Kano-based VIKOR Decision model for Supplier Selection – A Case Study

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Abstract – *Methodological approach for supplier selection gained importance in the recent times as the most of the firms have been spending considerable amount from their revenue on purchasing raw materials to meet their customers 'expectations . In fact, various qualitative and quantitative conflicting factors are involved in supplier selection problem. As the decision makers do not have sufficient, precise and exact information about the suppliers against these factors, the supplier selection problem becomes more difficult. In order to address the difficulty involved in the supplier selection problem, a decision model has been developed in this paper by using Kano model analysis and VIKOR (*technique for order preference by similarity to ideal solution*) techniques. The VIKOR resolves the uncertainty while selecting the best supplier among the suppliers of a firm. Kano model provides the weightages for the supplier selection attributes while implementing VIKOR. In order to demonstrate the proposed decision model, a case study in a manufacturing company is also presented in this paper.*

Keywords − ***Supplier selection, Kano technique, VIKOR.***

I. Introduction

In the present competitive market environment supplier selection is a key strategic decision in supply chain of any manufacturing firm. The decision makers in earlier days primarily considered price as a major factor while selecting a supplier because their main priority was the cost reduction. But in the present days the firms need to direct their attention towards the simultaneous consideration of supplier' quality, price, customer service, capability etc to achieve competitive advantage in the market. As the manufacturers have to purchase raw material from the suppliers, they are the customers and their satisfaction is the prime consideration. Therefore the need for supplier selection stems from the need to increase customer satisfaction (Ghorbani et al., 2013). The selection of right suppliers plays a key role in manufacturing firms because it significantly influences on its customers.

The supplier selection is a multi-criteria decision making problem as it is influenced by multiple criteria, which may be both qualitative as well as quantitative. In order to obtain solution for supplier selection problem, several decision models have been developed by the past researchers with the help of simple weighted techniques to advanced mathematical programming methods. The linear weighting model, categorical model, weighted point model, total cost of ownership model, artificial neural network model and principal component analysis models are widely used to solve supplier selection problems with only quantitative information. It is observed from the literature that there has been little work in the area of application of multi-criteria decision making methods in solving the supplier selection problems (Chatterjee et al., 2011). The researchers are currently focusing on developing hybrid methodologies or integrated methodologies to provide effective solution for supplier selection problem (Durga Prasad et al., 2016). Pal et al., (2013) reviewed and analysed the literature thoroughly and addressed the issues of selection criteria and methods. They concluded that further attention is needed on the part of developing supplier selection methods by harmonizing the combination of qualitative and quantitative criteria. Sevkli et al., (2008) proposed Analytic hierarchy process - weighted fuzzy linear programming (AHP-FLP) model for supplier selection. Wu (2009) presented a hybrid decision model using data envelopment analysis (DEA), decision trees (DT) and neural networks (NNs) to assess the performance of the suppliers. Elanchezhian et al., (2010) made an attempt to select the best vendor by using ANP and TOPSIS. Haldar et al., (2012) developed a hybrid MCDM model by using AHP-QFD methodology for resilient supplier selection. Durga Prasad et al., (2012) employed super efficiency and cross efficiency methods of Data Envelopment Analysis to establish suppliers' performance- efficiency score grid, which assists the purchases managers to select best supplier. Kassaee et al. (2013) proposed an integrated hybrid MCDM model using Fuzzy ANP and Fuzzy TOPSIS to determine the weights of sub-criteria and attain ranking of the vendors. Asadabadi (2014) developed a hybrid QFD-based approach to address supplier selection problem in product improvement process. Djordjevic et al. (2014) proposed a fuzzy MCDM approach by using fuzzy TOPSIS with a view to rank the artificial hip prosthesis suppliers. Siadat and

Maleki (2015) adopted TOPSIS method to prioritize the suppliers from the view point of green supply chain criteria. In recent past, many researchers have used TOPSIS andVIKOR methods for decision making of supplier selection problem. Use of these two methods can help for best supplier selection on the basis of different criteria while considering their relative importance (Rajiv and Darshana, 2014). As VIKOR has much advantage over TOPSIS under group decision making environment (Liu, 2016), in the present work, an attempt has been made to apply VIKOR method for developing the proposed decision model to address supplier selection problem. In order to categorize the attributes for supplier selection and to obtain their weightages, Kano technique has been employed in the proposed model. The over view of Kano and VIKOR techniques are discussed briefly in the following paragraphs.

A. Kano Technique

Kano technique was proposed by the Japanese professor Noriaki Kano and his colleagues in the 1980s. The technique is intended to categorize the attributes of a product or service, based on how well they are able to satisfy customers' needs (Shahin, 2004). In practice, Kano model can be classified the attributes into the following five categories (Ghorbani et al., 2013).

- *Must-be attributes (M)*: These are attributes that often are unnoticed by customers and sufficiency of them will not result more satisfaction but insufficiency of these elements will result dissatisfaction.
- *One-dimensional attributes (O)*: These are attributes that sufficiency of them will result satisfaction and insufficiency of them will result dissatisfaction. These attributes are also termed 'more is better' or 'faster is better'.
- *Attractive attributes (A)*: These are attributes that sufficiency of them will cause customers to feel excitement and their absence will not dissatisfy customers.
- *Indifferent attributes (I)*: These are attributes that sufficiency or insufficiency of them will not affect customer satisfaction.
- *Reverse attributes(R)*: These are attributes that if they are provided, customer will be dissatisfied and vice versa.

Kano questionnaire has to be developed and it helps to categorize the attributes.The questionnaire examines each customer need with a pair of questions in functional and dysfunctional forms. There are five possible answers for each pair of questions: like, must-be, one-dimensional, neutral, live with and dislike. On the basis of customer responses to both questions, the customer need is classified as one of the five Kano categories for that customer by checking the Kano evaluation table (Berger et al., 1993). The frequency of responses to the questionnaires leads to evaluate the expectation levels of customers' needs. Berger et al., (1993) proposed customer satisfaction index (CS), which is calculated by dividing the sum of frequencies of attractive (f_A) and one-dimensional (f_O) attributes with the sum of the frequencies of attractive, one-dimensional, must be (f_M) and indifferent attributes (f_I). The value of customer satisfaction index lies between 0 and 1. The values of CS close to 1 indicate greater satisfaction while the values close to 0 indicate lower satisfaction.

B. VIKOR

The VIKOR (the Serbian name is 'VIšekriterijumsko KOmpromisno Rangiranje' which means multi-criteria optimization and compromise solution) method was mainly established by Zeleny and later advocated by Opricovic and Tzeng (Adhikary et al., 2015). This method helps to solve multi-criteria decision making problems with conflicting and non-commensurable criteria (Opricovic and Tzeng, 2007), assuming that a compromise can be acceptable for conflict resolution, when the decision maker wants a solution that is the closest to the ideal solution and farthest from the negative-ideal solution, and the alternatives can be evaluated with respect to all the established criteria. It focuses on ranking and selecting the best alternative from a set of alternatives with conflicting criteria, and on proposing the compromise solution. The compromise solution is a feasible solution, which is the closest to the ideal solution, and a compromise means an agreement established by mutual concessions made between the alternatives (Rao, 2007). In VIKOR method, the best alternative is preferred by maximizing utility group and minimizing regret group. This method calculates ratio of positive and negative ideal solution. In fact, both TOPSIS and VIKOR methods provide a ranking list. The highest ranked alternative by VIKOR is the closest to the ideal solution. However, the highest ranked alternative by TOPSIS is the best in terms of the ranking index, which does not mean that it is always the closest to the ideal solution. In addition to ranking the VIKOR method proposes a compromise solution with an advantage rate (Tzeng and Huang, 2011). Therefore, in the present work a hybrid decision model has been developed by using Kano and VIKOR techniques with a view to solving supplier selection problem.

II. PROPOSED METHODOLOGY

In order to take wise decision on supplier selection, a methodology is proposed by combining Kano model analysis and VIKOR. In this methodology the priority structure of supplier selection attributes is obtained by using Kano technique. The weightages of the supplier selection attributes will be reflected in determining the VIKOR index for each supplier. On the basis of VIKOR indices it is easier for a decision maker to identify the best supplier. The step by step methodology is discussed below.

Step 1: Identification of supplier selection attributes

The attributes for supplier selection are usually depends on the type of firm, product, purchasing capability etc. The top level executives are generally involved in the identification of supplier selection attributes.

Step 2: Developing and administering Kano questionnaire

Kano questionnaire has to be prepared by incorporating the functional and disfunctional forms of questions on supplier selection attributes. To obtain the response data on supplier selection attributes, the questionnaires are distributed to purchasing personnel of manufacturing firms which are producing similar products.

Step 3: Determination of the weightages for the supplier selection attributes

After determining the customer satisfaction indices (CS) for all the attributes and then by normalizing those values gives the weightages for the supplier selection attributes.

Step 4: Formulation of MCDM decision matrix:

The MCDM decision matrix has to be formed as shown below.

	Cx_1	Cx_2	Cx_3	.	.	Cx_n
A_1	x_{11}	x_{12}	x_{13}	.	.	x_{1n}
A_2	x_{21}	x_{22}	x_{23}	.	.	x_{2n}
A_3	x_{31}	x_{32}	x_{33}	.	.	x_{3n}
.	.	.	.	.	.	.
.	.	.	.	.	.	.
A_m	x_{m1}	x_{m2}	x_{m3}	.	.	x_{mn}

Where A_i = the i^{th} alternative (i =1, 2,………., m)

Cx_j = the j^{th} criterion (j =1, 2,........., n)

x_{ij} = individual performance of an alternative.

Step 5: Representation of normalized decision matrix

The normalized decision matrix can be expressed as follows:

$$F = \left[f_{ij} \right]_{m\times n}$$

Where, $f_{ij} = \dfrac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$, i =1,2,……,m; j =1,2,……,n;

and x_{ij} is the performance of alternative A_j with respect to the j^{th} criterion.

Step 6: Determination of positive-ideal solution and negative-ideal solution

The positive ideal solution A^* and the negative ideal solution A^- are determined as follows:

$$A^* = \left\{ \left(\max f_{ij} \,|\, j \in J \right) \text{or} \left(\min f_{ij} \,|\, j \in J \right) \middle| i = 1,2,.....,m \right\}$$
$$= \left\{ f_1^*, f_1^*,....f_j^*,....., f_n^* \right\}$$
$$A^- = \left\{ \left(\min f_{ij} \,|\, j \in J \right) \text{or} \left(\max f_{ij} \,|\, j \in J \right) \middle| i = 1,2,.....,m \right\}$$
$$= \left\{ f_1^-, f_1^-,....f_j^-,....., f_n^- \right\}$$

Step 7: Calculation of Utility measure and Regret measure

The Utility measure (S_i) and Regret measure (R_i) for each alternative are computed using the following expressions

$$S_i = \sum_{j=1}^{n} w_j \times \left[\frac{\left(f_j^* - f_{ij} \right)}{\left(f_j^* - f_j^- \right)} \right]$$

$$R_i = \max_j \left[w_j \times \frac{\left(f_j^* - f_{ij} \right)}{\left(f_j^* - f_j^- \right)} \right]$$

Where w_j = weight of the j^{th} criterion.

Step 8: Computation of VIKOR index

The VIKOR index is calculated by using the following expression.

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

Where, Q_i represents the i^{th} alternative VIKOR value, i=1, 2,……., m ; $S^* = \min_i(S_i)$, $S^- = \max_i(S_i)$, $R^* = \min_i(R_i)$, $R^- = \max_i(R_i)$ and v is the weight of the maximum group utility and its value is usually set to 0.5 (Kacker, 1985 and Opricovic, 1994).

Step 9: Rank the order of preference

The alternative which is having smallest VIKOR index value is the best solution.

III. CASE STUDY

A case study has been carried in hydraulic and pneumatic cylinders manufacturing company located in Visakhapatnam, Andhra Pradesh, India with a view to demonstrating the application of proposed decision model. At present the company has five suppliers for procuring necessary raw materials. The company is currently implementing bidding technique for the selection of supplier for procuring raw materials. In the current practice, the parameters such as quality, lead time are not considered by the company. But, the company has to ensure that their products should meet the quality and specification standards for sustainability of the company in the competitive market environment. In order achieve this; the present study has been carried with a view to selecting the best supplier for the company to procure its raw materials. Kano questionnaire is prepared and administered to ten similar manufacturing companies for obtaining response data. On the basis of the data obtained through questionnaire survey, supplier selection attributes are categorized as per Kano method and are shown in Table 1. The customer satisfaction indices for the supplier selection attributes are computed by using the following formula.

$$CS_i = \frac{f(A) + f(O)}{f(A) + f(O) + f(M) + f(I)}$$

Table1. List of supplier selection attributes and Kano category

Sl. No	Supplier selection attributes	A	O	M	I	Total	Grade	CS	weightages
1	Quality	1	1	8	0	10	M	0.9	0.257
2	Price	7	1	0	2	10	A	0.8	0.228
3	Warranty	6	1	2	1	10	A	0.7	0.200
4	Capacity	4	1	3	2	10	A	0.5	0.143
5	Delivery	1	5	3	1	10	O	0.6	0.172

The response data on supplier selection attributes for the five suppliers of the case company are presented in Table 2.

Table 2. The response data on supplier selection attributes

Supplier	Supplier selection attributes				
	Quality	Price	Warranty	Capacity	Delivery
1	0.200	0.046	0.002	0.061	0.012
2	0.032	0.015	0.006	0.029	0.070
3	0.013	0.015	0.017	0.018	0.037
4	0.053	0.003	0.006	0.006	0.005
5	0.103	0.006	0.034	0.116	0.021

On the basis of qualitative and quantitative data of five suppliers, normalized decision matrix is developed as discussed in step 5 of the section 2. The normalized decision matrix is obtained as given below.

$$X_i = \begin{bmatrix} 0.858 & 0.451 & 0.901 & 0.051 & 0.146 \\ 0.137 & 0.214 & 0.294 & 0.153 & 0.853 \\ 0.055 & 0.133 & 0.294 & 0.435 & 0.451 \\ 0.227 & 0.044 & 0.058 & 0.153 & 0.060 \\ 0.442 & 0.859 & 0.117 & 0.871 & 0.256 \end{bmatrix}$$

The positive ideal solution (PIS) and negative ideal solutions (NIS) are determined by considering the data under two approaches such as larger is better and smaller is better. For each selection attribute the PIS $\left(f_j^*\right)$ and NIS $\left(f_j^-\right)$ are expressed as follows.

For Quality (Larger is Better):
$f_j^* = 0.858$ and $f_j^- = 0.055$

For Price (Smaller is Better):
$f_j^* = 0.044$ and $f_j^- = 0.859$

For Warranty (Larger is Better):
$f_j^* = 0.901$ and $f_j^- = 0.058$

For Capacity (Larger is Better):
$f_j^* = 0.871$ and $f_j^- = 0.051$

For Delivery (Smaller is Better):
$f_j^* = 0.060$ and $f_j^- = 0.853$

The utility measure (S_i) and regret measure (R_i) for all the supplier selection attributes have to be determined. As discussed in step 7 of the section 2, the values of (S_i) and (R_i) for quality are computed as follows.

$$S_{ij} = w_j \left[\frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right]$$

For quality: $w_j = 0.257$; $f_j^* = 0.858$; $f_j^- = 0.055$

$$S_{11} = 0.257 \times \frac{0.858 - 0.858}{0.858 - 0.055} = 0.00$$

$$S_{21} = 0.257 \times \frac{0.858 - 0.137}{0.858 - 0.055} = 0.230$$

$$S_{31} = 0.257 \times \frac{0.858 - 0.055}{0.858 - 0.055} = 0.257$$

$$S_{41} = 0.257 \times \frac{0.858 - 0.227}{0.858 - 0.055} = 0.201$$

$$S_{51} = 0.257 \times \frac{0.858 - 0.442}{0.858 - 0.055} = 0.133$$

In the same way utility measures for all other attributes with respect to all the suppliers are computed and are presented in utility matrix $\left(S_{ij}\right)$.

The utility measure (S_i) and regret measure (R_i) for all the suppliers are computed as discussed in the step 7 of section 2. The Table 3 shows the values of utility measure and regret measure for all the five suppliers.

$$S_{ij} = \begin{bmatrix} 0.000 & 0.114 & 0.000 & 0.172 & 0.127 \\ 0.230 & 0.180 & 0.144 & 0.150 & 0.000 \\ 0.257 & 0.203 & 0.144 & 0.091 & 0.072 \\ 0.201 & 0.228 & 0.200 & 0.150 & 0.143 \\ 0.133 & 0.000 & 0.186 & 0.000 & 0.107 \end{bmatrix}$$

Table 3 Utility measure and regret measure of the suppliers

Supplier	Utility measure (S_i)	Regret measure (R_i)
1	0.413	0.172
2	0.705	0.230
3	0.767	0.257
4	0.923	0.228
5	0.426	0.186

The VIKOR index for each supplier is computed as discussed in step 8 of the methodology discussed in the previous section.

For supplier 1:

$$Q_1 = 0.5\left[\frac{0.413 - 0.413}{0.923 - 0.413}\right] + (1 - 0.5)\left[\frac{0.172 - 0.172}{0.257 - 0.172}\right] = 0.00$$

For supplier 2:

$$Q_2 = 0.5\left[\frac{0.705-0.413}{0.923-0.413}\right]+(1-0.5)\left[\frac{0.230-0.172}{0.257-0.172}\right]=0.631$$

For supplier 3:

$$Q_3 = 0.5\left[\frac{0.767-0.413}{0.923-0.413}\right]+(1-0.5)\left[\frac{0.257-0.172}{0.257-0.172}\right]=0.847$$

For supplier 4:

$$Q_4 = 0.5\left[\frac{0.923-0.413}{0.923-0.413}\right]+(1-0.5)\left[\frac{0.228-0.172}{0.257-0.172}\right]=0.829$$

For supplier 5:

$$Q_5 = 0.5\left[\frac{0.426-0.413}{0.923-0.413}\right]+(1-0.5)\left[\frac{0.186-0.172}{0.257-0.172}\right]=0.095$$

The VIKOR indices for all the five suppliers are summarized in table 4.

Table 4 VIKOR Indices for all the suppliers

Supplier	1	2	3	4	5
VIKOR Index	0.0	0.631	0.847	0.829	0.095

IV. CONCLUSIONS

In order to address supplier selection problem in a manufacturing firm a decision model has been proposed in this work. The decision model is established by using Kano and VIKOR techniques. Kano technique is used to categorize the preferences of manufacturing firms on supplier selection attributes. It also helps to obtain the weightages of the supplier selection attributes by reflecting the preferences of manufacturing firms. As the supplier selection is a multi-criteria group decision problem, VIKOR technique is employed in the proposed decision model. Under the circumstances where qualitative and quantitative factors are involved in the multi-criteria decision making on supplier selection, the proposed methodology provides appropriate support to the decision makers of any manufacturing company.

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