628 | 0.1737 | 2.1891 | 1 |
| S3 | 0.0548 | 0.2059 | 0.0148 | 0.0072 | 0.3120 | 0.0312 | 0.0692 | 0.0510 | 0.0137 | 0.0759 | 0.0143 | 0.0385 | 0.0676 | 0.0539 | 0.0253 | 0.0135 | 0.7367 | 0.3120 | 0.4247 | 5 |
| S4 | 0.0151 | 0.2059 | 0.0764 | 0.0072 | 0.3120 | 0.0312 | 0.0692 | 0.0510 | 0.0137 | 0.0759 | 0.0143 | 0.0385 | 0.0676 | 0.0539 | 0.0308 | 0.0135 | 0.7641 | 0.3120 | 0.4521 | 4 |
| S5 | 0.0106 | 0.2059 | 0.8038 | 0.4620 | 0.0045 | 0.0312 | 0.0692 | 0.0510 | 0.0137 | 0.0759 | 0.1648 | 0.0385 | 0.0676 | 0.0539 | 0.0801 | 0.0111 | 0.1391 | 0.0045 | 2.1346 | 2 |

*Table 10 : Weighted normalized matrix and Ranking using MOORA method*

From Table 9 and 10 it is observed that suppliers S4 and S5 (with a cumulative Qj or Sj of 80e100%) can be considered as the benchmarks for suppliersS1, S2, and S3, (which form the second group with a cumulative Qj or Sj of 20e80%) and this second group can be adjudged as an improvement target for suppliers S1 and S2 (cumulative Qj or Sj of 0e20%).

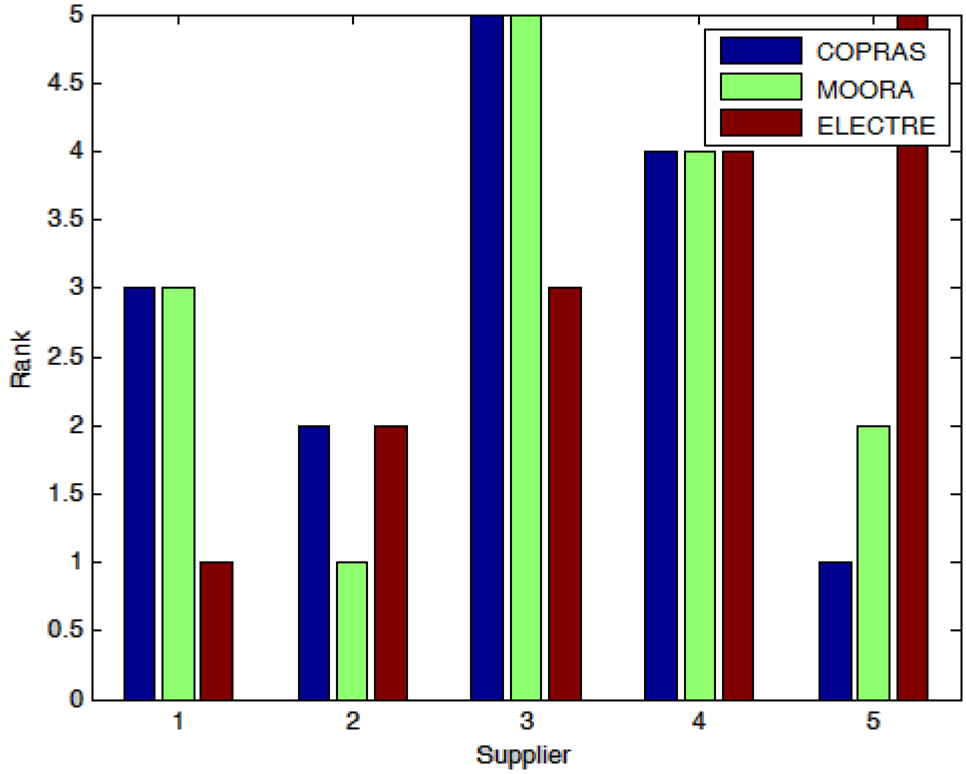


*Figure 2: The comparative ranking of supplier*

## 3. Conclusion

In view of today's severe competitive environment in the global market, whether in services the supplier selection criteria have to be redesigned first and foremost according to customer needs Then according to the company's objectives.

Ranking obtained from analysing complex structural models involving a causal relationship between complex factors of customers' requirement then identify the most important requirements of customers that allowed the establishment of an internal relations matrix (HOQ) between the needs of customers and the parameters of suppliers. Ranking obtained from determining correlation coefficient among suppliers criteria and features of customers' requirements indicated that the cost and delivery time are the more important for customers. This encourages companies to use suppliers that meet this requirement better than alternative suppliers do.

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