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Selection of Equipment by Using Saw and Vikor Methods

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ABSTRACT
Now a days, Lean manufacturing becomes a key strategy for global competition. In this environment the most important process is the selection of the equipment. Equipment selection is a very important issue for effective manufacturing companies due to the fact that improperly selected machines can negatively affect the overall performance of manufacturing system. The availability of large number of equipments are more hence, the selection of suitable equipment for certain operation/ product becomes difficult. On the other hand selecting the best equipment among many alternatives is a Multi-criteria decision making (MCDM) Problems.
In this Paper an approach which employs SAW, VIKOR Methods proposed for the equipment selection problem. The SAW and VIKOR is used to analyze the structure of the equipment selection problem and to determine weights of criteria and to obtain Final Ranking.
Keywords:- lean manufacturing, Equipment selection, fuzzy, VIKOR, SAW method.

I. INTRODUCTION

Multi Criteria Decision Making (MCDM) is one of the most considered Branches of Operations Research. Multi criteria decision making refers to making decisions that involves multiple usually, conflicting criteria.

The problem in multi criteria decision making are classified in to two categories. Multiple attributes decision making, multiple objective decision making.The terms MADM and MCDM are often used to indicate the identical class of models and are classified in practice. Usually MADM is used when the model cannot be started in mathematical equations others wise MODM is Used (HWANG & YOON; 1980)

Equipment Selection is one of the most prominent problems in spring manufacturing industry.

Mechanical engineers have to face difficult decision during equipment selection stage as the decision has a strong influence on the economic life of any industry. In addition the outputs of a manufacturing system (the rate, quality and cost) depend on the selection of equipment and its implementation. On the other hand the selection of a new machine is a time consuming and difficult process requiring advanced knowledge and experience deeply. So the selection process can be difficult task for engineers and managers. For a proper and effective evaluation, the decision maker may need a large amount of data to be analyzed and many attributes to be considered.

To solve the problem MCDM methods became popular in this field. MCDM consists of generating alternatives, establishing criteria (attributes) evaluation of alternatives, assessment of criteria weights and application of a ranking system each of the criteria is related with an objective in the given decision context and normalization is used for transformations different criteria in to a compatible measurement.

The properties whose higher values are desirable called positive criteria attributes and those properties whose smaller values are always preferable named negative criteria (or) cost criteria.

By Using MCDM techniques the decision Maker can evaluate the subjective criteria concerning the problem of equipment selection. The decision maker wishes to consider more than one objective criterion for the equipment selection stage. Among the number of alternatives the most suitable equipment must be selected according to the objectives and alternatives. The decision maker should be an expert (or) at least be very familiar with the specifications of Machines to select the most suitable one.

In spring manufacturing industry MCDM methods can be applied for equipment selection because these methods include subjective and objective criteria the affect the selection among alternatives.

II. 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 [1]. 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 [2] 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 [3]. However, it's troublesome in several problems to get a mathematical illustration of the choice maker's utility perform . 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 multi criteria optimization and compromise resolution. The VIKOR methodology was developed for multi-criteria optimization of advanced systems [4]. 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 [4] 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 ith aspect is denoted by f_{ij}, i.e. f_{ij} is that the value of ith criterion function for the choice aj; n is the number of criteria. Development of the VIKOR methodology started with the subsequent variety of Lp-metric

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

$1 \leq p \leq \infty, j=1,2,3 \ldots .j$

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.

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. furry aproach

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 (5) was introduced to specific the linguistic terms in decision making process (DM).

Bellman and Zadesh (6) 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 bivalent logic (yes/no,true/false), however the issues expose by the real life things and human thought processes and approaches to problemsolving are by number means that bivalent. Even as standard, bivalent logic relies on classic sets, formal logical 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 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 member ship, whereas all the intermediate values indicate degrees of partial membership , This approach helps decision making solve advanced deciding issues during a systematic, consistent and productive approach helps decision making solve advanced deciding issues during a systematic, consistent and productive approach (7) 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 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 (8) 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 conversion scales. To demonstrate the method, a 5- point scale having the linguistic terms low, fairly low, medium, fairly high, and high ,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
w	M_1	0.115
low average	M_2	0.295
erage	M_3	0.495
ove average	M_4	0.695
gh	M_5	0.895

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

A case study is conducted in spring manufacturing unit at Anatapuram. The data is collected for the current industry with the recommendation of decision makers. In the present study three decision makers are from various departments.

In this section a methodical approach of the SAW to solve the equipment 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 3.1. In other words, it is used to compare each criterion with each other criterion, one-by-one.

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

Table 3.1. Saaty's[13] 1-9 Scale of Pair-wise comparisons

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:

$CI = (\lambda_{max} - n)/(n-1)$ (3.1)

Where n is the matrix size.

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

9) CR = CI/RI (3.2)

10) Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table 2.2. 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 3.2 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:

$$nij = r_{ij}/r_j^{max} \quad ; \quad i=1,2,3……m;j=1,2,3……n \quad (3.3)$$

The normalized decision matrix for negative criteria

$$n_{ij}=r_j^{min}/r_{ij} \quad ; \; ; \quad i=1,2,3……m;j=1,2,3……n \quad (3.4)$$

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:

$$Ai = \sum wjx_{ij} \quad (3.5)$$

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. 3.1.

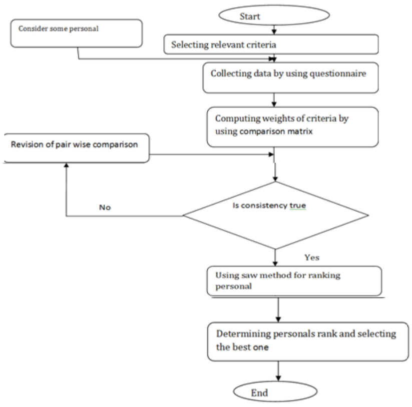


Fig. 3.1. Flow chart of the research frame work

By using the same set of criteria which has chosen for supplier selection using VIKOR method is applied in the present study. And the weights of criteria have been computed by using comparison matrix. The table 3.3 is shown as name of the criteria.

Table 3.3 Criteria's name

C_1	Productivity
C_2	Ease of Machine Tool Handling
C_3	Surface Finish
C_4	Machine availability
C_5	Spare parts availability

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.3.4

Table 3.4 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

3.2 Test of consistency for selected set of criteria

The consistency Rate calculated was 0.03897 that is less than0.1, indicating sufficient consistency. The following steps will show how the test of consistency will be done.

Step 1 : In order to calcuate computingg Weighted Sum Vector (WSM):

	C_1	C_2	C_3	C_4	C_5	Weights
C_1	1	1	2	1	2	0.24
C_2	1	1	2	2	2	0.27
C_3	0.5	0.5	1	2	2	0.19

C_4	1	0.5	0.5	1	1	0.14
C_5	0.5	0.5	0.5	1	1	0.12
Total	4	4.5	6	7	8	1

Table 3.5 Weights of criteria by Comparison matrix

1	1	2	1	2		0.24		1.270
1	1	2	2	2		0.27		1.410
0.5	0.5	1	2	2	X	0.19	=	0.965
1	0.5	0.5	1	1		0.14		0.730
0.5	0.5	0.5	1	1		0.12		0.610

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 3.6 consistency vector values (CV)

1.270		0.24		5.29
1.410		0.27		5.22
0.965	/	0.19	=	5.07
0.730		0.14		5.21
0.610		0.12		5.083

Consistency Index (CI) and consistency ratio are calculated using equations 3.1 and 3.2

$$CI = \frac{5.1746 - 5}{5 - 1} = 0.04365$$

$$\lambda_{max} = \frac{5.29 + 5.22 + 5.07 + 5.21 + 5.083}{5} = 5.1746$$

Consistence index (CI)and consistence ratio are calculated using equations

$$CI = (\lambda_{max} - n)/(n-1) \quad \text{---3.1}$$

Where n is the matrix size.

=5.1746-5/5-1 =0.04365

Consistency rate will be computed as follows as the amount of Random Index (RI) could be got by looking at

Table 3.7, according to the value of n (n is size of matrix).

CR = <u>C1/RI</u> = 0.04365/1.12=0.03897

Table 3.7 : Average stochastic uniformity index target value of judgment matrix

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	8.5	0.9	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 date from experts, based on scale values 1-9 in Table 3.4 and computing weights of criteria in Table 3.5, following steps shows the procedure of SAW method:

Table 3.8 Collected data based on scale values (1-9)

	C_1	C_2	C_3	C_4	C_5
E_1	7	6	6	6	5
E_2	7	6	6	6	6
E_3	7	6	5	7	6
E_4	6	7	6	6	5
E_5	7	6	7	6	6

<u>C</u> means Criteria and <u>E</u> means Equipment

Step 2:

In this case study, criteria has been taken as positive and normalized decision matrix for positive criteria are calculated using equations 3.3 The results are as shown in Table 3.9

Table 3.9 Normalized decision matrix :

	C_1	C_2	C_3	C_4	C_5
E_1	0.240	0.2295	0.1615	0.119	0.0996
E_2	0.240	0.2295	0.1615	0.119	0.120
E_3	0.240	0.2295	0.1349	0.140	0.120
E_4	0.204	0.270	0.1615	0.119	0.0996
E_5	0.240	0.2295	0.190	0.119	0.120

3.10 Weighted Criteria

C_1	C_2	C_3	C_4	C_5
0.24	0.27	0.19	0.14	0.12

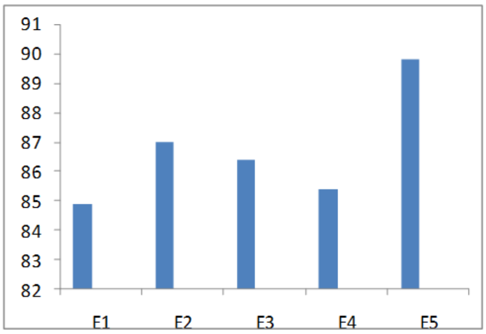
Step 3:

By using the equation 3.5, the simple additive weighting method evaluates each alternative, A and is presented in Table 3.11

Table 3.11 Ranked Personnel

E_1	E_2	E_3	E_4	E_5
0.849	0.870	0.864	0.854	0.898

in SAW method, the best equipment is E_5 and then E_2, E_3, E_4, and E_1 respectively for the selected set of criteria. The rating of equipment using second set of criteria is shown in Fig.3.1



ig:3.1 Ratings of Equipments by SAW method

(Iv) proposed methodology – vikor method :.

In this section a methodical approach of the VIKOR to solve the equipment selection problem under a fuzzy environment. The magnitude weights of various criteria and the rating of qualitative criteria measured as linguistic variables. Because linguistic assessment merely about the good judgment of decision makers. Equipment selection in lean manufacturing system first requires the identification of decision attributes (criteria). For this purpose,, it is consider as group multiple 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), E=(E1,E2,E3,E4,E5), and another set containing 3 criteria's DM = (D1,D2,D3).

Where DM-A set of decision makers,S-A set of possible equipment, C-A set of critieria's.

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

Step 1 : The company desires to select a good equipment. After preliminary screening, five equipments (E1,E2,E3,E4,E5),remains further evaluation.

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

Table 4.1 Set Of Criteria's

C1	Productivity
C2	Ease of Machine Tool Handling
C3	Surface finish
C4	Machine availability
C5	Spare parts availability

Step 3 : Three decision makers use the linguistic weighting variables to asses the importance of the criteria. The importance weights of the criteria determined by these decision makers are sown in table 4.2. Because to calculate the weights of criteria, it requires the first weight assessments from the experts of decision makers.

Table 4.2 Weights of each Criteria

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

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 equipments by the decision makers under the various criteria are illustrated in table 4.3 of each decision makers opinion

Table 4.3 : Rating of Equipments of five equipments under each criterion in terms of linguistic variables determined by DMs

Criteria	C1			C2			C3			C4			C5		
Equipment	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
E1	AA	A	BA	H	AA	AA	AA	AA	A	AA	A	A	H	AA	A
E2	BA	BA	L	AA	AA	A	H	A	A	AA	AA	A	H	H	AA
E3	H	AA	A	H	H	AA	H	H	AA	H	AA	A	AA	A	A
E4	AA	AA	BA	AA	A	A	AA	H	H	H	AA	BA	A	A	A
E5	BA	BA	L	AA	AA	AA	AA	A	BA	AA	A	A	A	A	BA

Step4 :

The linguistic evaluations shown in Tables 4.2 and 4.3 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 shown in Tables 4.4(a),4.4

Table 4.4 (a) Weight Evaluation of Equipment Criteria

Weights	DM_1	DM_2	DM_3	M3	Weight
C_1	0.895	0.895	0.895	2.685	0.267
C_2	0.695	0.495	0.695	1.885	0.189
C_3	0.895	0.895	0.695	2.485	0.248
C_4	0.495	0.495	0.295	1.285	0.128
	0.495	0.495	0.295	1.685	0.168

Table 4.4 Decision Matrix in Crisp score for Equipments

	C_1	C_2	C_3	C_4	C_5
Weights	**0.267**	**0.189**	**0.248**	**0.128**	**0.168**
E_1	0.50	0.76	0.63	0.56	0.70
E_2	0.24	0.63	0.63	0.63	0.83
E_3	0.70	0.83	0.83	0.70	0.56
	0.56	0.56	0.83	0.63	0.50
	0.24	0.70	0.50	0.56	0.43

Step : 5 : The values of S,R and Q are calculated by using the equations, for all the equipments.

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

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

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

(Where S- Utility measure, R- Regret measure, Q- Vikor index.)

table 4.5maximaum criterion fuction of equipments

C_1	C_2	C_3	C_4	C_5
0.70	0.83	0.83	0.70	0.83

Table 4.6 Minimum criterion function of Equipments

C_1	C_2	C_3	C_4	C_5
0.24	0.56	0.50	0.56	0.43

Table 4.7 Utility Measure (S) value of Equipments

E_1	E_2	E_3	E_4	E_5
0.497	0.621	0.113	0.473	1.214

Table 4.8 Regret Measure ® value of Equipments

E_1	E_2	E_3	E_4	E_5
0.150	0.267	0.113	0.189	0.480

Table 4.9 VIKOR Index (Q) value of Equipments

E_1	E_2	E_3	E	E_5
0.21	0.41	0.00	0.25	0.97

The ranking of the equipments by S, R and Q in decreasing order are shown in Table 4.10

Table 4.10 Ranking of the Equipments by S,R and Q in order

By S	E_3	E_4	E_1	E_2	E_5
By R	E_3	E_1	E_4	E_2	E_5
By Q	E_3	E_1	E_4	E_2	E_5

C1: $Q(E_1)- Q(E_3) \geq 1/(m-1)$
$(0.21-0) \leq (1/4)$
Condition C_1 is NOT satisfied.
C_2: Equipment E_3 has been ranked as best in S and R
Condition C_2 is satisfied.

From the table 4.10 it can be seen that, the compromise solution for the decision is Equipment E_3 with the advange rate of 21% than the alternative equipment E1 which is second ranked. The best ranked equipment E3 have 21%,25%,41%,59% advantage rate over the alternatives E1,E4,E2,E5 as shown in fig 4.1

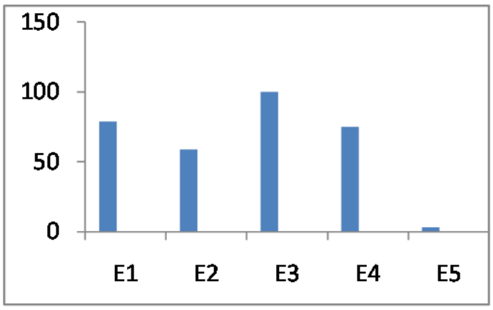
Fig. 4.1 Advantage Rate Of Equipments By Vikor Index.

Rank	VIKOR method	SAW method
1	E3	E5
2	E1	E2
3	E4	E3
4	E2	E4
5	E5	E1

V. CONCLUSTIONS RESULTS

In this study, the application of VIKOR and SAW method are presented for the selection of equipment in the spring manufacturer industry. Five alternatives are considered to illustrate the application capability of his method. I is quite clear that Selection of a proper machine tool for a given manufacturing involves a large number of considerations.

Table 5.1 Ranking of Lean equipment by using VIKOR and SAW



VIKOR uses the measures of the considered criteria with their relative importance and the final ranking is arrived as E3, E1, E4, E2, E5. And from the SAW method E5, E2, E3, E4, E1 is the ranking sequence. This popular MCDA method can be successfully employed by the decision makers for the process of equipment selection in spring manufacturing domain

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