Multi attribute outranking approach for supplier selection

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Abstract

Multi attribute outranking approach has been widely used in supply chain management. Compromise ranking and Outranking method has been used extensively for solving the multi criteria decision problems. Elimination and Choice Translating Reality (Electre) and Preference Ranking Organization Method for Enrichment Evaluations (Promethe) are the most widely used outranking methods to solve multi-criteria decision problems. The above methods may be used to solve problems involving both conflicting qualitative and quantitative criteria. This work focuses on the application of improved outranking based method electre, for solving a real problem of supplier selection. A case study is done for selection of supplier for the spherical roller bearing for finding the rank of the alternatives. The need of this case study is to select the best possible supplier out of the available alternative suppliers.

1. Introduction

One major task of the purchasing department is supplier selection which includes the acquisition of required materials, services and equipment for all type of business organization. The increasing importance of supplier selection decision is forcing the organization to rethink their purchasing and evaluation strategies because a successful purchasing decision directly depends on selecting the best supplier to fulfill the strategies goals apart from the operational requirements of the organization. One of the important areas in purchasing research that has significant practical implication is supplier evaluation and selection. The decision of selecting the best supplier from a wide supplier base is an unstructured, complicated and time consuming task. The decision-making process involves evaluation of different alternative based on various criteria. [Chatterjee et al. 2011]. A general decision making process can be divided into the following steps : Define the problem, Determine requirements, Establish goals, Identify alternatives, Define criteria, Select a decision making tool, Evaluate alternatives against criteria and Validate solutions against problem statement.

Roy (1991) introduced the concept of *Elimination and Choice Expressing Reality (ELECTRE)* which evolved as ELECTRE I, ELECTRE II, ELECTRE III, ELECTRE IV, ELECTRE IS and ELECTRE TRI (ELECTRE Tree). This method consists of two sets of parameters: importance coefficient and the veto thresholds. Effect of Normalization Norms in Flexible manufacturing system selection using multi criteria decision making tool Promethe has been investigated by Chatterjee et al 2014.

Various research works have been done in the past on Multi criteria decision making, using outranking methods like Electre, Promethee, etc. In Electre method a pair wise comparison of alternatives in each attribute is done in order to determine partial binary relations denoting the strength of preference of one alternative over the other. Roodhooft et al. (1996) proposed an activity based costing approach for supplier selection and evaluation which allow computation of total cost caused by a supplier in an organization's production process, thereby increasing the objectivity in the selection process. Savadogo et al. (2006) applied Electre (Elimination and Choice Expressing the Reality) method which would provide a more precise selection of material for a particular application while producing a material selection decision matrix and criteria sensitivity analysis. Almeida et al. (2007) proposed a multi-criteria decision model for outsourcing supplier selection using contribution from utility theory associated with Electre method.
Chatterjee et al. (2011) attempted to solve the supplier selection problem using two most potential multi-criterion decision making approach and compare the relative performance for a giving organization environment. Electre and Vikor method are used to rank the alternative supplier for whom several requirement are consider simultaneously. Chatterjee et al. (2014) study on the application of a very popular Multi-Criteria Decision-Making (MCDM) tool, i.e. Elimination and Et Choice Translating Reality (ELECTRE) for solving an automated inspection device selection problem in a discrete manufacturing environment. Kumar et al. (2015) compared the different multi criteria decision making methods (MCDM) such as TOPSIS & VIKOR for the selection of alternative industrial welding machine. Both the method are aggregating function that represent closeness to the ideal solution.

2. ELECTRE METHOD

The ELECTRE (Elimination and Choice Translating Reality) method was first introduced in 1966 to overcome some deficiencies of popularly used MCDM tools to deal with ordinal attributes without the need for transforming them into cardinal values. ELECTRE is a well known MCDM method that has a history of successful real world applications for its robust ranking technique. It has been applied in various types of decision-making situations. The basic concept of the ELECTRE method is to deal with "outranking relations" by using pairwise comparisons among alternatives under each one of the criteria separately. In the ELECTRE approach, the concordance and dis-concordance indexes are used for outranking the supplier in choosing one alternative over the other alternative. In the first stage the opinion of experts and the study of outranking literature is used to recognize variables and effective criteria in supplier selection. The dominating criteria are extracted, which will be used in the evaluation. Thereafter, the lists of qualified suppliers are identified. The decision criteria identified are then approved by decision-making team, who assigns the weights on them. Finally the calculated weights of the criteria are approved by decision making team and the ranks are determined, using ELECTRE method. Based on the average ranking, then that alternative is selected which has best average rank. (Chatterjee et al 2014)

The basic concept of the ELECTRE method is to deal with "outranking relations” by using pairwise comparisons among alternatives under each one of the criteria separately.

- Concordance-C (i, j): for any two alternative i and j, this is a weighted measure of the number of criteria for which i is preferred over alternative j.
- Discordance-D (I, j): It handles the set of criteria for which i is not preferred over j and gives a measure of the degree of “discomfort or discontent” as a result of preferring i to j.

The ELECTRE II method is basically devoted to the ranking problems and the obtained results are in the form of a total ranking preorder among the non-dominated alternatives. The procedural steps as involved in ELECTRE II method are presented below

- In the first step determine the objective and to identify the attribute value for each alternative.
- Then develop the initial decision matrix, X

$$X = [X_{ij}]_{m\times n} = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix} \quad (1)$$

where x_{ij} is the performance value of i^{th} alternative on j^{th} criterion, *m* is the number of alternatives compared and *n* is the number of criteria.

- Then using the above matrix to develop the normalized decision matrix using the equation (2) The purpose of normalization is to calculation of weight of different attribute and obtain dimensionless values of different criteria to make them comparable with each other. Several normalization techniques have been proposed by the past researchers to transform the different units into dimensionless values. In ELECTRE based methods, vector normalization is generally adopted in which each element of the quantified decision-making matrix is divided by its own Euclidian norm. The norm represents the square root of the addition of element value squares, according to each criterion.[10]

$$G=[g_{ij}]_{mxn} = X_{ij}/[\sum_{i=1}^{m} x_{ij}^2]^{1/2} \quad 1\le i\le m, \quad 1\le j\le n \quad (2)$$

Where $x_{ij} = \begin{cases} x_{ij} & \text{for beneficial attribute} \\ \frac{1}{x_{ij}} & \text{for non} - \text{beneficial attribute} \end{cases}$

- Depending upon the relative importance of different attributes obtain weight for each attribute which can be calculated given as

$$w_j = v_j / \sum_{i=1}^{m} v_j \ \& \ \sum_{j=1}^{m} w_j = 1$$

(3)

Where v_j is the variance of each attribute which can be calculated as

$$V_j = (1/n) \sum_{i=1}^{n} \left(g_{ij} - g_{ijmean}\right)^2 \qquad (4)$$

- Determine the weighted normalization decision matrix Y

$$Y = [y_{ij}]_{m\times n} = w_j \times g_{ij} \quad (i=1,2\ldots.m;,j=1,2\ldots.n) \qquad (5)$$

Where g_{ij} is the normalized performance value of i^{th} alternative on j^{th} criterion and w_j is the weight of j^{th} criterion.

- Determine the concordance index c(i,j) for every pair of the alternatives Ai and A_j

$$c(i,j) = \sum w_k \ \ i,j=1,2..m, i\neq j \qquad (6)$$

$$g_k(i) \geq g_k(j)$$

where gk(i) and gk(j) are the normalized measures of performance of the i^{th} and j^{th} alternative respectively with respect to the j^{th} criterion in the decision matrix. Thus, for an ordered pair of alternatives (A_i, A_j), the concordance index c(i,j) is the sum of all the weights for those criteria where the performance score of Ai is at least as that of Aj. Clearly, the concordance index lies between 0 and 1.

- The discordance matrix D expresses the degree that a certain alternative A_i is worse than a competing alternative A_j. The elements d_{ij} of the discordance matrix are defined as follows:

$$d(i,j)=0 \text{ if } y_k(A_i) \geq y_k(A_j) \qquad \text{for all } k$$

$$d(i,j) = \frac{(\max(y_k(j) - y_k(i))}{(\max|(y_k(j) - y_k(i)|)} \qquad \text{otherwise} \qquad (7)$$

- Compute pure concordance and pure disconcordance indices as follow.

Pure Concordance index $C_j = \sum_{k=1}^{n} c(j,k) - \sum_{j=1}^{n} c(k,j) \quad (j\neq k)$ (8)

Pure Disconcordance index $D_j = \sum_{k=1}^{n} d(j,k) - \sum_{j=1}^{n} d(k,j) \quad (j\neq k)$ (9)

Once two indices are estimated, two ranking are obtained on the basis of these two indices and an average ranking is determined from these two ranking. Based on the average ranking, then that alternative is selected which has best average rank.

3. Case Study

In order to show the application of ELECTRE method, the supplier selection problem for the Spherical Roller Bearing is considered. The Spherical Roller Bearing (Bearing no-22326) considered has a Bore diameter, Outside diameter, width and radius of 130mm,280mm,93mm and 4mm respectively. The data used for supplier selection for spherical roller bearing shown in Table 6.1 has been taken from government workshop located at Jhansi. For this spherical roller bearing there are four alternative suppliers with different criteria. The suppliers are NBC, TIMKEN, FAG and SKF indicated by S1, S2, S3, S4 as per academic interest only. The assumptions for supplier selection are that the delivery time, performance, service and price are similar in nature. Hence the criteria considered for selection of supplier are dynamic load (D), static load (S), mass (M) and reference speed (R). Among these four criteria, D, S, R are beneficial attribute where higher value is desirable and M is non-beneficial attribute requiring smaller value.

Table 1. Quantitative data for Supplier selection

Suppliers	Basic Dynamic Loading Rating(KN)	Basic Static Load Rating(KN)	Mass (Kg)	Reference Speed (rpm)
S1	1043	1343.6	26.8	1800
S2	1270	952	28.2	1900
S3	1250	1370	28	2400
S4	1176	1320	29	2400

The normalized decision matrix for calculating weight criteria shown in Table 2 calculated by using equation (2) according to beneficial and non beneficial criteria

$$G=[g_{ij}]_{mxn} = X_{ij}/[\sum_{i=1}^{m} x_{ij}^2]^{½} \qquad 1\leq i\leq m \qquad 1\leq j\leq n \qquad (2)$$

$$\text{Where } x_{ij}=\begin{cases} x_{ij} \text{ for beneficial attribute} \\ \frac{1}{x_{ij}} \text{ for non}-\text{beneficial attribute} \end{cases}$$

For Supplier S1 beneficial attribute D, S & R

$X_{ij}^2=1043^2+1270^2+1250^2+1176^2=5646225$ $\qquad g_{11}=1043/[5646225]^{½}=0.4389$

Similarly for $X_{ij}^2= 6330864.96$, $\quad g_{21}= 0.5339$

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For X_{ij}^2=1837000 , g_{41}=0.4199

For Supplier S1 non-beneficial attribute M

$1/X_{ij}^2 = 5.1144\times10^{-3}$ $g_{31} = 0.5224$

Table 2. Normalized decision matrix for selection of bearing

Supplier	D	S	M	R
S1	0.4389	0.5339	0.5224	0.4199
S2	0.5344	0.3783	0.4957	0.4433
S3	0.5260	0.5444	0.5001	0.5599
S4	0.4949	0.5246	0.4817	0.5599

The variance of different attribute shown in Table 3 calculated by using equation (4)

$$V_j=(1/n)[\sum_{i=1}^{n} (g_j - g_{ijmean})^2] \quad (4)$$

(4)

For Dynamic Loading

$V_1= [(0.4389-0.49855)^2+ (0.5344-0.49855)^2+ (0.5260-0.49855)^2+ (0.4949-0.49855)^2]/4=0.0014$

Table 3. Variance of different attribute

Variance	D	S	M	R
V_j	0.0014	0.0046	0.0002	0.0042

The weight of different attribute shown in Table 4 calculated by using equation (3)

$$w_j=v_j/\sum_{i=1}^{m} v_j \& \sum_{j=1}^{m} w_j = 1 \quad (3)$$

w_1=0.0014/0.0104=0.14

Similarly $w_2 = 0.44$, $w_3 = 0.02$, $w_4 = 0.40$

Table 4. Weight of different attributes

Weight	D	S	M	R
W_j	0.14	0.44	0.02	0.40

The supplier selection problem is solved by using ELECTRE- II

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The normalized decision matrix of ELECTRE Method shown in Table 5 calculated by using equation 2 according to beneficial and non beneficial criteria

Table 5. Normalized decision matrix for selection of bearing

Suppliers	D	S	M	R
S1	0.4389	0.5339	0.5224	0.4199
S2	0.5344	0.3783	0.4957	0.4433
S3	0.5260	0.5444	0.5001	0.5599
S4	0.4949	0.5246	0.4817	0.5599

Table 6. Priority Weights

Weights	0.14	0.44	0.02	0.40

Weighted normalized matrix shown in Table 7 calculated by using equation (5)

$$Y=[y_{ij}]_{m\times n}=w_j\times g_{ij} \qquad (i=1,2\ldots m;,j=1,2\ldots n)$$

(5)

Weight criteria for Supplier S1

$y_{11}=0.14\times0.4389=0.0614$

Similarly $y_{12} = 0.2349$, $y_{13} = 0.0104$, $y_{14} = 0.1679$

Table 7. Weighted normalized matrix

Supplier	D	S	M	R
S1	0.0614	0.2349	0.0104	0.1679
S2	0.0748	0.1664	0.0099	0.1773
S3	0.0736	0.2395	0.0100	0.2239
S4	0.0692	0.2308	0.0096	0.2239

Concordance matrix shown in Table 8 calculated by using equation (6) While calculating the concordance index, if there are ties between the alternatives, they would receive one half of the criteria weights

$$c(i,j)=\sum w_k \quad i,j=1,2..m, i\neq j \qquad (6)$$

$$g_k(i) \geq g_k(j)$$

comparing normalized matrix of S1 with S2 then $g_{12}>g_{21}$ & $g_{13}>g_{23}$

the corresponding weight is 0.44 and 0.02

c(1,2)=0.44+0.02=0.46

comparing normalized matrix of S1 with S3 then $g_{13}>g_{33}$

the corresponding weight is 0.02

c(1,3)=0.02

comparing normalized matrix of S1 with S4 then $g_{12}>g_{42}$ & $g_{13}>g_{43}$

the corresponding weight is 0.44 & 0.02

c(1,4)=0.44+0.02=0.46

Table 8. Concordance matrix

Supplier	S1	S2	S3	S4
S1	-	0.46	0.02	0.46
S2	0.54	-	0.14	0.16
S3	0.98	0.86	-	0.80
S4	0.54	0.84	0.20	-

Discordance matrix shown in Table 9 calculated by using equation (7)

$$d(i,j)=0 \text{ if } y_k(A_i)\geq y_k(A_j) \quad \text{for all } k$$

$$d(i,j)=\frac{(\max(y_k(j)-y_k(i))}{(\max|(y_k(j)-y_k(i)|)} \tag{7}$$

d(1,2) = (0.0748-0.0614)/|0.1664-0.2349|=0.1956

Similarly d(1,3) = 1, d(1,4) = 1

Table 9. Dis-concordance matrix

Supplier	S1	S2	S3	S4
S1	-	0.1956	1	1
S2	1	-	1	1
S3	0.0071	0.0164	-	0
S4	0.0737	0.0869	1	-

Pure Concordance index and Pure Disconcordance index shown in Table 10 calculated by using equation (8) and (9)

Pure concordance index $C_j=\sum_{k=1}^{n} c(j,k)-\sum_{j=1}^{n} c(k,j)$

(8)

Pure dis-concordance index $D_j=\sum_{k=1}^{n} d(j,k)-\sum_{j=1}^{n} d(k,j)$ (9)

C_1 = (0.46+0.02+0.46)-(0.54+0.98+0.54) = -1.12

D_1 = (0.1895+1+1)-(1+0.0071+0.0737) = 1.1087

4. RESULT

Table 10. Ranking of supplier

Supplier	Pure Concordance index	Intial Ranking	Pure Disconcordance index	Intial ranking	Average ranking	Final rank
S1	-1.12	3	1.1087	4	3.5	3
S2	-1.32	4	2.7104	3	3.5	4
S3	2.28	1	-2.9765	1	1	1
S4	0.16	2	-0.8394	2	2	2

The pure concordance and pure discordance indices for the supplier are computed using Equations (8) and (9) respectively, as exhibited in Table 10. From this table, the ranking of the supplier is observed as S3>S4>S1>S2. S3 is the best supplier, S4 emerges out as the second best choice and S2 is the worst device.

5. Conclusion

The present study explores the use of Electre methods in solving a supplier selection problem and the results obtained can be valuable to the decision maker in framing the supplier selection strategies. MCDM methodology applied for selection of supplier for spherical roller bearing. With the help of normalized decision matrix we estimate criteria weight so that human judgment can be avoided by assigning weights to different attributes. The results show that supplier 3 is best in term of ranking index.

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