Supplier selection through Attractive criteria: a Fuzzy Kano based integrated MCDM approach

Naveen Jain
Department of Mechanical Engineering
Shri Shankaracharya Institute of Professional Management and Technology
Raipur, India,
naveenjainbit@gmail.com

Vinay Surendra Yadav; H.K. Narang and A. R. Singh
Department of Mechanical Engineering
National Institute of Technology Raipur
Chhattisgarh, India
vinaysyadav93@gmail.com, harenar.me@nitrr.ac.in, amitrajsingh1@gmail.com

Abstract

In the present modern technological driven production scenario, most of the suppliers are having basic capabilities and possess necessary competencies to qualify the selection process. Hence for decision makers, selection of right suppliers based on elementary criteria is a challenging task. Therefore there is a need of identification of some criteria (Attractive Criteria) that will help not only decision makers in selection of suppliers but also will increase the satisfaction level. In this work Fuzzy Kano model has been applied for selection criteria classification and identification of Attractive criteria. Fuzzification of Kano model has been done for capturing the vagueness of decision makers. Further Step-wise Weight Assessment Ratio Analysis (SWARA) Multi Criteria Decision Making (MCDM) method has been used to assign influential weights to attractive criteria. Finally, Complex Proportional Assessment of Alternatives (COPRAS) MCDM technique has been applied for supplier's assessment through Attractive criteria. For the illustration the efficacy of proposed work, a case study of Indian Iron and Steel plant of central India has been considered in which seven suppliers are selected for evaluation. It is observed that supplier 4 has highest utility values.

Keywords: Supplier Selection, COPRAS, SWARA, Fuzzy KANO model, MCDM

1. Introduction

Qualified and potential suppliers helps in deciding the competitive position of industry in market and also aids in maintaining a long term relationship with suppliers (Banaeian et al., 2016; Jain and Singh, 2017). With right suppliers, industries also achieves manifold advantages such as production cost reduction, enhanced product quality, improved customer satisfaction, minimum lead time, increased profitability and so on (Jain and Singh, 2014). Thus selection of qualified suppliers is a strategic and critical activity performed by purchase department of organization (Kannan et al., 2013). Selection of right supplier depends on many diversified factors/criteria such as value for money, quality of product supplied, after sale services etc. (Chai and Liu, 2014). Thus supplier selection process is A Multi-Criteria Decision Making (MCDM) problem because selection criteria's are quantitative, qualitative and conflicting in nature (Jain et al., 2016, 2013). Figueira et al., (2005) reported criteria analysis, choice, ranking and sorting as the four main aspects of MCDM and emphasised the importance of criteria in decision making process. In literature authors have proposed different supplier selection methodologies based over various criteria (Boer et al., 2001; Dickson, 1966; Ware et al., 2012). From literature review it is observed selection of criteria for supplier selection has been mostly done on the basis of literature review and decision maker's involvement is less. Further it is also seen that most of the authors have considered traditional criteria as reported by Dickson (1966). However with evolution of newer technology and greater customer expectations, inclusion of newer criteria in supplier selection process is inevitable. Incorporation of new criteria for supplier selection is also important for improving customer satisfaction. This fact can be better understood by considering the mobile phone case.

In 1973, first hand held mobile phone was launched and over the years, different features have been added in hand set and today they are known as smart phones. In earlier days customer made selection of mobile phones on the basis of criteria's like weight, size, price and network availability. Apart from communication today mobile are being used for many other purposes like internet access, multimedia device, camera, calculator, etc. Today traditional criteria's for mobile selection has been replaced by attractive criteria's such as memory space, camera resolution, pixel density, battery life, operating system, etc. (Yildiz and Ergul, 2015). These attractive criteria are preferred by customers as they bring higher level of satisfaction to customers.

Analogously in today's competitive business environment suppliers are having modern technical knowledge and capability along with newfangled tools and equipment's at their ends. With advancement in technology, suppliers have also excelled and enhanced their performance and are at par with each other when assessed on traditional criteria. As a result industries are facing great difficulty in evaluating and selecting suppliers for contract allocation. Supplier's way of doing business and way of full filling the contract can influence the industry operations and reputation significantly. For example if the supplier supplies poor quality material for manufacturing of a product , in that case the final product delivered to end user will be of inferior quality which will ultimately affect the reputation of industry and will effect business adversely. Further after contract allocation suppliers supply raw materials to industries thus industries are on receiving side and thus act as a customer for suppliers. Thus industry satisfaction can be considered as customer satisfaction. Hence industries are in search for Attractive criteria's, based on which supplier choice can be made effectively and also customer's satisfaction level can be increased.

In literature, very little attention has been paid towards classification of criteria's and determination of 'Attractive' criteria's for supplier selection. Hence there is a need of a methodology which empowers decision makers of the industry to identify relevant criteria and classify then in to different sets. Further proposed methodology should facilitate the establishment of Attractive criteria over which selection of right suppliers can be made by the decision makers of the industry, for achievement of higher level of customer satisfaction.

The objective of this paper is to develop a methodology which provides decision makers a set of 'Attractive' criteria's for supplier selection, assigns importance weights to these criteria's and finally evaluate and rank suppliers for selection. According to philosophy of Kano model, Attractive criteria's are the criteria's whose presence increases level of positive customer satisfaction while its absence does not bring any dissatisfaction to customer (Chaudha et al., 2011; Chen and Chuang, 2008). Further to capture the vagueness and ambiguity in decision maker's linguistic responses, fuzzification has been incorporated with Kano model. Further, as Step-wise Weight Assessment Ratio Analysis (SWARA) method involves less pair wise comparison as compared to analytic hierarchy process (AHP) (Alimardani et al., 2013). Hence in this proposed method influential weights of criteria's have been allocated with SWARA method. Further alternatives have been ranked by applying Complex Proportional Assessment of Alternatives (COPRAS) method (Zavadskas et al., 1994). The efficacy of the proposed approach has been demonstrated by a case study of Iron and Steel Plant from central India.

Organization of paper is as follows; in next section fuzzy Kano model has been covered. Section three describes the steps of SWARA and COPRAS method. Proposed methodology has been explained in section four. Case study has been covered in section five. Application of methodology has been shown in next section. Finally, the conclusions have been drawn in section seven

2. KANO Model

Kano et al., (1984) developed a two dimensional model which facilitates understanding of effect of presence or absence of a product or service attribute on level of customer satisfaction level. Kano model philosophy captures customer satisfaction by asking two questions: functional and dysfunctional form. Functional form of question records customer satisfaction level when attribute is present and dysfunctional form of question records satisfaction level when product attribute is absent. Further a 5 by 5 Kano evaluation table is utilized to classify criteria in to five main classes.

(1) *Must-be attributes*: Sufficiency of these attributes will not bring more satisfaction but insufficiency will result in customer dissatisfaction.

(2) *One-dimensional attributes*: Fulfillment of these attributes results in satisfaction and their absence will result in dissatisfaction

(3) *Attractive attributes*: Presence of these attributes that will bring higher level of customer's satisfaction and customer feel excitement where as their absence will not bring dissatisfaction.
(4) *Indifferent attributes*: These are attributes whose presence or absence in product will not affect customer satisfaction level.
(5*) Reverse attributes*: Presence of these attributes in product will bring dissatisfaction and vice versa.
In traditional Kano model response of decision maker is single and crisp in nature and available choices of response are A (attractive), M (must-be), O (one-dimensional), Q (questionable), I (indifferent) and R (reverse).Traditional Kano model fails to record response when respondent has multiple responses for both functional and dysfunctional questions. Hence to capture human vagueness and uncertainties in responses of respondent, fuzzification has been incorporated with Kano model. In traditional Kano model, respondent response is in form of single (crisp) answer where as in fuzzy Kano model respondent is free to give multiple answers in numerical percentage form. Decision maker's response for both functional and dysfunctional form question is displayed with a five element row vector (Lee and Huang, 2009). For example if response of decision maker is as per Table 1. then for analysis of responses of decision makers a row vector for functional form {0.6,0.4,0,0,0} and dysfunctional form {0,0,0.3,0.3,0.4} is established respectively.
Further a 5 x 5 fuzzy relation matrix is obtained by multiplying transpose of functional vector with dysfunctional vector. A fuzzy relation matrix is established by multiplication and resultant matrix is shown in Figure 1. Further results of fuzzy relation matrix are interpreted with the help of Kano evaluation table (Figure. 2). Matrix T is established by comparing matrix R with Kano matrix and then summing all values corresponding to each attribute.

$$T = \left\{\frac{0.09}{\mathrm{M}}, \frac{0.49}{\mathrm{A}}, \frac{0}{\mathrm{R}}, \frac{0.21}{\mathrm{I}}, \frac{0}{\mathrm{Q}}, \frac{0.21}{\mathrm{O}}\right\}$$

From the values of matrix T it is elicited that highest value is of entry A, hence criterion is classified as Attractive in nature.

$$R = \begin{pmatrix} 0 & 0 & 0.21 & 0.28 & 0.21 \\ 0 & 0 & 0.09 & 0.12 & 0.09 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

Figure 1. Fuzzy relation matrix

$$Kano = \begin{pmatrix} Q & A & A & A & O \\ R & I & I & I & M \\ R & I & I & I & M \\ R & I & I & I & M \\ R & R & R & R & Q \end{pmatrix}$$

Figure 2. Kano evaluation table

3. SWARA AND COPRAS

3.1 SWARA method

In Multi Criteria Decision Making (MCDM) problems weight assignment to criteria is an important issue. In this method SWARA method has been applied for weight assignment. SWARA method has been proposed by Keršuliene et al (2010) and has been applied by many authors and researchers in various fields such as finding solution of rational dispute, selection of architect, machine tool ,energy systems, packaging design (Aghdaie et al., 2013; Keršulienė and Turskis, 2011; Keršuliene et al., 2010; Stanujkic et al., 2015; Zolfani and Saparauskas, 2013). In this work, choice of SWARA over Analytic Hierarchy Process (AHP) has been made due to two reasons. Firstly SWARA method comprises of only n-1 comparisons for n number of criteria's which is very less as compared to AHP and secondly SWARA methods offers liberty to respondent to give his response as it does not have any predefined scale as in case of AHP (Stanujkic et al., 2015). Procedural steps of SWARA method for weight assignment are:

Step 1: Arranging and listing of criteria's in decreasing order of expected significances (based over decision maker's response) (Zolfani and Saparauskas, 2013)
Step 2: Commencing from second criterion, decision maker compares each criterion with its predecessor and express its relative importance.
Step 3: Coefficient K_j is Established as:

$K_j = 1 \quad \text{if} \quad j = 1$ (i)

$K_j = S_j + 1 \ \text{if} \quad j > 1$ (ii)

Step 4: Recalculated weight Q_i is determined as;

$Q_j = 1 \quad \text{if} \ j = 1$ (iii)

$Q_j = \frac{K_{j-1}}{K_j} \quad \text{if} \quad j > 1$ (iv)

Step 5: Assigning relative weights to the evaluation criteria W_j

$$W_j = \frac{Q_j}{\sum_{k=1}^{n} Q_k} \quad \text{(v)}$$

3.2 COPRAS method

In order to evaluate and select suppliers, it is necessary to assess suppliers on finalized criteria's and award ranks to suppliers on the basis of performance. In this method ranks have been awarded to suppliers with COPRAS method. This method was developed by Zavadskas, Kaklauskas and Sarka in 1994 (Zavadskas et al., 1994). COPRAS method compares available alternatives and prioritizes by considering criteria weights under MCDM environment. This method considers both, the positive ideal solution and negative ideal solution and determines the significance of alternatives under consideration. Accordingly alternatives are accepted or rejected by decision makers. The procedural steps of COPRAS method are:

Step 1: Establish a normalized decision matrix consisting of criteria's, and the alternatives. (Zolfani, 2014)

$$[X_{ij}]_{mxn} = \begin{bmatrix} X_{11} & X_{12} & - & - & X_{1n} \\ X_{21} & X_{22} & - & - & X_{2n} \\ - & - & - & - & - \\ - & - & - & - & - \\ X_{m1} & X_{m2} & - & - & X_{mn} \end{bmatrix} \quad \text{(vi)}$$

Where X_{ij} is assessment value of the ith alternative with respect to the jth criterion, m is number of alternatives. n is number of criteria's.

Step 2: Establish a normalized decision matrix: values of decision matrix are normalized by linear transformation sum method where $X_{ij}$is the performance of the ith alternative with respect to the jth criterion $\tilde{x}_{ij}$ is its normalized value, and m is number of alternatives.

$$\tilde{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad \text{(vii)}$$

Step 3: Establish a weighted normalized decision matrix:

$\overline{X} = \tilde{x}_{ij}.w_j$; i=1 ……m, j=1….n, where w_j is the criteria weights of it criterion.

Step 4: Calculating the sums S_{+i} of criterion values, whose larger values are more preferable:

$$S_{+i} = \sum_{j=1}^{k} \tilde{x}_{ij} \cdot q_j \quad \text{(viii)}$$

Step 5: Calculating the sums S_{-i} of criterion values, whose smaller values are more preferable:

$$S_{-i} = \sum_{j=k+1}^{n} \tilde{x}_{ij} \cdot q_j \quad \text{(ix)}$$

In equations (viii) and (ix), k represents number of maximizing criteria; n represents total number of criteria; and q_j is significance of the jth criterion.

Step 6: Calculate relative weight Q_j of ith alternative as:

$$Q_i = S_{+i} + \frac{\min_i S_{-i} \sum_{i=1}^{m} S_{-i}}{S_{-i} \sum_{i=1}^{m} \frac{\min_i S_{-i}}{S_{-i}}}$$

.

Or in simpler terms

$$Q_i = S_{+i} + \frac{\sum_{i=1}^{m} S_{-i}}{S_{-i} \sum_{i=1}^{m} \frac{1}{S_{-i}}} \qquad \text{(x)}$$

Step 7: Calculate utility degree of each alternative as

$$U_i = \frac{Q_i}{Q_{max}} X\ 100 \qquad \text{(xi)}$$

Here Q_i and $Q_{max}$are the significances of the alternatives obtained from equation. (x). All alternatives have been arranged in decreasing order of utility degree values. An alternative having highest value of U_i signifies highest priority (i.e. rank) and successively alternatives with lesser values are ranked thereafter.

4. Proposed Methodology

Proposed methodology of supplier selection provides following advantages:

1) Provides criteria pool with larger number of criteria for supplier selection.
2) Empowers decision makers to identify the relevant criteria for supplier selection.
3) Facilitate decision makers to classify criteria in to different sets.
4) Identification of attractive criteria for selection.

Supplier selection through proposed methodology is accomplished in six steps. Six steps of methodology are:
Step 1: Formulation of decision making team.
Step 2: Identification of supplier selection criteria's.
Step 3: Framing of fuzzy Kano questionnaire and collection of responses from decision makers.
Step 4: Classification of criteria's in to Kano categories.
Step 5: Application of SWARA method for weight assignment to Attractive criteria's.
Step 6: COPRAS method application for awarding ranks to suppliers.
Step 7: Final selection of suppliers.
Flow chart of proposed methodology has been shown in Figure 3.

5. Case Study

India is a developing country and Iron and steel industry contributes significantly to economic development of nation. India was the third largest producer of steel in year 2016 and has implemented National Steel Policy for year 2017 which aims to boost steel industry and achieve second position in steel production globally. Iron and Steel industry of India manufacturer's products which are procured by both public and private organizations and products are also exported globally. Nevertheless due to globalization of markets, industry is facing tough competition from steel manufacturers from other countries. To withstand in tough competitive global environment management is in view of having improved supplier selection methodology for selection of suppliers. Selection of right suppliers on the basis of Attractive criteria will enable industries to have better competitive position and at the same time will support in achieving higher level of satisfaction.
Thus with this motivation, proposed methodology focuses on Iron and steel plant located in central part of India. Plant is leading manufacturer of steel rails, steel plates and wires The proposed methodology facilitate industry in selecting right suppliers by providing criteria's which increases customer satisfaction and also helps to assign weights to criteria's and finally rank the potential suppliers.

6. Application of Methodology

Step 1: A team of decision maker's consisting of six persons from top and middle management of steel plant has been formed. These decision makers belong to marketing, purchase, quality and production departments of steel plant. All the experts are having adequate experience in their fields and have a thorough knowledge of their work. The average experience of the team was calculated as 8.3 years.
Step 2: Initially thirty five criteria were identified for proposed work. However after discussion with the team experts three criteria were found to be less relevant and were not considered for further consideration. Finally thirty six criteria were found to be most appropriate for the industry and have been included in this work (refer table 2).
Step 3: A fuzzy Kano questionnaire summarizing both functional and dysfunctional form of question for each criterion has been framed and has been presented to decision makers for response. Fuzzy Kano model provides liberty to decision makers formarking multiple choices for functional and dysfunctional questions respectively.

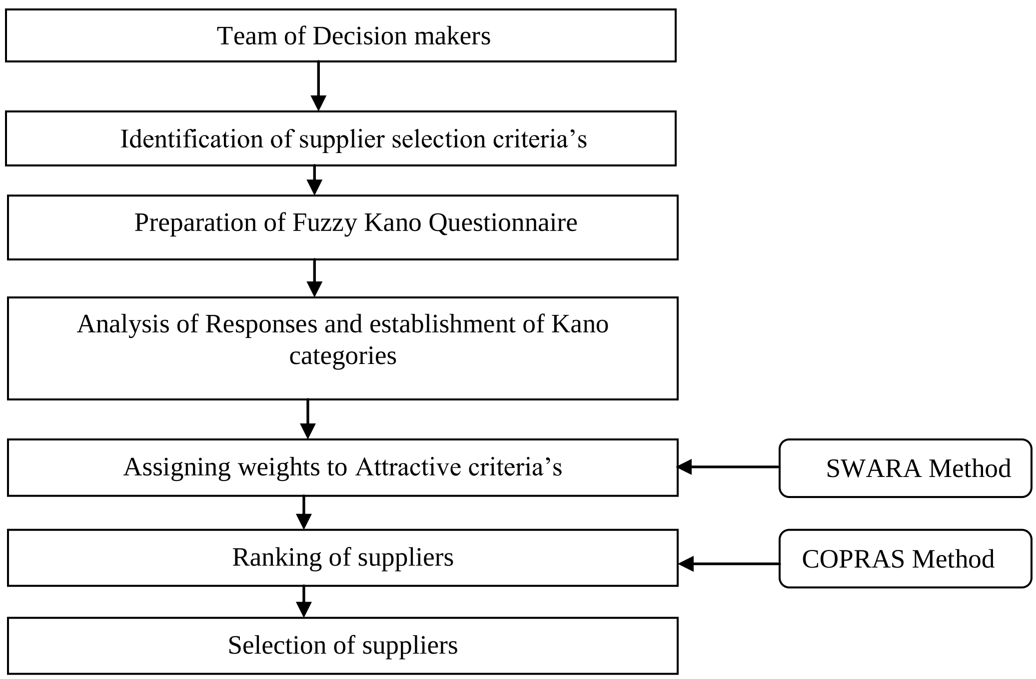

Figure 3. Flowchart of proposed methodology

Step 4: Responses from all decision makers has been collected and analyzed.On the basis of responses, thirty six criteria's were classified in to different Kano categories. Eight criteria were identified as attractive category criteria. Attractive criteria has been presented in table 3.
Step 5: Attractive criteria's are presented to decision makers and on their experience and knowledge they rank these criteria's on decreasing order of significance individually. Responses from decision makers are gathered and average of criteria ranks has been calculated. Finally criterion having least average is ranked first and criterion having largest average value is ranked last.Further, starting from second criterion, decision maker compares each criterion with its predecessor and comparative importance of average vales S_j has been assigned. Further with the help of equations (i) and (ii) coefficient K_j has been calculated and by utilizing equations (iii) and (iv) recalculated weight (Q_i) has been calculated. Final weights have been assigned to criteria's using equation (v). Results for SAWARA method has been tabulated in table 4. From results it is elicited that criteria, performance history (C1) has highest criteria weight and economic situation of supplier has least criteria weight.

Step 6: After calculation of criteria weights, COPRAS method has been applied for awarding ranks to suppliers. With the help of equation (vi) and (vii) a weighted normalized matrix has been established as per table 5. Among

eight criteria of attractive category six criteria's, C1, C2, C3, C5, C6 and C8 are beneficial and there higher values are desirable whereaslower values are preferred for two criteria C4 and C7. Further applying equations (viii)-(xi) utility degrees for COPRAS method has been calculated and results have been tabulated in table 6. Based over the calculated values of utility degree for each supplier, ranks are awarded to suppliers. Supplier having the highest value of utility degree has been awarded rank 1 and subsequently suppliers have been awarded ranks with decreasing utility values.
From table 6. it is observed that supplier 4 has highest utility values and thus has been awarded first rank followed by supplier 2 and supplier 1 has been awarded last rank.

7. Conclusions

In present work, a sequential approach has been used for supplier selection based on attractive criteria's. These attractive criteria's facilitate decision makers when most of the suppliers are at par with each other on Must be criteria. Introduction of attractive criteria's in supplier selection process along with MCDM techniques, helps to increase the level of satisfaction.
In this research, fuzzification has been incorporated with Kano model for capturing the vagueness of decision makers. Allocation of weights to different criteria's is accomplished by SWARA method and ranks are provided to potential suppliers by using COPRAS method. These methodologies facilitate decision maker for selecting the optimal supplier based on attractive criteria's to increase customer satisfaction that may help manufacturers to remain competitive in the market.
Finally, the results of present research paper are very useful for industrial practitioners, decision makers and researchers to understand how attractive criteria's are incorporated in supplier selection process.
However supplier selection through attractive criteria's is not fruitful when suppliers are not at par with each other on must be criteria's.

Table 1. Fuzzy Kano model questionnaire

		Like	Must be	Neutral	Live with	Dis-like
Functional form of question	How would you feel if "Price" is considered as criteria of supplier selection	70%	30%	-	-	-
Dysfunctional form of question	If "Price" is not considered as criteria for supplier selection ,How would you feel	-	-	30%	40%	30%

Table 2. Criteria for supplier selection

Quality	Technical capability	Management and organization	Labor relations record	Flexibility	Professionalism
Delivery	Financial position	Operating controls	Geographical location	Process Improvement	JIT (Just in Time)
Performance history	Procedural compliance	Repair services	Amount of past business	Product Development	Commitment
Warranties and claim policies	Communication system	Packaging ability	Training aid	Environment and Social Responsibility	Economy Situation
Production facilities	Reputation and position in the industry	Desire to do business	Reciprocal arrangement	Occupational Safety And Health	Long Term Relationship
Net price	Impression	Attitude	Reliability	Integrity	Political Situation

Table 3.Criteria of Attractive category

S.No	Criterion	Q	A	M	I	R
1	Performance history (C1)	0	0.36	0.16	0.24	0
2	Impression (C2)	0	0.48	0.04	0.12	0
3	Packaging Ability(C3)	0	0.56	0.06	0.14	0
4	Training Aids(C4)	0	0.63	0.03	0.27	0
5	Reciprocal Arrangements(C5)	0	0.42	0.09	0.21	0
6	Flexibility (C6)	0	0.54	0.04	0.36	0
7	JIT(C7)	0	0.48	0.08	0.32	0
8	Economy Situation(C8)	0	0.6	0	0.4	0

Table 4. Final results of SWARA method in weighting criteria

S. No	Criteria	Comparative Importance Of Average Value S_j	Coefficient $K_j = S_j + 1$	Recalculated Weight $W_j = \frac{X_{J-1}}{K_J}$	Weight $Q_j = \frac{W_J}{\sum W_J}$
1	Performance history (C1)		1	1	0.171858
2	Impression (C2)	0.155	1.155	0.86580	0.148795
3	Packaging Ability(C3)	0.14	1.14	0.75947	0.130522
4	Training Aids(C4)	0.15	1.15	0.66041	0.113497
5	Reciprocal Arrangements(C5)	0.112	1.112	0.59390	0.102066
6	Flexibility (C6)	0.134	1.134	0.52372	0.090005
7	JIT(C7)	0.18	1.18	0.44383	0.076275
8	Economy Situation(C8)	0.15	1.15	0.38594	0.066327

Table 5. Weighted normalized matrix for COPRAS method

	C1 (max)	C2 (max)	C3 (max)	C4 (min)	C5 (max)	C6 (max)	C7 (min)	C8 (max)
SUPPLIER 1	0.00554	0.01145	0.01450	0.01534	0.01041	0.01703	0.00587	0.01218
SUPPLIER 2	0.02772	0.01908	0.02030	0.01534	0.01458	0.01703	0.00587	0.01218
SUPPLIER 3	0.00554	0.01145	0.02610	0.00920	0.01875	0.01216	0.00978	0.00948
SUPPLIER 4	0.04989	0.02671	0.01450	0.02761	0.01041	0.01703	0.01369	0.01218
SUPPLIER 5	0.01663	0.03434	0.00870	0.02147	0.01875	0.00730	0.00978	0.00948
SUPPLIER 6	0.02772	0.01908	0.02030	0.00920	0.01458	0.01216	0.01369	0.00677
SUPPLIER 7	0.03881	0.02671	0.02610	0.01534	0.01458	0.00730	0.01760	0.00406

Table 6. Evaluation of utility degree for COPRAS

	S_{+i}	S_{-i}	Q_i	U_i= (Q_i/ Q_{max})*100	Ranks
SUPPLIER 1	0.0711	0.0212	0.1034	70.1929	7
SUPPLIER 2	0.1109	0.0212	0.1432	97.1936	2
SUPPLIER 3	0.0835	0.0190	0.1195	81.1516	5
SUPPLIER 4	0.1307	0.0413	0.1473	100.0000	1
SUPPLIER 5	0.0952	0.0313	0.1171	79.4906	6
SUPPLIER 6	0.1006	0.0229	0.1305	88.5991	4
SUPPLIER 7	0.1176	0.0329	0.1383	93.9132	3

REFERENCES

Banaeian,N., Mobli,H., Fahimnia,B., Nielsen,I. E., and Omid,M.,Green supplier selection using fuzzy group decision making methods: A case study from the agri-food industry,*Computers & Operations Research*, vol. 89, pp. 337–347, 2016.

Jain,N., and Singh,A. R.,Fuzzy kano integrated MCDM approach for supplier selection based on must be criteria,*International Journal of Supply Chain Management*, vol. 6, no. 2, pp. 49–59, 2017.

Jain,N., and Singh,A. R., AHP And QFD Methodology For Supplier Selection, *International Proceedings of Economics Development and Research*, vol. 75, p. 106, 2014.

Kannan,D., Khodaverdi,R., Olfat,L., Jafarian,A., and Diabat,A., Integrated fuzzy multi criteria decision making method and multi-objective programming approach for supplier selection and order allocation in a green supply chain, *Journal of Cleaner Production*, vol. 47, pp. 355–367, 2013.

Chai,J., and Liu,J. N. K., A novel believable rough set approach for supplier selection, *Expert Systems with Applications*, vol. 41, no. 1, pp. 92–104, 2014.

Jain,R., Singh,A. R., and Mishra,P. K., Prioritization of supplier selection criteria: A fuzzy-AHP approach, *MIT International Journal of Mechanical Engineering*, vol. 3, no. 1, pp. 34–42, 2013.

Jain,N., Singh,A. R., and Choudhary,A. K., Integrated methodology for supplier selection in supply chain management, in *Industrial Engineering and Engineering Management (IEEM), 2016 IEEE International Conference on*, 2016, pp. 807–811.

Figueira,J., Greco,S., and Ehrgott,M., Multicriteria Decision Analysis: State of the Art Surveys. 2005. Springer, Boston, 2005.

Dickson,G. W., An analysis of vendor selection and the buying process, *Journal of Purchasing*, vol. 2, no. 1, pp. 5–17, 1966.

Ware,N. R., Singh,S. P., and Banwet,D. K., Supplier selection problem: A state-of-the-art review, *Management Science Letters*, vol. 2, no. 5, pp. 1465–1490, 2012.

De Boer,L., Labro,E., and Morlacchi,P., A review of methods supporting supplier selection, vol. 7, 2001.

Yildiz,A., and Ergul,E. U., A two-phased multi-criteria decision-making approach for selecting the best smartphone, *South African Journal of Industrial Engineering*, vol. 26, no. 3, pp. 194–215, 2015.

Chen,C.-C., and Chuang,M.-C., Integrating the Kano model into a robust design approach to enhance customer satisfaction with product design, *International Journal of Production Economics*, vol. 114, no. 2, pp. 667–681, 2008.

Chaudha,A., Jain,R., Singh,A. R., and Mishra,P. K., Integration of Kano's Model into quality function deployment (QFD), *The International Journal of Advanced Manufacturing Technology*, vol. 53, no. 5–8, pp. 689–698, 2011.

Alimardani,M., Zolfani,S. H., Aghdaie,M. H., and Tamošaitienė,J., A Novel Hybrid SWARA and VIKOR Methodology for Supplier Selection in an Agile Environment, *Technological and Economic Development of Economy*, vol. 19, no. 3, pp. 533–548, 2013.

Zavadskas,E. K., Kaklauskas,A., and Sarka,V., The new method of multicriteria complex proportional assessment of projects, *Technological and Economic Development of Economy*, vol. 1, no. 3, pp. 131–139, 1994.

Kano,N., Seraku,N., Takahashi,F., and Tsuji,S., Attractive quality and must-be quality, 1984.

Lee,Y.-C., and Huang,S.-Y., A new fuzzy concept approach for Kano's model, *Expert Systems with*

Applications, vol. 36, no. 3, pp. 4479–4484, 2008.
Keršuliene,V., Zavadskas,E. K., and Turskis,Z., Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA), *Journal of Business Economics and Management*, vol. 11, no. 2, pp. 243–258, 2010.
Keršulienė,V. and Turskis,Z., Integrated fuzzy multiple criteria decision making model for architect selection, *Technological and Economic Development of Economy*, vol. 17, no. 4, pp. 645–666, 2011.
Aghdaie,M.H., Zolfani,S.H., and Zavadskas,E. K., Decision making in machine tool selection: An integrated approach with SWARA and COPRAS-G methods, *Engineering Economics*, vol. 24, no. 1, pp. 5–17, 2013.
Zolfani,S. H., and Saparauskas,J., New Application of SWARA Method in Prioritizing Sustainability Assessment Indicators of Energy System, *Engineering Economics*, vol. 24, no. 5, pp. 408–414, 2013.
Stanujkic,D., Karabasevic,D., and. Zavadskas,E. K, A framework for the Selection of a packaging design based on the SWARA method, *Engineering Economics*, vol. 26, no. 2, pp. 181–187, 2015.
Zolfani,S. H. and Saparauskas, J., New application of SWARA method in prioritizing sustainability assessment indicators of energy system, *Engineering Economics*, vol. 24, no. 5, pp. 408–414, 2013.
Zolfani,S. H., Technological and Economic Development of Economy Investment prioritizing in high tech industries based on SWARA-COPRAS approach, *Technological and Economic Development of Economy*, vol. 20(3), pp. 534–553, 2014.

Biographies

Naveen Jain is working as Head of Mechanical Engineering Department at Shri Shankaracharya Institute of Professional Management and Technology, Raipur, India. He has an experience of more than 20 years in teaching different subjects of Mechanical Engineering. He has completed his Bachelor of Engineering in Mechanical Engineering from Barkatullah University, Bhopal, India. He holds Master's degree in Production Engineering. His research areas are Supply Chain Management and Multi Criteria Decision Making (MCDM). He has published papers in International and National journals and has presented papers in International Conferences.

Vinay Surendra Yadav is a research scholar in Mechanical Engineering Department at National Institute of Technology, Raipur, India. He has completed his Bachelor of Engineering degree in Mechanical engineering from Pune University, India. He also holds Master degree in Industrial Engineering and Management from NIT Raipur India. His areas of research include supply chain management, optimization techniques and multi criteria decision making. He has published papers in International journals and has presented papers in International Conferences.

Dr. H. K. Narang is an Assistant Professor in the Mechanical Engineering Department at National Institute of Technology, Raipur, India. He holds a PhD in Production Engineering from Indian Institute of Technology Roorkee, India. He has Master of Technology degree in Production Engineering from National Institute of Technology, Rourkela, India. He has completed his Bachelor of Engineering degree in Mechanical engineering from KIT, Raigarh (C.G.), India. His areas of specialization are operation research, production engineering, arc welding, composites, FEM modelling, soft computing and optimization techniques. He has published more than 25 papers in International journals and International/National Conferences. Some of the international journals in which his papers are published include – International Journal of Engineering, Science and Technology, Journal of materials engineering and performance, Journal of Marine Science and Application, International Journal of Mechanical Engineering, International Journal of Steel Structures, Cogent Engineering and Journal for Manufacturing Science & Production etc.

Dr. A. R. Singh is an Assistant Professor in the Mechanical Engineering Department at National Institute of Technology, Raipur, India. He has completed his Bachelor of Engineering degree in Mechanical engineering from U.P.T.U, University, India. He has Master of Technology degree in CAD-CAM from Motilal Nehru National Institute of Technology, Allahabad, India. He holds a PhD in Mechanical Engineering from Motilal Nehru National Institute of Technology, Allahabad, India. His areas of specialization are operation research, supply chain management, optimization techniques and multi criteria decision making. He has published more than 30 papers in International journals and International/National Conferences. Some of the international journals in which his papers are published include – International Journal of Advanced Manufacturing Technology, International journal of multi criteria decision making, Journal of intelligent manufacturing, International Journal of Design Engineering, International journal of manufacturing systems, Applied Mathematics and Computation etc.