Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 12; July-September, 2015 pp. 8-13

http://www.krishisanskriti.org/jmsme.html

A Comprehensive VIKOR and TOPSIS Method for Supplier Selection in Supply Chain Management: A Case Study

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Abstract—*In today's fierce competitive environment characterized by thin profit margins, high consumer expectations for quality products and short lead-times, companies are forced to take the advantage of any opportunity to optimize their business processes. To reach this aim, academics and practitioners have come to the same conclusion: for a company to remain competitive, it has to work with its supply chain partners to improve the chain's total performance. The nature of supplier selection is a complex multi-criteria problem including both quantitative and qualitative factors which may be in conflict and may also be uncertain. The VIKOR method was developed to solve multiple criteria decision making (MCDM) problems with conflicting and non-commensurable (different units) criteria, assuming that compromising is acceptable for conflict resolution, the decision maker wants a solution that is the closest to the ideal, and the alternatives are evaluated according to all established criteria. The objective of this work is to develop decision support system to assist the decision-makers in selection and evaluation of different suppliers by VIKOR and TOPSIS method. A comparative analysis of results by VIKOR and TOPSIS method is presented. A real life case of a manufacturing company of North India is illustrated to demonstrate the steps of the decision support system. Present approach also enables the purchasing managers to better understand the complex relationships of the relevant attributes in the decision making environment and subsequently improve the reliability of the decision making process.*

Keywords: *VIKOR, TOPSIS, Supply Chain Management, Vendors.*

1. INTRODUCTION

Supply Chain Management and its demands on the firms in the value chain have led to the operational integration of suppliers within the supply chain [1]. Selecting an appropriate supplier (or vendor) among different suppliers is a critical issue for top management. In industries that are concerned with large scale production the raw materials and component parts can equal up to 70% product cost. In such circumstances the purchasing department can play a key role in cost reduction, and supplier selection is one of the most important functions of purchasing management [4]. There-fore, using an appropriate method for this purpose is a crucial issue; supplier selection has been shown to be a multiple criteria decision making (MCDM) problem [5]. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was first developed by Yoon and Hwang. In supply chains; Co-ordination between a manufacturer and suppliers is typically a difficult and important link in the channel of distribution. Once a supplier becomes part of a well managed and established supply chain, this relationship will have a lasting effect on the competitiveness of the entire supply chain. Because of this, supplier selection problem has become one of the most important issues for establishing an effective supply chain system. Besides, selection of suppliers is a complicated process by the facts that numerous criteria must be considered in the decision making process [7].

Supplier selection process is one of the most significant variables, which has a direct impact on the performance of an organization. As the organization becomes more and more dependent on their suppliers, the direct and indirect consequences of poor decision making will become more critical. The nature of this decision is usually complex and unstructured. On the other hand, supplier selection decision-making problem involves trade-offs among multiple criteria that involve both quantitative and qualitative factors, which may also be conflicting. In this paper, with the help of going over expertise of experts and their relevant specialized literature, we can recognize variables and effective criteria in supplier selection, with regards to this point that, considering all criteria for supplier selection is impossible, the main and important criteria have been extracted by expert judgment. Thereafter, we will evaluate and determine weight of each supplier and finally, by implementing TOPSIS method, the rank of each supplier is determined. TOPSIS has been a favourable technique for solving multi criteria problems. This is mainly for two reasons, 1) its concept is reasonable and easy to understand, and 2) in comparison with other MCDM methods, like AHP, it requires less computational efforts, and therefore can be applied easily. TOPSIS is based on the concept that the optimal alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS). TOP-SIS method are powerful decision making processes which help people to set priorities on parameters that are to be considered by reducing complex decision to a series of one-to-one comparisons, thereby synthesizing the result [2]. VIKOR (Vlse Kriterijumska Optimizacija Kompromisno Resenje), also known as Compromise Ranking method is a possible solution that is closest to the ideal solution and the meaning of compromise is agreement generated by mutual concession. The VIKOR method is an effective tool in multi-criteria decision making, particularly in situations where the decision maker is not able, or does not know to express his/her preference at the beginning of system design. The VIKOR method is extended with a stability analysis determining the weight stability intervals and with trade-offs analysis.

VIKOR method as mentioned before has some advantages:

(a) VIKOR method is ranking alternatives by closeness to PIS and farness from NIS.
(b) The best alternative is preferred by maximizing utility group and minimizing regret group.

2. PROPOSED METHODOLOGY

(I)VIKOR METHOD

The proposed methodology for supplier selection problem composed of VIKOR Method the MCDM method is very popular technique widely applied for determining the best solution among several alternatives having multiple attributes or alternatives [29]. A MCDM problem can be presented by a decision matrix as follows:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ \vdots \\ A_m \end{array} \begin{pmatrix} Cx_1 & Cx_2 & \cdots & Cx_n \\ X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & & \vdots \\ \vdots & \vdots & & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{pmatrix}$$

Here, i A represents ith alternative, i =1, 2,........., m; j Cx represents the jth criterion, j =1, 2,.........,n ; and xij is the individual performance of an alternative. The procedures for evaluating the best solution to an MADM problem include computing the utilities of alternatives and ranking these alternatives. The alternative solution with the highest utility is considered to be the optimal solution.

The following steps are involved in VIKOR method

Step 1: Representation of normalized decision matrix

The normalized decision matrix can be expressed as follows:

$$F=[f_{ij}]_{m\times n} \quad (1)$$

Here, fij $= \frac{xij}{\sqrt{\sum_{i=1}^{m} x2ij}}$, where I = 1,2,…..and X_{ij} is the performance of alternative A_i with respect to the jth criterion.

Step 2: Determination of ideal and negative-ideal solutions

The ideal solution $A*$ and the negative ideal solution $A-$ is determined as follows:

$$A^* = \{(max f_{ij} | j \in J) \; or \; (min f_{ij} | j \in J'), i = 1,2, \ldots\ldots, m\} = \{f_1^*, f_2^*, \ldots f_j^*, \ldots f_n^*\} \quad (2)$$

$$A^- = \{(min f_{ij} | j \in J) \; or \; (max f_{ij} | j \in J'), i = 1,2, \ldots\ldots, m\} = \{f_1^-, f_2^-, \ldots f_j^-, \ldots f_n^-\} \quad (3)$$

Where,

$$J = \{j = 1,2, \ldots, n | f_{ij}, if \; desire \; response \; is \; large\}$$

$$J' = \{j = 1,2, \ldots, n | f_{ij}, if \; desire \; response \; is \; small\}$$

Step 3: Calculation of utility measure and regret measure

The utility measure and the regret measure for each alternative are given as:

$$S_i = \sum_{j=1}^{n} \frac{w_i(f_j^* - f_{ij})}{f_j^* - f_j^-} \quad (4)$$

$$R_i = \max\left[\frac{w_i(f_j^* - f_{ij})}{f_j^* - f_j^-}\right] \quad (5)$$

Where, Si and Ri , represent the utility measure and the regret measure, respectively, and wj is the weight of the jth criterion.

Step 4: Computation of VIKOR index

The VIKOR index can be expressed as follows:

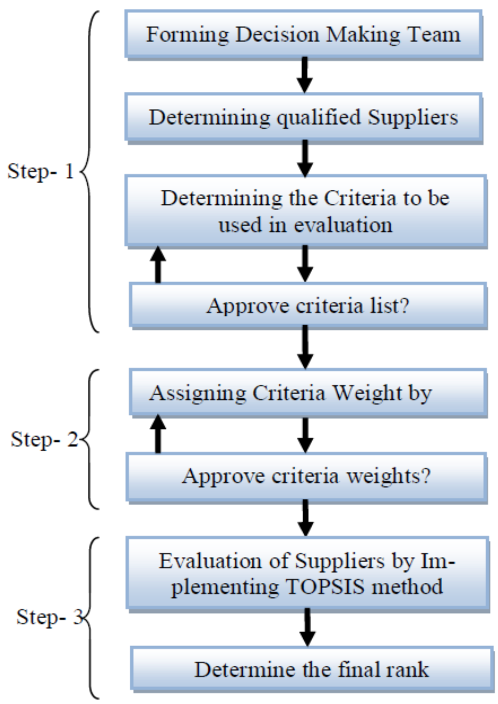
$$Q_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1-v)\left[\frac{R_i - R^*}{R^- - R^*}\right] \quad (6)$$

Where, Qi, represents the ith alternative VIKOR value, i =1, 2,........ , m; $S^+ = min_i S_i$,

$$S^- = max_i S_i, \; R^+ = min_i R_i, \; R^- = max_i R_i,$$

Where v is the weight of the maximum group utility (usually it is to be set to 0.5). The alternative have smallest VIKOR determined to be the best solution.

(II) TOPSIS METHOD
The proposed methodology for supplier selection problem, composed of TOPSIS method, consists of three Steps [3]:
(1) Identify the criteria to be used in the model.
(2) Weigh the criteria by using expert views.
(3) Evaluation of alternatives with TOPSIS and determination of the final rank.



The TOPSIS method is expressed in a succession of six steps as follows:

Step 1: Calculate the normalized decision matrix. The normalized value r_{ij} is calculated as:

$$r_{ij} = x_{ij} \sqrt{\sum_{i-1}^{m} x_{ij}^{2}} \quad \text{i =1, 2...m and j = 1, 2, ..., n.} \qquad (1)$$

Step 2: Calculate the weighted normalized decision matrix. The weighted normalized value v_{ij} is calculated as follows:

$$v_{ij} = r_{ij} \times w_{j} \quad \text{where i =1, 2,., m and j = 1, 2., n.} \qquad (2)$$

Where, w_j is the weight of the j^{th} criterion or attribute and $\sum_{j=1}^{n} w_j = 1$.

Step 3: Determine the ideal (A^*) and negative ideal (A^-) solutions.

$$A^* = \{(\max_i v_{ij} \mid j \in C_b), (\min_i v_{ij} \mid j \in C_c)\} = \{v_j^* \mid j = 1,2,...,m\} \qquad (3)$$

$$A^- = \{(\min_i v_{ij} \mid j \in C_b), (\max_i v_{ij} \mid j \in C_c)\} = \{v_j^- \mid j = 1,2,...,m\} \qquad (4)$$

Step 4: Calculate the separation measures using the m-dimensional Euclidean distance. The separation measures of each alternative from the positive ideal solution and the negative ideal solution, respectively, are as follows:

$$S_i^* = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^*)^2}, \; j = 1,2,...,m \qquad (5)$$

$$S_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2}, \; j = 1,2,...,m \qquad (6)$$

Step 5: Calculate the relative closeness to the ideal solution. The relative closeness of the alternative A_i with respect to A^* is defined as follows:

$$RC_i^* = \frac{S_i^-}{S_i^* + S_i^-}, \; i = 1,2,...,m \qquad (7)$$

Step 6: Rank the preference order.

3. CASE STUDY

A case study of an automobile company has been developed. The automobile industry wants to choose their best suppliers. Based on proposed methodology as following:

Use of a MCDM approach for selection of suppliers in an Auto Industry

In selection of a supplier various criterions are to taken into account, so we require a MCDM approach to determine which supplier will meet our requirements best according to the criteria values set by us. Here we encounter various issues related to supplier selection in an Case Industry. The various criteria involved in decision making process are:

(C1) PPM (Part per million) customers: It measures the number of parts returned per million by the customer.

(C2) Quality: The quality of goods provided by the suppliers.

(C3) Price/ cost: The cost which the enterprise pays for the goods.

(C4) Standardization: The extent of pre-set standards followed by the company during the manufacturing process.

(C5) Service: The support and service provided by a supplier after sales of the product.

(C6) Flexibility: The extent to which the supplier is able to cope up with the change in demand of the customer.

(C7) On time delivery: The time taken by the supplier to supply the parts. Here the criteria C1 and C3 are non-beneficial and the attributes pertaining to other criteria are beneficial.

Here the criteria C1 and C3 are non-beneficial and the attributes pertaining to other criteria are beneficial.

The weight calculated by AHP method from the following table 1 (as shown below) of weight attributes are {W1, W2, W3, W4, W5, W6, W7} = {0.167707, 0.124385, 0.318955, 0.185164, 0.099591, 0.065518, 0.038681}.

Table 1: Weight attributes for supplier selection of an Auto Industry

Alternative	C1	C2	C3	C4	C5	C6	C7
C1	1	3	1/3	1/2	4	2	3
C2	1/3	1	1/3	1/3	4	5	2
C3	3	3	1	4	2	3	5
C4	2	3	1/4	1	2	2	4
C5	1/4	1/4	1/2	1/2	1	4	5
C6	1/2	1/5	1/3	1/2	1/4	1	4
C7	1/3	1/2	1/5	1/4	1/5	1/4	1

Table 2: Objective data of attributes for suppliers selection

Alternative	C1	C2	C3	C4	C5	C6	C7
A	50	15	20	24	13	10	2
B	45	18	18	30	10	20	4
C	48	12	15	26	20	30	1
D	60	28	16	28	14	40	3

4. EVALUATION OF PROBLEM USING VIKOR METHOD

All the steps mentioned previously are followed for the selection of suppliers of an Auto industry. The further calculation is shown below in table no 3.

Step 1. The value of **(f_j^*-f_{ij})** is calculating as:

Table 3: (f_j^*-f_{ij}) value

Alternative	C1	C2	C3	C4	C5	C6	C7
A	10	13	0	6	7	30	2
B	15	10	2	0	10	20	0
C	12	16	5	4	0	10	3
D	0	0	4	2	6	0	1

Step 2. The value of **(f_j^*-f_j^-)** is calculated in table no. 4

Table4: (f_j^*-f_j^-) value

ALTERNATIVE	C1	C2	C3	C4	C5	C6	C7
A	15	16	5	6	10	30	3
B	15	16	5	6	10	30	3
C	15	16	5	6	10	30	3
D	15	16	5	6	10	30	3

Table 5: Normalized matrix

Alt.	C1	C2	C3	C4	C5	C6	C7
A	0.111	0.101	0	0.185	0.069	0.065	0.025
B	0.167	0.077	0.127	0	0.099	0.043	0
C	0.134	0.124	0.318	0.123	0	0.021	0.038
D	0	0	0.255	0.061	0.059	0	0.012

Step 3. The value of $\frac{w_i(f_j^* - f_{ij})}{f_j^* - f_j^-}$ is calculated in table no .5

Step 4. Calculation of utility measure and regret measure by using in table 6.

$$S_i = \sum_{j=1}^{n} \frac{w_i(f_j^* - f_{ij})}{f_j^* - f_j^-} \quad (1)$$

$$R_i = \max\left[\frac{w_i(f_j^* - f_{ij})}{f_j^* - f_j^-}\right] \quad (2)$$

Where, *Si* and *Ri* , represent the utility measure and the regret measure, respectively, and *wj* are the weight of the *jth* criterion.

Table 7: Value of Utility Measure and Regret Measure

ALTERNATIVE	UTILITY MEASURE Si	REGRET MEASURE Ri
A	0.55905	0.185164
B	0.516299	0.167707
C	0.761468	0.318955
D	0.389533	0.255164

Step 5 computation of VIKOR index by using

The VIKOR index can be expressed as follows:

$$Q_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1\text{-}v)\left[\frac{R_i - R^*}{R^- - R^*}\right]$$

Where, *Qi*, represents the *ith* alternative

VIKOR value, *i* =1, 2,........ , *m*;

$$S^+ = min_i S_i , \quad S^- = max_i S_i,$$

$$R^+ = min_i R_i, \quad R^- = max_i R_i,$$

Where v is the weight of the maximum group utility (usually it is to be set to 0.5) the alternative has smallest VIKOR determined to be the best solution. As shown in table 8.

Table 8: VIKOR index

Alt.	Si	Ri	Qi	RANK
A	0.5590	0.1851	0.2855	2
B	0.5162	0.1677	0.1704	1
C	0.7614	0.3189	1	4
D	0.3895	0.2551	0.2891	3

Table 8 clearly shows that 'B' is the best alternative available for supplier selection in a Case Industry by this process.

5. EVALUATION OF PROBLEM USING TOPSIS METHOD

The following data is given by the company for the selection of best suppliers in Case -industry. As shown above in table 2.

Alt.	C1	C2	C3	C4	C5	C6	C7
A	50	15	20	24	13	10	2
B	45	18	18	30	10	20	4
C	48	12	15	26	20	30	1
D	60	28	16	28	14	40	3

Now weighted matrix is used to calculate normalized matrix by using above table. Weighted matrix are shown in table1.The calculated weight attributes are {W1, W2, W3, W4, W5, W6, W7} = { 0.167707, 0.124385, 0.318955, 0.185164, 0.099591, 0.065518, 0.038681}.

The decision matrix obtained by using:

$$r_{ij} = x_{ij}\sqrt{\sum_{i-1}^{m} x_{ij}^2} \quad \text{i =1, 2, ..., m and j = 1, 2, ..., n.}$$

Table 9: Decision matrix

Alt.	C1	C2	C3	C4	C5	C6	C7
A	0.489	0.3903	0.576	0.442	0.4420	0.182	0.365
B	0.440	0.4683	0.518	0.553	0.3400	0.365	0.730
C	0.470	0.3122	0.432	0.479	0.6800	0.547	0.182
D	0.587	0.7285	0.460	0.516	0.4760	0.730	0.547

Now multiply with decision matrix with weighted attributes we get normalized matrix.

Table 10: Normalized matrix

ALTERNATIVE	C1	C2	C3	C4	C5	C6	C7
A	0.0821	0.048548	0.183766	0.082014	0.04402	0.011962	0.014124
B	0.0739	0.058257	0.16539	0.102518	0.033862	0.023924	0.028248
C	0.078826	0.038838	0.137825	0.088849	0.067724	0.035886	0.007062
D	0.098533	0.090622	0.147013	0.095683	0.047407	0.047848	0.021186

Now the best ideal solution is showed by red colour in table 10V_1= 0.098533, V_2 = 0.090622, V_3 = 0.183766, V_4 = 0.102518, V_5 =0.067724, V_6= 0.047848, V_7= 0.028248

The negative ideal solution are showed by blue colour in table 20 are as; V_1= 0.0739 V_2 = 0.038838, V_3 = 0.137825, V_4 = 0.082014, V_5 = 0.033862, V_6 =0.011962, V_7= 0.007062

The Euclidean separation distance between the positive ideal solution (Si^+) and the Negative-ideal solution (Si^-) for each alternative is calculated as :

$$S_i^* = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^*)^2}, \; j = 1,2,...,m \quad (1)$$

$$S_i^- = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^-)^2}, \; j = 1,2,...,m \quad (2)$$

Table 11: Value of PIS and NIS

Alternative	(Si+)	(Si-)
A	0.067153	0.049248
B	0.060918	0.04636
C	0.077197	0.042308
D	0.04313	0.072322

The relative closeness to the ideal solution of each alternative is calculated as:

$$C_i = \left(s_i^- / s_i^- + s_i^+ \right)$$

The relative closeness to the ideal solution of each alternative is calculated in table12:

Table 12: Relative closeness values

Alt.	Rel. closeness	Value	Rank
A	C1	0.423091	3
B	C2	0.43215	2
C	C3	0.354026	4
D	C4	0.626425	1

Table12. Clearly shows that 'D 'is the best alternative available for supplier selection in a Case Industry by this process.

6. RESULT & DISCUSSION

Present work explains the two MCDM methods namely VIKOR and TOPSIS clearly and the solution of real life case study and gives a clear cut idea on the diverse applications of these two MCDM methods. Author have different alternative of problem based on selection of suppliers for a case industry. According to the VIKOR method alternative are ranked as **B > A > D > C** in the decreasing order of preference as shown above in table no 8.When TOPSIS method are apply on same problem author find that alternative are ranked as **D > B > A > C** and 'D' is the best alternate which rank is 1 as shown above in table no.12. Both methods follow different algorithm so the results obtained by both algorithms are slightly different.

7. CONCLUSIONS

For an automobile industry it is necessary to maintain the good coordination between management and supplier in terms of material quality, quantity, cost, and time. The work presented in this paper demonstrates the MCDM approaches in supplier evaluation.

VIKOR methods gives solution on the basis of value of Q_I .a small value of Q_I will increase the rank. For the supplier selection problem solved by VIKOR Method we get different value of Q_I for different alternate. These value of Q_i are: 0.285594, 0.170414, 1, 0.289117 for alternate A, B, C,D . So the best alternate is B because value of Q_I is small for it. Similarly, again the same problem was observed by a TOPSIS method. TOPSIS method gives rank according to the relative closeness of the attributes. For this problem relative closeness values for different attributes are:

C_1 = 0.423091, C_2= 0.43215, C_3=0.354026, C_4= 0.626425. In the above value of relative closeness higher value is **0.626425** among all. So rank of the alternate 4 is 'one' according to TOPSIS method.

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