Lean Facilitator Selection with VIKOR and SAW under Fuzzy Environment for Implementing the Spring Manufacturing unit

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Abstract - *Now a day, Lean manufacturing becomes a key strategy for international competition. In this environment selection of the best lean facilitator, choice of the simplest lean assistant could be a complicated and is a complex multi criteria problem and this draw back associate degreed a key success for an organization. To resolve such forms of issues in VIKOR and SAW methodology is applied. By using these methods the choice manufacturers will take the choice that is nearer to the perfect solutions. In this paper linguistic fuzzy data is employed to search out the ratings and weights and also the introduced methodologies employed to pick the simplest assistant is used to select the best facilitator.*

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

1.INTRODUCTION

In manufacturing plants across the globe, lean manufacturing techniques are accustomed meet increasing demands and stand up to within the world market. Lean manufacturing techniques have expedited them to dramatically increase their competitive edge. The journey starts from Henry Ford's continuous assembly lines for the Ford Model. The mixture of this idea moreover as a eminent industrial apply of the many others has come back together to make what we all know currently as lean manufacturing.

The most plan behind lean manufacturing is increasing client price whereas minimizing the deadly wastes. Waste is outlined as associate degree activity that doesn't add price to the product. Through the elimination of waste on the whole producing method the corporate will manufacture quality Product at cheap.

Several firms have enforced lean manufacturing techniques t o make a lot of economical work flows. In a lean manufacturing setting the role of lean facilitator is significant as a result of they play the role of implementing lean on the processing line.

Several studies have reported a positive association between numerous human resources practices and objective and sensory activity measures of choosing human resources, some authors have expressed concern that results could also be biased owing to methodological issues. Ancient ways for choice of human resources are principally supported on applied mathematics analyses of test scores that are treated as correct reflections of reality. Trendy approaches, however, acknowledge that choice could be a advanced method that involves a big quantity of unclearness and subjectivity[1].

In general, personnel choice, looking on the firm's specific targets, the supply of means that and therefore the individual preferences of the decision manufacturers (DMs), could be a extremely advanced drawback. The multi criteria nature of the matter makes Multi-Criteria decision making (MCDM) ways and copes with this, provided that they contemplate several criteria at an equivalent time, with numerous weights and thresholds, having the potential to replicate at a awfully satisfactory decree the obscure preferences of the DMs.

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

2. MULTI CRITERIA DECISION MAKING METHODS

2.1. Introduction

Multi-criteria decision-making (MCDM) consigns to screening, prioritizing, ranking, or choosing a group of choices
underneath sometimes freelance, unequal or conflicting attributes [2]. Over some years, the Multi-criteria decision-making ways are featured.

The ways take issue in several areas theoretical surroundings, type of quarries asked and therefore the type of results known. Some ways are crafted significantly for one specific drawback, and aren't helpful for alternative issues. Alternative ways are additional universal, and lots of them have earned quality in numerous areas.

The foremost necessary plan for all the ways is to form a additional formalized and better-informed decision-making method. There are several attainable ways that to classify the present MCDM ways.

Belton and Steward [3] classified them in three broad classes, value measuring model like multi-attribute utility theory(MAUT)and analytical hierarchy method (AHP), outranking models like Elimination and choice Translating Reality (ELECTRE) and Preference Ranking Organization technique for Enrichment analysis (PROMETHEE) and at last, goal aspiration and reference level models like Technique for Order Preference by Similarity to Ideal solution (TOPSIS). The elemental assumption in utility theory is that the choice maker chooses the choice that the expected utility price could be a most [4]. However, it's troublesome in several problems to get a mathematical illustration of the choice maker's utility perform [5]. The analytic hierarchy method (AHP) is wide used for endeavor multi attribute decision-making issues in real things. In spite of its quality and ease in concept, this technique will cause by the choice maker's inability to translate his/her preferences for a few alternatives to another into a completely consistent preference structure.

2.2.VIKOR METHOD

Chu et al 2007 developed multicriteria optimization and compromise resolution. The VIKOR methodology was developed for multi-criteria optimization of advanced systems[5]. This methodology focuses on ranking and choosing from a collection of alternatives, and determines compromise solutions for a retardant with conflicting criteria, which may facilitate the choice manufacturers to achieve a judgment. Here, the compromise resolution could be a possible resolution that is that the nearest to the perfect, and a compromise means that an agreement established by mutual concessions. It introduces the multi-criteria ranking index supported the actual live of Closeness to the ideal resolution. Consistent with [5] the multi-criteria measure for compromise ranking is developed from the PLp-metric used as an aggregating function in an exceedingly compromise programming methodology. The assorted J alternatives square measure denoted as a1; a2; ….., aj. For various aj, the rating of the i^{th} aspect is denoted by f_{ij}, i.e. f_{ij} is that the value of i^{th} criterion function for the choice a_j; n is the number of criteria. Development of the VIKOR methodology started with the subsequent variety of Lp-metric:

$$LP.J = \left\{ \sum_{I=1}^{n} [w_i (f_1^* \quad - f_{ij} \quad)/(f^* \quad - f_1^-)p]1/p \right\}$$

$1 \le p \le \infty, j=1,2,3....j$

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.

2.3.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.

2.4.FUZZY APPROACH

In the decision making method, the decision maker is often faced with doubts, issues and doubts. In different words usual language to specific observation or judgment is often subjective, unsure or unclear. To work out the unclearness, ambiguity and judgment of human judgment, fuzzy set theory [6] was introduced to specific the linguistic terms in decision making process (DM).
Bellman and Zadesh [7] developed fuzzy multi criteria decision methodology (FMCDM) to resolve the lack of precision in distribution importance weights of criteria and therefore the ratings of alternatives concerning analysis criteria. This logical tool that people can depend on are generally measured the outcome of a bivalent logic (yes/no, true/false), however the issues expose by real-life things and human thought processes and approaches to problem-solving are by number means that bivalent. even as standard, bivalent logic relies on classic sets, formal logic relies on fuzzy sets. A fuzzy set could be a set of objects during which there's no clear-cut or predefined the boundary between the objects that are or don't seem to be members of the set. The key conception behind this definition is that of membership any object could also be a member of a collection to some degree, and a logical proposition may hold true to some degree. Every component during a set is related to a worth indicating to what degree element is a member of the set. This value comes inside the vary (0,1), wherever zero and one, severally, indicate the minimum and most degree of membership, whereas all the intermediate values indicate degrees of partial membership [8]. This approach helps decision making solve advanced deciding issues during a systematic, consistent and productive approach [9] and has been wide applied to tackle DM issues with multiple criteria and alternatives. In short, fuzzy set theory offers a mathematically precise approach of modeling obscure preferences as an example once it involves setting the weights of performances scores on criteria.

2.4.1.Conversion of Fuzzy to Crisp score

The five point method proposed by Chen and Hwang [10] first converts linquistic terms into fuzzy numbers and then the fuzzy numbers into crisp scores. The method is described below: This method systematically converts linquistic terms into their corresponding fuzzy numbers. It contains eight conversion scales. To demonstrate the method, a 5-point scale having the linquistic terms low, fairly low, medium, fairly high, and high [10], is considered. These linguistic terms can be equated to other terms like low, below average, average, above average and high.
The linguistic evaluations are converted into fuzzy numbers by using Chan and Hwang Five point scale as specified below.

Table.2.1 Five point conversion Scale

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

3. PROPOSED METHOD FOR FACILITATOR SELECTION -VIKOR

In this section a methodical approach of the VIKOR 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 good judgment of decision makers.Facilitator selection in lean manufacturing system first requires the identification of decision attributes (criteria). For this purpose, it is consider as group mulitple criteria decision making problem. This is illustrated the following set of terms.

Among various sets, two sets containing 5 criteria's, C = (C1, C2, C3, C4, C5),F=(F1,F2,F3,F4,F5), and another set containing 3 criteria's DM= (D1,D2,D3).

Where DM- A set of decision makers, F-A Set of possible facilitators, C- A set of criteria's.

The main aspects of the work are described; the proposed model has been applied to a lean facilitator selection process of a firm working in the field of spring manufacturing unit. The following steps are

Step1: The company desires to select a good lean facilitator. After preliminary screening , five candidate facilitator (F1,F2,F3,F4,F5) remains further evaluation.

Step 2: Committee of three decision makers (D1,D2,D3) have been formed to select the most suitable facilitator. The following first set of criteria have been defined.

C_1 - Education Qualification
C_2 - Knowledge of the Process
C_3 - Communication skills
C_4 - Leadership Ability
C_5 - Report Writing

Step3: Three decision makers use the linguistic weighting variables to asses the importance of the criteria. The importance weights of the criteria determined by these three decision makers are shown in table 3.1. Because to calculate the weights of criteria, it requires the first weight assessments from the experts of decision makers.

Table 3.1 Weights of each Criteria

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

The decision makers is also used the linguistic rating variables to evaluate the ratings of candidates with respect to each criterion. The ratings of the five facilitator by the decision makers under the various criteria are illustrated in tables 3.2,3.3, 3.4 of each decision makers opinion.

Table 3.2 Ratings of the five facilitators by DM1

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

Table 3.3 Ratings of the five facilitators by DM 2

Facilitator	C_1	C_2	C_3	C_4	C_5
F_1	BA	A	A	BA	A
F_2	AA	A	H	A	H
F_3	AA	AA	H	AA	H
F_4	H	AA	AA	AA	AA
F_5	BA	H	A	AA	A

Table 3.4 Ratings of the five facilitators by DM 3

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

Table 3.5: Final ratings of decisions makers

Criteria	DM_1	DM_2	DM_3	Score	Weights
C_1	0.895	0.895	0.895	2.685	0.267
C_2	0.895	0.895	0.695	2.485	0.248
C_3	0.695	0.495	0.695	1.885	0.189
C_4	0.495	0.695	0.495	1.685	0.168
C_5	0.495	0.495	0.295	1.285	0.128

Step 4: The linguistic evaluation shown in tables 3.1-3.4 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 3.6.

Table 3.6: Converted data

	C_1	C_2	C_3	C_4	C_5
Weights	0.267	0.248	0.189	0.168	0.128
F_1	0.43	0.50	0.43	0.43	0.43
F_2	0.56	0.63	0.70	0.63	0.70
F_3	0.83	0.56	0.83	0.56	0.76
F_4	0.83	0.56	0.76	0.56	0.76
F_5	0.37	0.62	0.24	0.62	0.36

Step 5: The values of S, R and Q are calculated by the following equations which are tabulated in tables (Where S-Utility measure, R- Regret measure, Q- Vikor index.)

$$Si = \sum_n^m w_j[((m_{ij})max) - (m_{ij})]/[(m_{ij})max) - (m_{ij})min]$$

$$Ri = Max\ of \sum_n^m w_j[((m_{ij})max) - (m_{ij})]/[(m_{ij})max) - (m_{ij})min]$$

$$Qi = v((s_i - s_{i\,min})/(S_{i\,max} - S_{i\,min})) + (1-v)((R_i - R_{min})/(R_{imax} - R_{imin}))$$

Table 3.7 Maximum criterion function of facilitators

C_1	C_2	C_3	C_4	C_5
0.83	0.63	0.83	0.63	0.76

Table 3.8 Minimum criterion function of facilitators

C_1	C_2	C_3	C_4	C_5
0.37	0.50	0.24	0.43	0.36

Table 3.9 Utility Measure (s) value of facilitators

F_1	F_2	F_3	F_4	F_5
0.8816	0.2168	0.1923	0.2147	0.6114

Table 3.10 Regret Measure (R) value of facilitators

F_1	F_2	F_3	F_4	F_5
0.2480	0.1560	0.1335	0.1335	0.2670

Table 3.11 VIKOR Index (Q) value of facilitators

F_1	F_2	F_3	F_4	F_5
0.920	0.101	0.000	0.016	0.804

Table 3.12 Ranking of the facilitators by S, R and Q in order

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

C_1 : $Q(F_4) - Q(F_3) \geq 1/(m-1)$

$(0.016-0) \leq (1/4)$

Condition C_1 is not satisfied.

C_2 : Facilitator F3 has been ranked as best in S and R

Condition C_2 is satisfied.

The ranking of the lean facilitator by S, R and Q in decreasing order is shown in Table 3.12, the compromise solution for the decision for set-1 is the facilitator F_3. The advantage rate of facilitators by S, R and Q are shown in the Figs. 3.1 to 3.3 respectively.

Fig. 3.1. Advantage rate of facilitators by Utility Measure by S

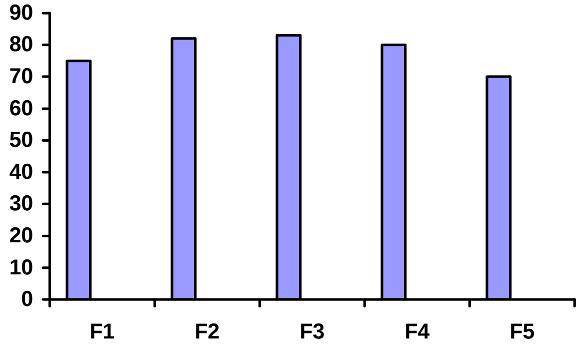


Fig.3.2 Advantage rate of facilitators by Regret Measure By R

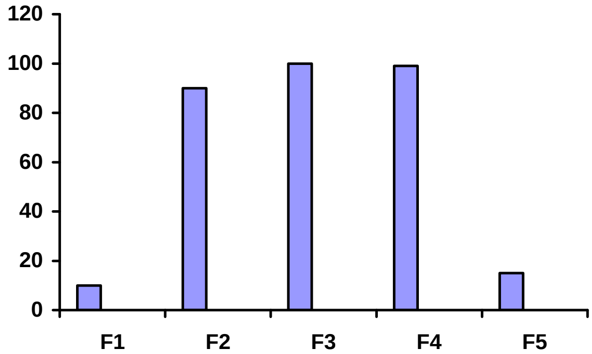
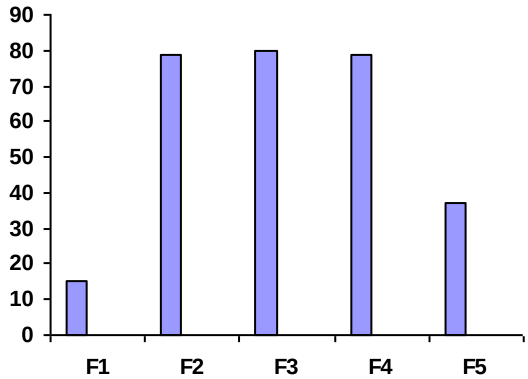


Fig. 3.3 Advantage rate of facilitators by VIKOR Index by Q



4. PROPOSED METHOD FOR FACILITATOR SELECTION –SAW

In this section a methodical approach of the SAW 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 good judgment of decision makers.

Process of SAW consist of these steps:

Step 1:

1) Construct a pair-wise comparison matrix (n x n) for criteria with respect to objective by using Saaty's 1-9 scale of pair-wise comparisons shown in Table 4.1. In other words, it is used to compare each criterion with each other criterion, one-by-one.

Table4.1. Saaty's[11] 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 favored very strongly over another
8	Very, very strong	
9	Extreme Importance	The evidence favoring 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
7) Find the consistency Index, CI, as follows:

CI = $(\lambda_{max} - n)/(n-1)$ (4.1)

Where n is the matrix size.

8) Calculate the consistency ratio, CR, as follows:
9) CR = CI/RI (4.2)
10) Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table 4.2. 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 4.2 Average Random Consistency (RI)

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

Step 2:

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

$nij = r_{ij} / r_j^{max}$; i=1,2,3……m;j=1,2,3……n (4.3)

The normalized decision matrix for negative criteria

$n_{ij} = r_j^{min} / r_{ij}$; ; i=1,2,3……m;j=1,2,3……n (4.4)

Where $r_j^{max} = maximum\ number\ of\ r\ in\ the\ column\ of\ j$

r_j^{min}=minimum number of r in the column of j

Step 3:

Evaluate each alternative, A by the following formula:

$$Ai = \sum wjx_{ij} \quad (4.5)$$

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

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. 4.1.

By using the same set of criteria which has chosen for facilitator selection using VIKOR method is applied in the present study. And the weights of criteria have been computed by using comparison matrix. The comparison matrix is shown in table 4.3. it indicating the relative importance of the criterion in the columns compared to the criterion in the rows.

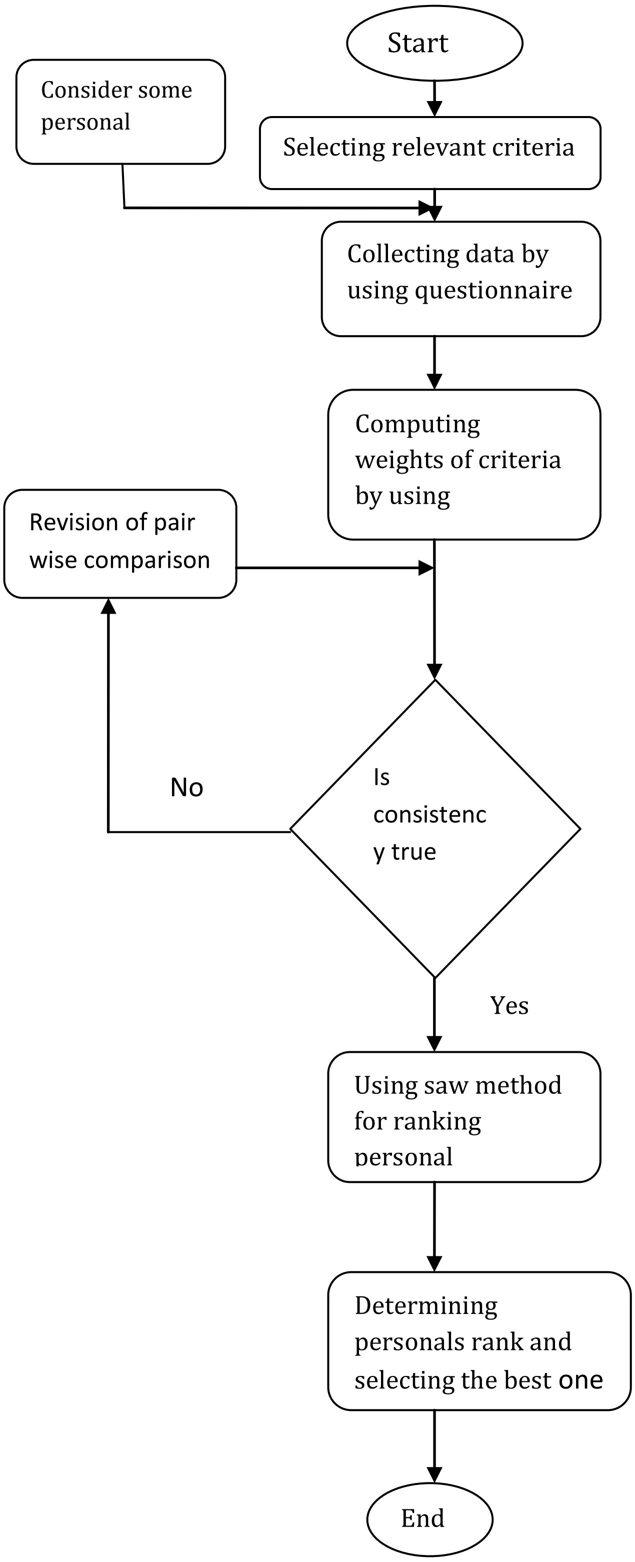


Fig. 4.1. Flow chart of the research frame work

Table 4.3 Criteria's name

C_1	Education Qualification
C_2	Knowledge of the Process
C_3	Communication skills
C_4	Leadership Ability
C_5	Report Writing

The weights of the criteria have been computed by using comparison matrix mean while data was gathered from three experts of the opinion with questioner in one of the spring manufacturing unit by using saaty[11] scale values as shown in the table.4.4

Table 4.4 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

Table 4.5 Weights of criteria by Comparison matrix.

Criteria	C_1	C_2	C_3	C_4	C_5	Weights
C_1	1	2	2	3	3	0.39
C_2	0.5	1	2	1	1	0.19
C_3	0.5	0.5	1	1	1	0.14
C_4	0.33	1	1	1	1	0.15
C_5	0.33	1	1	1	1	0.15
Total	2.66	4.5	7	7	7	1

5. Test of consistency for the criteria

The consistency Rate calculated was 0.0125 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) :Table 5.1 computing weighted sum vector

1	2	2	3	3		0.39		1.950
0.5	1	2	1	1		0.19		0.965
0.5	0.5	1	1	1	X	0.14	=	0.730
0.33	1	1	1	1		0.15		0.750
0.33	1	1	1	1		0.15		0.750

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.

Table 5.2 consistency vector values (CV)

1.950		0.39		5.00
0.965		0.19		5.07
0.730	/	0.14	=	5.21
0.750		0.15		5.00
0.750		0.15		5.00

$$\lambda_{max} = \underline{(5.00 + 5.07 + 5.21 + 5.00 + 5.00)}\ /5 = 5.056$$

Consistency Index (C1) and consistency ratio are calculated using equations 4.1 and 4.2

$$C1 = \frac{5.056 - 5}{5 - 1} = 0.014$$

Consistency rate will be computed as follows as the amount of Random Index (R1) could be got by looking at Table 5.3, according to the value of n (n is size of matrix).

CR = C1/R1 = 0.014/1.12 = 0.0125

Table 5.3 Average stochastic uniformity index target value of judgment matrix

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	.85	.9	1.12	1.24	1.32	1.41	1.45	1.51

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 4.1 and computing weights of criteria in Table 4.5, following steps shows the procedure of SAW method

Table 5.4 Collected data based on scale values (1-9)

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

C means Criteria and F means Facilitator

Step 2: In this case study, criteria has been taken as positive and normalized decision matrix for positive criteria are calculated using equations 4.3 .

The results are as shown in Table 5.6.

Table 5.5 Weighted Criteria

C_1	C_2	C_3	C_4	C_5
0.39	0.19	0.14	0.15	0.15

Table 5.6 Normalized decision matrix

	C_1	C_2	C_3	C_4	C_5
F_1	0.39	0.1615	0.119	0.1275	0.1275
F_2	0.39	0.1349	0.140	0.150	0.150
F_3	0.39	0.1615	0.119	0.1275	0.150
F_4	0.39	0.190	0.099	0.1275	0.1275
F_5	0.39	0.190	0.119	0.1275	0.1065

Step 3:

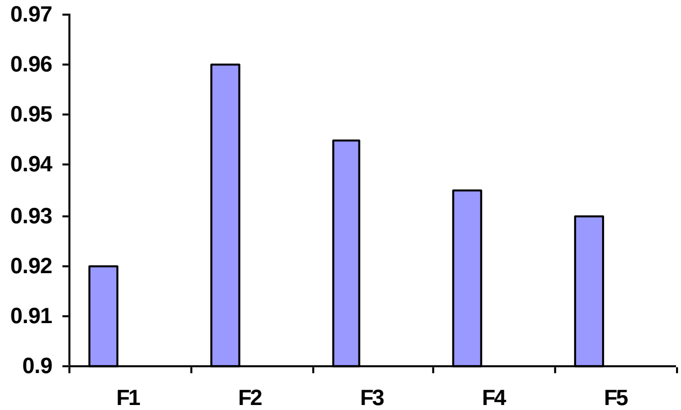
By using the equation 4.5, the simple additive weighting method evaluates each alternative, Ai and is presented in Table5.7

Table 5.7 Ranked Personnel

F_1	F_2	F_3	F_4	F_5
0.925	0.960	0.945	0.934	0.933

Finally in SAW method, the best personnel is F_2 and then F_3, F_4, F_5 and F_1 will be respectively for the selected first set of criteria. The rating of facilitators using first set of criteria is shown in Fig. 5.1.

Fig. 5.1 Rating of facilitators (Method : SAW)



6. RESULTS AND DISCUSSION

In the global competition of spring markets, the concept of the skilled and trained personnel selection problem has a vast interest for future survival. It depends mostly on the appropriate dedication of their personnel to companies thereby selecting a Lean facilitator becomes very important.

In this study, the application of the VIKOR and SAW methods are presented for the selection Lean facilitator in the spring manufacturing industry. Five alternatives are considered to illustrate the application capability of this method. It is quite clear that selection of a right person for a given manufacturing application involves a large number of considerations.

Table 6.1 Ranking of Lean facilitators by using VIKOR and SAW

VIKOR Method	SAW Method
First criteria	First criteria
F_3	F_2
F_4	F_3
F_2	F_4
F_5	F_5
F_1	F_1

For the first criteria F3, F4, F2, F5, F1 and F2, F3, F4, F5, F1 are the ranking sequence according to VIKOR and SAW method respectively. Thus, this popular MCDA method can be successfully employed by the decision makers for the process of facilitator selection in the spring manufacturing domain.

7. CONCLUSION

Several industries have exposed the advantage of the lean manufacturing system to increase the competitive advantage.

Selection of facilitator problem becomes more important issue to implement a successful organization. The selection problem is often controlled by uncertainity in practice, and in such situation fuzzy set theory is an appropriate tool to deal with this kind of problem.In real situation the decision maker is not able to express his ratings precisely in numerical values and the evaluations is expressed in linguistic terms. In the present work two multi criteria decision making methods are adopted for facilitator selection problem. The methods are VIKOR and SAW. The proposed methods are very flexible and also enable us to determine the ratings and outranking order. In this study fuzzy environment is proposed to deal with both qualitative and quantitative criteria and select the suitable facilitator effectively.

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