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Lean Manufacturing Facilitator Selection with VIKOR under Fuzzy Environment and SAW method

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ABSTRACT

Now a day, Lean manufacturing becomes a key strategy for global competition. In the lean manufacturing environment selection of the best lean facilitator is a complex multi criteria problem and a key success for an organization. To solve such types of problems the VIKOR method is applied. By using the VIKOR method the decision makers can take the decision which is closer to the ideal solutions. In this paper linguistic fuzzy data is used to find the ratings and weights and the introduced method is used to select the best facilitator. This paper also considers a real application of facilitator selection with using the opinion of expert by one of the decision making model, it is called SAW method. This paper has applied five criteria that they are qualitative and positive for selecting the best one amongst five personnel and also ranking them.

Key words: ***Lean manufacturing, facilitator selection, fuzzy, VIKOR, SAW method.***

1. INTRODUCTION

In manufacturing plants across the world, lean manufacturing techniques are used to meet increasing demands and withstand in the global market .Lean manufacturing techniques have facilitated them to dramatically increase their competitive edge, The journey starts from Henry Ford's continuous assembly lines for the Ford Model. The combination of this concept as well as a successful industrial practice of many others has come as one to create what we know now as lean manufacturing.

The main idea behind lean manufacturing is maximizing customer value while minimizing the deadly wastes. Waste is defined as an activity that does not add value to the product. Through the elimination of waste along the entire manufacturing process the company can produce quality products at low-cost.

Many companies have implemented lean manufacturing techniques to create more efficient workflows. In a lean manufacturing environment the role of lean facilitator is vital because they play the role of implementing lean in on the process line.

Many studies have reported a positive association between various human resources practices and objective and perceptual measures of selecting human resources, some authors have expressed concern that results may be biased because of methodological problems. Traditional methods for selection of human resources are mostly based on statistical analyses of test scores that are treated as accurate reflections of reality. Modern approaches, however, recognize that selection is a complex process that involves a significant amount of vagueness and subjectivity (Kulik, 2007).

In general, personnel selection, depending on the firm's specific targets, the availability of means and the individual preferences of the decision makers (DMs), is a highly complex problem. The multi criteria nature of the problem makes Multi- Criteria Decision Making (MCDM) methods and copes with this, given that they consider many criteria at the same time, with various weights and thresholds, having the potential to reflect at a very satisfactory degree the vague preferences of the DMs.

In this paper, VIKOR method and SAW method are suggested to solve facilitator selection problem using multi-criteria decision-making process in spring manufacturing unit.

2. MCDA

Multi-criteria decision-making (MCDM) consigns to screening, prioritizing, ranking, or selecting a set of options under usually independent, incommensurate or conflicting attributes (Hwang & Yoon, 1981). Over some years, the Multi-criteria decision-making methods have been featured. The methods differ in many areas - theoretical environment, type of questions asked and the type of results known. Some methods have been crafted particularly for one specific problem, and are not useful for other problems. Other methods are more universal, and many of them have attained popularity in various areas. The most important idea for all the methods is to make a more formalized and better-informed decision-making process. There are many possible ways to classify the existing MCDM methods. Belton and Stewart (2002) classified them in 3 broad categories: Value measurement model such as multi-attribute utility theory (MAUT) and analytical hierarchy process (AHP); outranking models such as Elimination and (Et) Choice Translating Reality (ELECTRE) and Preference Ranking Organization METHod for Enrichment Evaluation (PROMETHEE) and at last, goal aspiration and reference level models such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The fundamental assumption in utility theory is that the decision maker chooses the alternative for which the expected utility value is a maximum (Keeney & Raiffa, 2006). However, it is difficult in many problems to obtain a mathematical representation of the decision maker's utility function (Opricovic & Tzeng, 2007). The analytic hierarchy process (AHP) is widely used for tackling multi attribute decision-making problems in real situations. In spite of its popularity and simplicity in concept, this method can deal with imprecision caused by the decision maker's inability to translate his/her preferences for some alternative to another into a totally consistent preference structure.

3. VIKOR METHOD

Opricovic and Tzeng developed VIKOR, the Serbian name: Vlse Kriterijumska Optimizacija I Kompromisno Resenje, means multi-criteria optimization and compromise solution (Chu, et al. 2007). The VIKOR method was developed for multi-criteria optimization of complex systems (Opricovic & Tzeng, 2002). This method focuses on ranking and selecting from a set of alternatives, and determines compromise solutions for a problem with conflicting criteria, which can help the decision makers to reach a final decision. Here, the compromise solution is a feasible solution which is the closest to the ideal, and a compromise means an agreement established by mutual concessions. It introduces the multi-criteria ranking index based on the particular measure of ‘‘closeness” to the ‘‘ideal” solution (Opricovic, 1998).According to (Opricovic & Tzeng, 2007) the multi-criteria measure for compromise ranking is developed from the PLp-metric used as an aggregating function in a compromise programming method. The various J alternatives are denoted as a_1; a_2; . . . ; a_J. For alternative a_j, the rating of the i^{th} aspect is denoted by f_{ij} , i.e. f_{ij} is the value of i^{th} criterion function for the alternative a_j ; n is the number of criteria. Development of the VIKOR method started with the following form of Lp-metric:

$$L_p;j = \left\{ \sum_{i=1}^{n} \left[w_i \left(f_1^* - f_{ij} \right) / (f^* - f_1^-)^p \right]^{1/p} \right\}$$

$$1 \leq p \leq \text{infinity};\ j = 1, 2, 3, \ldots, j.$$

Within the VIKOR method L1;j and L1;j is used to formulate ranking measure. L1;j is interpreted as ‘concordance’ and can provide decision makers with information about the ‘maximum group utility’ or ‘majority’. Similarly, L1;j is interpreted as ‘discordance’ and provides decision makers with information about the minimum individual regret of the ‘opponent’. The VIKOR method uses linear normalization, and the normalized value in the VIKOR method does not depend on the evaluation unit of criterion function.

4. FUZZY APPROACH

In the decision making process, the decision maker is frequently faced with doubts, problems and doubts. In other words usual language to express observation or judgment is always subjective, uncertain or unclear. To determine the vagueness, ambiguity and subjectivity of human judgment, fuzzy set theory (Zadeh, 1965) was introduced to express the linguistic terms in decision making (DM) process. Bellman and Zadeh (1970) developed fuzzy multi criteria decision making (FMCDM) methodology to resolve the lack of precision in assigning importance weights of criteria and the ratings of alternatives regarding evaluation criteria. This logical tools that people can depend on are generally measured the outcome of a bivalent logic (yes/no, true/false), but the problems posed by real-life situations and human thought processes and approaches to problem-solving are by no means bivalent. Just as conventional, bivalent logic is based on classic sets, fuzzy logic is based on fuzzy sets. A fuzzy set is a set of objects in which there is no clear-cut or predefined the boundary between the objects that are or are not members of the set. The key concept behind this definition is that of ‘‘membership”: any object may be a member of a set ‘‘to some degree”; and a logical proposition may hold true “to some degree”. Each element in a set is associated with a value indicating to what degree the element is a member of the set. This value comes within the range [0, 1], where 0 and 1, respectively, indicate the minimum and maximum degree of membership, while all the intermediate values indicate degrees of ‘‘partial” membership (Bevilacqua, Ciarapica, & Giacchetta, 2006). This approach helps decision makers solve complex decision making problems in a systematic, consistent and productive way (Carlsson & Fuller, 1996) and has been widely applied to tackle DM problems with multiple criteria and alternatives. In short, fuzzy set theory offers a mathematically precise way of modelling vague preferences for example when it comes to setting the weights of performance scores on criteria.

5. CHEN AND HWANG 5 POINT METHOD

The method proposed by Chen and Hwang (1992) first converts linguistic terms into fuzzy numbers and then the fuzzy numbers into crisp scores. The method is described below:

This method systematically converts linguistic terms into their corresponding fuzzy numbers. It contains eight conversion scales. To demonstrate the method, a 5-point scale having the linguistic terms low, fairly low, medium, fairly high, and high (Chen and Hwang 1992), is considered. These linguistic terms can be equated to other terms like low, below average, average, above average and high.

The method uses a fuzzy scoring approach that is a modification of the fuzzy ranking approaches proposed by Jain (1976), and Chen (1985). The crisp score of fuzzy number ‘M’ is obtained as follows:

Linguistic term	Fuzzy number	Crisp score
Low	M_1	0.115
Below average	M_2	0.295
Average	M_3	0.495
Above average	M_4	0.695
High	M_5	0.895

6. PROPOSED METHOD FOR FACILITATOR SELECTION

In this section a methodical approach of the VIKOR being applied to solve the facilitator selection problem under a fuzzy environment. The magnitude weights of various criteria and the ratings of qualitative criteria measured as linguistic variables. Because linguistic assessments merely about the slanted judgment of decision makers.

Facilitator selection in the lean manufacturing system is a group multiple criteria decision making (GMCDM) problem. This is illustrated by the following sets.

1. A set of decision makers called D = {D1, D2, D3}

2. A set of possible facilitator called F= {F1, F2, F3, F4, F5}

3. A set of criteria, C = {C1, C2, C3, C4, C5}

The main steps of the wok are:

The proposed model has been applied to a lean facilitator selection process of a firm working in the field of spring manufacturing unit in the following steps:

Step 1:

The Company desires to select a good lean facilitator. After preliminary screening, five candidate facilitator (F1, F2, F3, F4, and F5) remains for further evaluation.

Step 2:

A committee of three decision makers (DM), D1; D2 and D3, has been formed to select the most suitable facilitator. The following criteria have been defined: C_1 – Interpersonal Skills, C_2 – Learning Orientation, C_3 – Eye for waste (Resource Management), C_4 – Innovation and Creativity, C_5 – Critical Thinking.

Step 3:

Three decision makers use the linguistic weighting variables to assess the importance of the criteria. The importance weights of the criteria determined by these three decision makers are shown in Table 1. Also the decision makers use the linguistic rating variables to evaluate the ratings of candidates with respect to each criterion. The ratings of the five facilitators by the decision makers under the various criteria are shown in Table 2.

Table 1 Importance weight of criteria

Criteria	**DM_1**	**DM_2**	**DM_3**
C_1	A	AA	A
C_2	A	A	BA
C_3	H	H	H
C_4	H	H	AA
C_5	AA	A	AA

Table 2 Rating of Facilitators of five facilitators under each criterion in terms of linguistic variables determined by DMs

Criteria	C_1			C_2			C_3			C_4			C_5		
Facilitator	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
F_1	A	AA	L	A	AA	BA	A	AA	BA	AA	H	A	AA	H	A
F_2	H	AA	A	AA	H	A	AA	AA	A	A	AA	BA	A	AA	BA
F_3	BA	A	L	A	A	A	A	AA	BA	L	A	BA	L	A	BA
F_4	AA	H	A	H	AA	A	AA	H	A	A	AA	BA	A	AA	BA
F_5	H	AA	AA	AA	A	A	H	AA	AA	H	AA	AA	AA	AA	A

Step 4:

The linguistic evaluations shown in Tables 1 and 2 are converted into fuzzy numbers. Then the aggregated weight of criteria and aggregated fuzzy rating of alternatives is calculated to construct the fuzzy decision matrix and determine the fuzzy weight of each criterion, as in Tables 3.

Table 3 Decision Matrix in Crisp score for facilitators

	C_1	C_2	C_3	C_4	C_5
Weights	**0.168**	**0.128**	**0.267**	**0.248**	**0.189**
F_1	0.43	0.49	0.49	0.69	0.69
F_2	0.69	0.69	0.62	0.49	0.49
F_3	0.30	0.62	0.49	0.30	0.30
F_4	0.69	0.62	0.69	0.49	0.49
F_5	0.76	0.56	0.76	0.76	0.62

Step 5:

The values of S, R and Q are calculated by using the equations, for all the facilitators.

$$S_i = \sum_n^m \frac{w_j[((m_{ij})\max) - (m_{ij})]}{[((m_{ij})\max) - (m_{ij})min]} \quad (1)$$

$$R_i = \text{Max of } \sum_n^m \frac{w_j[((m_{ij})\max) - (m_{ij})]}{[((m_{ij})\max) - (m_{ij})\min]} \quad (2)$$

$$Q_i = v ((S_i - S_{imin}) / (S_{imax} - S_{imin})) + (1 - v) ((R_i - R_{imin}) / (R_{imax} - R_{imin})) \quad (3)$$

Table 4 Values of S, R and Q for all facilitators

	F_1	F_2	F_3	F_4	F_5
S	0.552	0.404	0.920	0.380	0.110
R	0.267	0.145	0.267	0.145	0.083
Q	0.77	0.384	1.00	0.32	0.00

Step 6:

The ranking of the Lean facilitator by S, R and Q in decreasing order is shown in Table 5, in decreasing order.

Table 5 Ranking of the facilitators by S, R and Q in order

Ranking of Lean Facilitators					
By S	F_5	F_4	F_2	F_1	F_3
By R	F_5	F_4	F_2	F_1	F_3
By Q	F_5	F_4	F_2	F_1	F_3

From Table 5 and Figs. 1 to 3, it can be concluded that, the facilitator F5 is the best ranked.

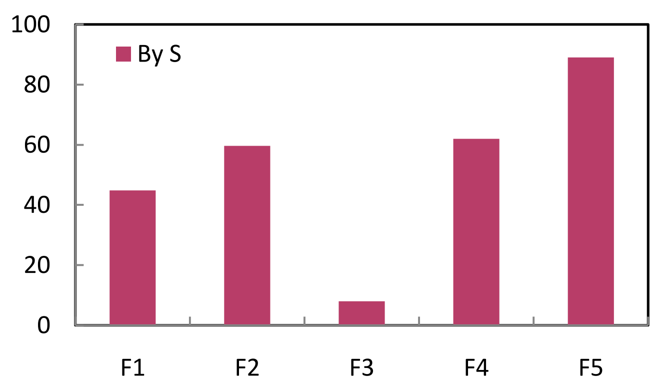

Fig. 1 Advantage rate of facilitators by Utility Measure

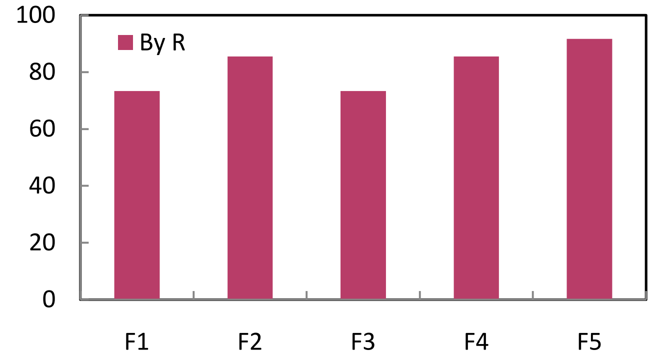

Fig. 2 Advantage rate of facilitators by Regret Measure

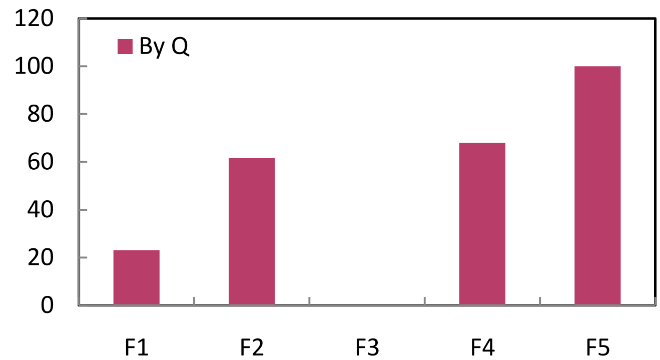

Fig. 3 Advantage rate of facilitators by VIKOR Index

7. SAW METHOD

Simple Additive Weighting (SAW) which is also known as weighted linear combination or scoring methods is a simple and most often used multi attribute decision technique. The method is based on the weighted average. An evaluation score is calculated for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of relative importance directly assigned by decision maker followed by summing of the products for all criteria. The advantage of this method is that it is a proportional linear transformation of the raw data which means that the relative order of magnitude of the standardized scores remains equal. Process of SAW consist of these steps:

Step 1:

1) Construct a pair-wise comparison matrix (n × n) for criteria with respect to objective by using Saaty's 1-9 scale of pair wise comparisons shown in Table 6. In other words, it is used to compare each criterion with each other criterion, one-by-one.

Table 6 Saaty's 1-9 scale of pair wise comparisons

Intensity of importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or Slight	
3	Moderate Importance	Experience and judgment slightly favour one activity over another
4	Moderate Plus	
5	Strong Importance	Experience and judgment strongly favour one activity over another
6	Strong Plus	
7	Very Strong	An activity is favoured very strongly over another
8	Very, very Strong	
9	Extreme Importance	The evidence favouring one activity over another is of the highest possible order of affirmation

2) For each comparison, we will decide which of the two criteria is most important, and then assign a score to show how much more important it is.

3) Compute each element of the comparison matrix by its column total and calculate the priority vector by finding the row averages.

4) Weighted sum matrix is found by multiplying the pair-wise comparison matrix and priority vector.

5) Dividing all the elements of the weighted sum matrix by their respective priority vector element.

6) Compute the average of this value to obtain max λ_{max} .

7) Find the Consistency Index, CI, as follows:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \quad (4)$$

Where n is the matrix size.

8) Calculate the consistency ratio, CR, as follows:

9) $$CR = \frac{CI}{RI} \quad (5)$$

10) Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table7. The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.

Table 7 Average Random Consistency (RI)

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Step 2:

Construct a decision matrix (m × n) that includes m personnel and n criteria. Calculate the normalized decision matrix for positive criteria:

$$n_{ij} = \frac{r_{ij}}{r_j^*} \qquad i = 1, \dots, m, \qquad j = 1, \dots, n \qquad (6)$$

And for negative criteria:

$$n_{ij} = \frac{r_j^{min}}{r_{ij}} \qquad i = 1, \dots, m, \qquad j = 1, \dots, n \qquad (7)$$

r_j^* is a maximum number of r in the column of j.

Step 3:

Evaluate each alternative, A_i by the following formula:

$$A_j = \sum w_j * x_{ij} \qquad (8)$$

Where x_{ij} is the score of the i^{th} alternative with respect to the j^{th} criteria, w_j is the weighted criteria.

This methodology is designed in order to select and consider suitable criteria and facilitator in spring manufacturer unit. The way of data collection that is applied for this phase is questionnaire. By using Comparison Matrix the weights of criteria will be computed. After computing weights of criteria, specifying of Consistency Rate will be executed. If Consistency of data is more than 0.1, revision of pair-wise comparison must be done. So we will continue it until consistency Rate reach to less than 0.1. After CR is less than 0.1, it indicates sufficient consistency. In that time, we use SAW method for ranking personnel. The procedure of methodology has been shown in Fig. 4.

Same criteria chosen for facilitator selection using VIKOR method, have considered for the facilitator selection using SAW method.

The weights of criteria have been computed by using comparison matrix. Meanwhile, Data was gathered from five expert's opinion with questionnaire in spring manufacturer unit by using scale values of 1-5 as shown in Table 8.

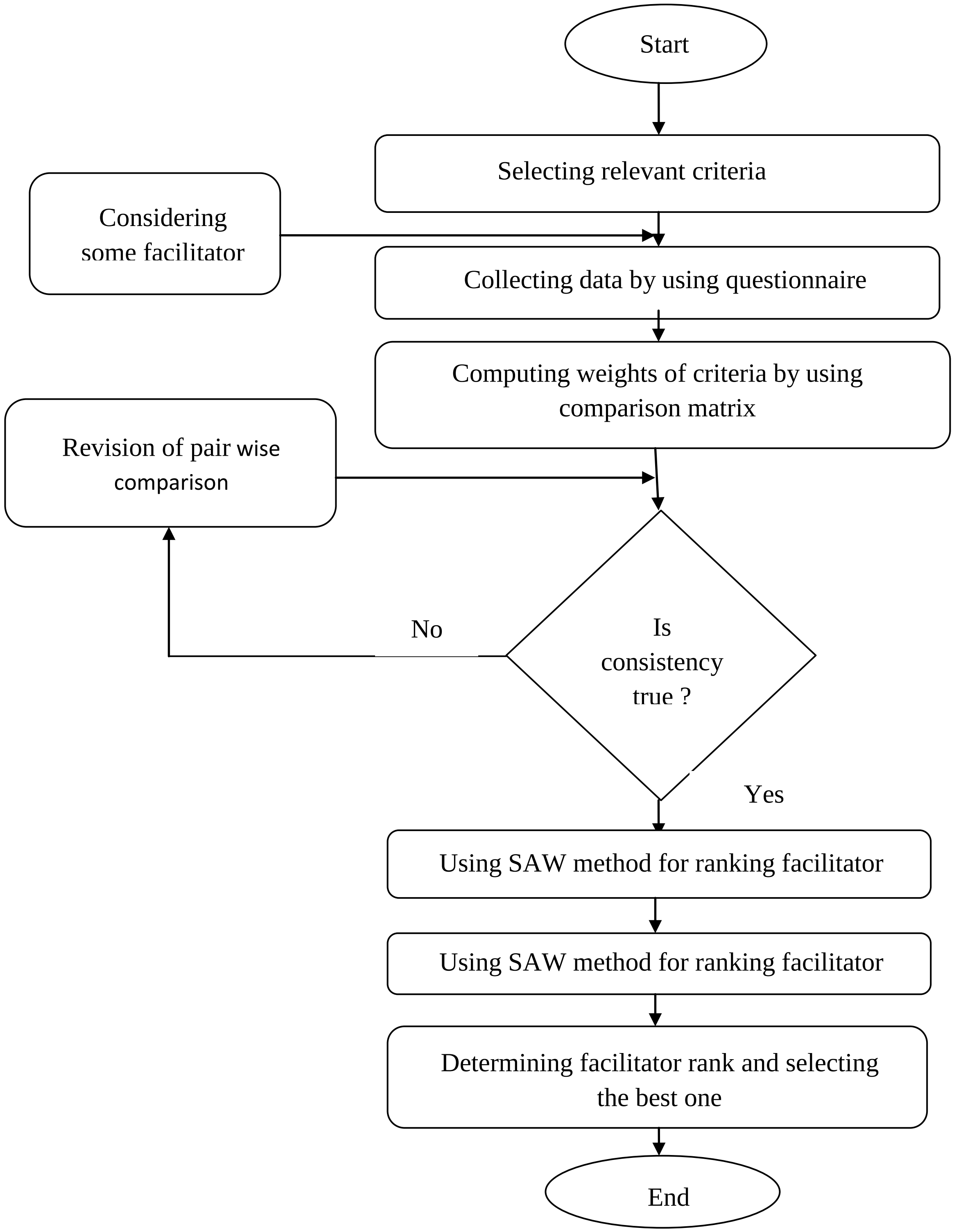

Fig. 4 Research Framework

Table 8 specifying the scale values of 1-5

Intensity of importance	**Definition**
1	Equal importance
2	Moderate importance
3	Strong importance
4	Very strong
5	Extreme importance

The comparison matrix is shown in Table 9, indicating the relative importance of the criterion in the columns compared to the criterion in the rows.

Table 9 Weights of criteria by Comparison matrix

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**Weights**
C_1	1	2	2	2	2	0.33
C_2	0.5	1	1	1	1	0.16
C_3	0.5	1	1	1	1	0.16
C_4	0.5	1	1	1	1	0.16
C_5	0.5	1	1	1	1	0.16
Total	3	6	6	6	6	1

TEST OF CONSISTENCY FOR SELECTED SET OF CRITERIA

The consistency Rate calculated was 0.042 that is less than 0.1, indicating sufficient consistency. The following steps will show how the test of consistency will be done.

Step 1:

In order to calculate computing Weighted Sum Vector (WSM):

1	2	2	2	2		0.33		1.930
0.5	1	1	1	1		0.16		0.805
0.5	1	1	1	1		0.16		0.805
0.5	1	1	1	1	**x**	0.16	=	0.805
0.5	1	1	1	1		0.16		0.805

By rounding off the number to three decimal places, we will get Consistency vector (CV). In following division, each corresponding cell must be divided each other.

1.930		0.33		5.84
0.805		0.16		5.03
0.805	/	0.16	=	5.03
0.805		0.16		5.03
0.805		0.16		5.03

$$\lambda_{max} = \frac{5.84 + 5.03 + 5.03 + 5.03 + 5.03}{5} = 5.192$$

Consistency Index (CI) and consistency ratio are calculated using equations 4 and 5.

$$CI = \frac{5.192 - 5}{5 - 1} = 0.048$$

Consistency rate will be computed as follows as the amount of Random Index (RI) could be got by looking at Table 7, according to the value of n (n is size of matrix).

$$CR = \frac{CI}{RI} = \frac{0.048}{1.12} = 0.042$$

So the Consistency Index is indicating that the opinion of experts is sufficient. After preparing collected data from experts, based on scale values 1-9 in Table 4.35 and computing weights of criteria in Table 4.43, following steps shows the procedure of SAW method:

Table 10 Collected data based on scale values (1-9)

	C_1	C_2	C_3	C_4	C_5
F_1	6	4	5	7	6
F_2	6	5	6	6	6
F_3	6	4	6	6	6
F_4	6	6	5	7	5
F_5	6	6	5	7	6

C means Criteria and F means Facilitator

Step 2:

Calculate the normalized decision matrix (m × n) that includes m personnel and n criteria.

$$n_{ij} = \frac{r_{ij}}{r_j^*} \qquad i = 1, \ldots., m, \qquad j = 1, \ldots., n \qquad (9)$$

And for negative criteria:

$$n_{ij} = \frac{r_j^{min}}{r_{ij}} \qquad i = 1, \ldots., m, \qquad j = 1, \ldots\ldots, n \qquad (10)$$

r_j^* is a maximum number of r in the column of j.

In this case study, criteria has been taken as positive and normalized decision matrix for positive criteria are calculated using equation 9. The results are as shown in Table 11.

Table 11 Normalized decision matrix

	C_1	C_2	C_3	C_4	C_5
F_1	1.0	0.67	0.83	1.0	1.0
F_2	1.0	0.83	1.0	0.85	1.0
F_3	1.0	0.67	1.0	0.85	1.0
F_4	1.0	1.0	0.83	1.0	0.83
F_5	1.0	1.0	0.83	1.0	1.0

Table 12 Weighted Criteria

C_1	C_2	C_3	C_4	C_5
0.33	0.16	0.16	0.16	0.16

Step 3:

Evaluate each alternative, A_i by the following formula as shown below and results are tabulated in Table 13 and final ranked personnel are presented Table 14 and Fig. 5.

$$A_j = \sum w_j * x_{ij} \quad (11)$$

Where x_{ij} is the score of the i^{th} alternative with respect to the j^{th} criteria, w_j is the weighted criteria.

Table 13 Weighted normalized decision matrix

	C_1	C_2	C_3	C_4	C_5
F_1	0.33	0.1072	0.1328	0.160	0.160
F_2	0.33	0.1328	0.160	0.136	0.160
F_3	0.33	0.1072	0.160	0.136	0.160
F_4	0.33	0.160	0.1328	0.160	0.1328
F_5	0.33	0.160	0.1328	0.160	0.160

Table 14 Ranked Personnel

F_1	F_2	F_3	F_4	F_5
0.890	0.910	0.893	0.915	0.940

Finally in SAW method, the best facilitator is F_5 and then F_4, F_2, F_3 and F_1 will be respectively.

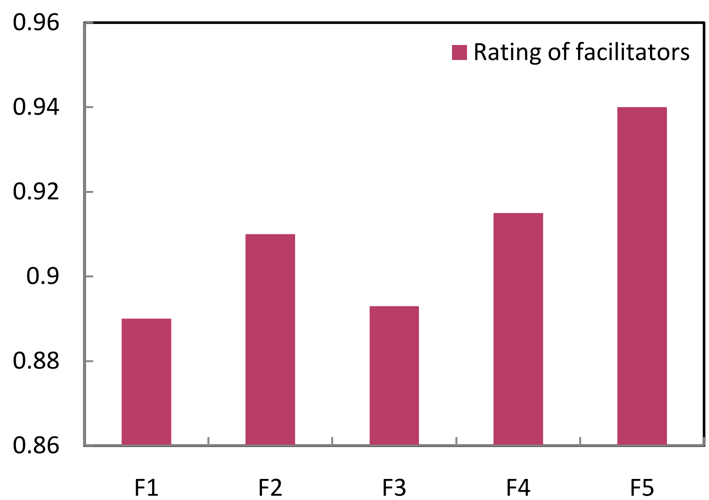

Fig. 5 Rating of facilitators (Method: SAW)

8. CONCLUSIONS

In this study, we presented a MCDM methodology for facilitator selection. The method was applied using data from a real case in the spring manufacturer unit in Ananthapur, India. In actual factory system, the decision maker is not able to express his rating precisely in numerical values and the evaluations are very often expressed in linguistic terms. In this work the VIKOR, a newly introduced MCDM method, in fuzzy environment is proposed to deal with the both qualitative and quantitative criteria and select the suitable facilitator effectively. Whereas the SAW method used in this analysis SAW ignores the fuzziness of executive's judgment during the decision-making process.

For the selected criteria, F5, F4, F2, F1, F3 and F5, F4, F2, F3, F1 are the ranking sequence according to VIKOR and SAW method respectively. Both the methods used in the present study indicate F5 is the best Lean facilitator. Thus, these popular MCDA methods can be successfully employed by the decision makers for the process of facilitator selection in the spring manufacturing domain.

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