

Solution of different multi-criteria decision making engineering problems by PROMETHEE II and VIKOR

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By

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Certificate of Approval

This is to certify that the thesis entitled *Solution of different multi-criteria decision making engineering problems by PROMETHEE II and VIKOR* submitted by *Aditya Kumar Gautam* has been carried out under my supervision in partial fulfilment of the requirements for the Degree of Bachelor of Technology (B. Tech.) in Mechanical Engineering at National Institute of Technology, Rourkela, and this work has not been submitted elsewhere before for any other academic degree/diploma.

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Abstract

In our day to day life we come across situations in which we have a number of choices available in front of us and it is difficult to choose among them on the basis of a single criterion. Different alternatives have different attributes related to them so it is important for the decision maker to weigh all the alternatives and come up with a common index on the basis of which he can compare his alternatives. In this thesis, to encounter with such problems, multi criteria decision making methods have been used to come up with the best alternative. Two methods namely PROMETHEE II (preference ranking organization method for enrichment evaluation) and VIKOR (višekriterijumsko kompromisno rangiranje) have been used to solve different engineering problems ranging from selection of machining parameters to choosing a supplier for an industry. PROMETHEE II uses the outranking method for the ranking of alternatives and VIKOR is a compromise solution method. Four selected real life problems have been solved by both the methods and the results have been compared with each other.

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1. Introduction

Making a choice about a certain thing is very difficult in this world because we have a variety of choices and we make our choices based on various criteria having some positive and some negative attributes. We make our choices by comparing and ranking objects according to criteria defined by us, such as while choosing a car we look through various properties of the car like it's top speed, its comfort level, safety, cost, mileage etc. and after that we make our choice depending on what is most important for us. One of the various methods to rank, compare and order several alternatives is based on the notion of "Multiple Criteria Decision Making (MCDM)". It has been recognized as an efficient statistical method in which we can combine different indices of various criteria for all the choices available to us into a single feasible data which can help in comparing and ranking the objects. A typical MCDM problem has a series of alternatives with different criteria which have to be assessed using different methods and then the alternatives have to be ranked.

The MCDM problems can be mainly classified into two types [1]: -

- Multi-Criteria evaluation problems: - Here the number of alternatives is finite and are clearly known at the beginning of the solution process.
- Multi-Criteria design problems: - The alternatives here are not explicitly known. We have an infinite number of alternatives available or are very typically large in number if countable.

MCDM problems can be solved by methods that are commonly classified based on the timing of preference information obtained from the decision maker. Criterion space or the decision space can be used to represent a MCDM problem. But if the criteria are combined together using a linear weighted function than it is possible to represent the problem in weighted space. Various analytical methods have been proposed to give a suggestion in conflict management situations by a large number of papers. Among these approaches available to make a difficult choice involving various alternatives and criteria, one of the most appropriate is multi-criteria decision making. The various steps involved in a MCDM problem are [2]: -

- a) The system relations attributes are obtained that relate the system capability to reach the goals.
- b) Various alternatives are then generated to reach the goal.
- c) The performance function of these alternatives for every criterion available is obtained.
- d) Applying the chosen method of MCDM to solve for the best alternative among the available ones.
- e) Accepting the best alternative available to reach the goal.
- f) If our aim is not fulfilled we gather more data about the model and go for next iteration of the MCDM process.

The steps a) and e) are taken care of by upper level decision makers and the rest of the steps are carried upon by the engineers. Here in this thesis out of various MCDM methods available PROMETHEE II and VIKOR method have been used to encounter various engineering problems. Various other MCDM methods are shown below in Figure 1. Various engineering problems relating to determination of machining parameters, determinations of a warehouse location and problem regarding choosing a vendor has been taken up and have been solved by using the above mentioned two methods. To determine the weightage of various criteria AHP has been used. The main aim of the project is to determine the ranks of different alternatives available to us in the chosen problems and analyse and compare the results obtained by both the processes.

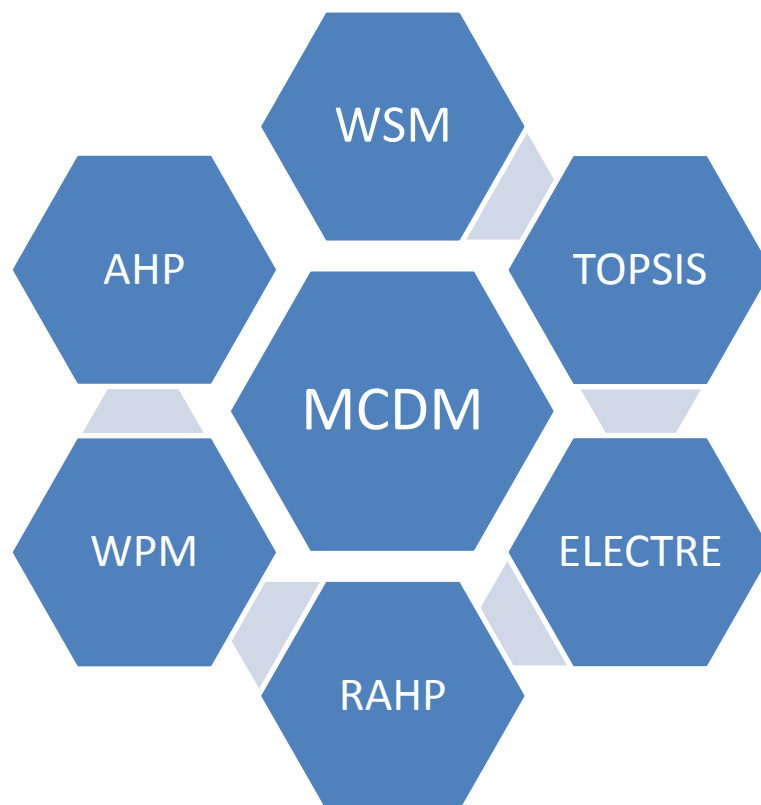


Figure 1. Classification of MCDM methods

2. Literature Review

The main aim of this literature review is to determine the importance of various MCDM methods in helping us to make a choice based on various criteria from different available alternatives. Many engineering problems have been taken up by various authors and in all those problems MCDM methods have been used to determine the best alternative may it be machining parameters or selection of cutting tool etc.

Chauhan and Vaish [3] used various MCDM approach for the selection of hard coating material. Various materials have given rise to intense research in the field of material selection. Technique for order preference by similarity to ideal solution (TOPSIS) was used for ranking these materials by him. He used material selection charts (Ashby approach) to select hard coating materials. Pareto-optimal hard coating materials were determined for trade-off between hardness (H), H/E and H^3/E^2 (E: Young's modulus). Çalışkan [4] used EXPROM2 (preference ranking organization method for enrichment evaluation), TOPSIS (technique for order performance by similarity to ideal solution) and VIKOR for the selection of boron based tribological hard coatings. The alternatives consisted of multicomponent nanostructured TiBN, TiCrBN, TiSiBN and TiAlSiBN coatings and the material selection criteria were hardness (H), young's modulus (E), elastic recovery, friction coefficient, critical load, H/E and H^3/E^2 ratios.

Ren et al. [5] studied four biomass-based technologies including pyrolysis, conventional gasification, supercritical water gasification and fermentative hydrogen production and used a novel fuzzy multi-actor multi-criteria decision making method to determine that the best process was biomass gasification for sustainable production of hydrogen. Keramati et al. [6] proposed a method based on the grouped fuzzy decision-making approach in order to evaluate and rank the most suitable suppliers for outsourcing activities in Iran national steel industrial group. The proposed method was used and experts presented their views in linguistic words, a range of numbers, deterministic or fuzzy numbers. Thereafter every supplier was ranked based on the available model criteria. The most effective criterion for determining the supplier selection was also determined by him. Adhikary and Kundu [7] used MCDM methods in selection of the various small parameters involved in a small hydropower project where the investment is a bit risky and depends on different factors and policies.

Various engineering problems as mentioned above have been solved by using different MCDM techniques. Here this project thesis also involves solution of different engineering problems which have been solved by the help of different MCDM techniques by using PROMETHEE II and VIKOR methods. The different engineering problems taken up are mentioned below: -

- a) Thirumalai and Senthilkumaar [8] conducted experiment for the selection of machining parameters for Inconel 718 and optimized the experimental values to obtain non dominated solutions and then ranked the different alternatives available on the basis of various criteria using TOPSIS.
- b) Ozcan et al. [9] used AHP, TOPSIS, ELECTRE and Grey Theory to make a comparative analysis of the 4 choices available for the warehouse selection based on the criteria of unit price, stock holding capacity of warehouse, average distance to shops , average distance to main suppliers and the movement flexibility of the warehouse.
- c) Maity et al. [10] determined the process of selecting the cutting tool material by using the grey complex proportional assessment (COPRAS-G) method and assessed all the alternatives available for the selection based on the decided criteria.
- d) Shahroudi and Rouydel [11] proposed an integrated approach of ANP- TOPSIS to evaluate suppliers in Iran's auto industry. Selection of a supplier in any industry is a very difficult task and we have to consider various factors such as cost, on time delivery etc. to determine the supplier and the amount of supply we should order from various suppliers. This paper shows a detailed study for selection of a supplier for auto industry.

3. Calculation of Weights

As mentioned earlier to determine the rank of different alternatives available we need to determine the weights of each criterion. Weightage can be defined as the importance of those criteria for determining our choice. Both AHP and ENTROPY methods can be used to determine the weightage of different criterion. These two methods can be used together or separately as required. In this thesis AHP method has been used to determine the weightage of each criterion in different problems.

AHP METHOD

Saaty [12] developed the AHP method to model subjective decision-making processes based on MCDM in a hierarchical system [13]. This strategy involves fundamentally three standards: firstly, structure of the model; also, relative judgment of the options and the criteria; in conclusion, amalgamation of the necessities. For correlation of a set of n criteria pairwise as indicated by their relative significance weights, the pairwise examination matrix is utilized and it can be represented as [13]: -

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{1n} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix}, a_{ii} = 1, a_{ij} = 1/a_{ji}, a_{ji} \neq 0$$

where the criteria are denoted by a_1, a_2, \dots, a_n . The relative importance between two criteria is rated by use of a scale with the digits 1, 3, 5, 7 and 9, where 1 denotes “equally important”, 3 for “slightly more important”, 5 for “strongly more important”, 7 for “demonstrably more important” and 9 for “absolutely more important”. The digits 2, 4, 6 and 8 are used to facilitate a compromise between slightly differing judgments [14]. These comparative weights are obtained by finding the eigenvector w with respective λ_{\max} that satisfies $A*w = \lambda_{\max}*w$, where λ_{\max} is the largest eigenvalue of the matrix A. In order to ensure the consistency of the subjective perception and the accuracy of the comparative weights, the consistency index (C.I.) and the consistency ratio (C.R.) are calculated. The consistency index (C.I.) is $CI = (\lambda_{\max} - n)/(n - 1)$ where n is the number of the criteria. The numerical value of the C.I. should be lower than 0.1 for confident result. The consistency ratio (C.R.) can be calculated as:
 $CR = CI/RI$.

The R.I. is determined for different size matrixes, and its value is 1.25 for a 6 *6 matrix. The C.R. should be under 0.1 for a reliable result [13].

4. PROMETHEE II

The EXPROM2 method is the modified and extended version of PROMETHEE II method which is based on the notion of ideal and anti-ideal solutions. In this method, first a basic concept of fuzzy outranking relation is considered and built into each criterion by pairwise comparison measures for alternatives to different relation- degrees in each other. These different relation-degrees are then used to set up different orders on a finite set of feasible solutions. These different relation-degrees are then used to set up different orders on a finite set of feasible solutions [13].

The steps of PROMETHEE II method are summarized below [15-17]: -

- First, the normalization of the decision matrix for beneficial criteria and non-beneficial criteria is performed by the below mentioned equations: -

$$r_{ij} = [x_{ij} - \min(x_{ij})] / [\max(x_{ij}) - \min(x_{ij})] \quad i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n$$

$$r_{ij} = [\max(x_{ij}) - x_{ij}] / [\max(x_{ij}) - \min(x_{ij})]$$

where x_{ij} designates the performance measure of i^{th} alternative with respect to j^{th} criterion and r_{ij} shows the normalized value of x_{ij} .

- The differences in criteria values (d_j) between different alternatives pair-wise are calculated.
- In order to calculate preference function $P_j(i, i')$ the below mentioned equations are used. The preference functions are utilized for the measurement of the degree by which alternative i dominates alternative i' for j^{th} criterion. Usual criterion, which is one of the generalized preference functions, is used here.

$$P_j(i, i') = 0 \quad \text{if } r_{ij} \leq r_{i'j} \qquad P_j(i, i') = (r_{ij} - r_{i'j}) \quad \text{if } r_{ij} \geq r_{i'j}$$

- The weak preference index (aggregated preference function), $WP_{ij}(i, i')$, is calculated using following equation: -

$$WP(i, i') = \left[\sum_{j=1}^n w_j \times P_j(i, i') \right] / \sum_{j=1}^n w_j$$

where w_j is the weight of j^{th} criterion obtained by the compromised weighting method.

- The strict preference function, $SP_j(i, i')$, is defined as: -

$$SP_j(i, i') = [\max(0, d_j - L_j)] / [dm_j - L_j]$$

where L_j indicates the limit of preference (0 for usual criterion preference function, and indifference values for other five preference functions) and dm_j is the difference between ideal and anti-ideal values of j^{th} criterion.

Strict preference index, $SP(i, i')$, is,

$$SP(i, i') = \left[\sum_{j=1}^n w_j \times SP_j(i, i') \right] / \sum_{j=1}^n w_j$$

- Total preference index, $TP_j(i, i')$, is,

$$TP(i, i') = \text{Min}[1, WP(i, i') + SP(i, i')]$$

- Leaving (positive) flow for i^{th} alternative is obtained by the below mentioned and shows how much an alternative dominates the other alternatives.

$$\varphi^+(i) = \frac{1}{m-1} \sum_{i'=1}^m TP(i, i') \quad (i \neq i')$$

- Entering (negative) flow for i^{th} alternative is obtained by the below mentioned and expresses how much an alternative is dominated by the other alternatives.

$$\varphi^-(i) = \frac{1}{m-1} \sum_{i'=1}^m TP(i', i) \quad (i \neq i')$$

- In order to obtain the complete pre-order, the net outranking flow, $\varphi(i)$, for each alternative is calculated.

$$\varphi(i) = \varphi^+(i) - \varphi^-(i)$$

The best alternative is determined by the one with the highest $\varphi(i)$ value.

5. VIKOR

The VIKOR, the compromise solution method, was introduced as an applicable technique to implement within MCDM [18].

The main procedure of the VIKOR method is described below:

- First, the best, i.e. $(x_{ij})_{\max}$ and the worst, i.e. $(x_{ij})_{\min}$ values of all criteria are determined from decision matrix.
- The values of E_i and F_i are calculated from equations below respectively.

$$E_i = \sum_{j=1}^n w_j [(x_{ij})_{\max} - (x_{ij})] / [(x_{ij})_{\max} - (x_{ij})_{\min}]$$

$$F_i = \text{Max}^p \text{ of } \{w_j [(x_{ij})_{\max} - (x_{ij})] / [(x_{ij})_{\max} - (x_{ij})_{\min}]\}$$

- The values of P_i are calculated.

$$P_i = v((E_i - E_{i-\min}) / (E_{i-\max} - E_{i-\min})) + (1 - v)((F_i - F_{i-\min}) / (F_{i-\max} - F_{i-\min}))$$

where $E_{i-\max}$ designates the maximum value of E_i , and $E_{i-\min}$ designates the minimum value of E_i ; $F_{i-\max}$ is the maximum value of F_i , and $F_{i-\min}$ is the minimum value of F_i , v is used as the weight of the strategy of 'the majority of criteria'. The value of v is usually taken as 0.5, while it can take any value from 0 to 1.

- According to the values of P_i , E_i and F_i , the alternatives are separately arranged in the ascending order in order to obtain three ranking lists. The compromise ranking list for a given v is obtained by ranking according to P_i measures. The best alternative is determined as the one with the minimum value of P_i in the P ranking.

6. Problems and their Solutions

6.1 Use of PROMETHEE II and VIKOR in the selection of machining parameters for Inconel 718.

The set of non-dominated solutions obtained using the non-sorted genetic algorithm for multi-objective functions is taken from the paper available [8] and multi-criteria decision making (MCDM) is used to determine a single solution from the set of non-dominated solutions. The experiment involves the high-speed using carbide cutting tool for the machining of Inconel 718 where 6 output parameters are measured that are considered as attributes against the process variables of cutting speed (v), feed (f), and depth of cut (a). The attributes or the output parameters are surface roughness (R_a), flank wear (V_b), tool life (TL), cutting force (F), power consumption (P) and material removal rate (MRR). The objective functions R_a , V_b , F , and P are non-beneficial (minimum values are better) whereas attributes TL and MRR are beneficial (maximum values are better). First of all the weights are calculated using the AHP method and then PROMETHEE II and VIKOR methods described above are used to get the ranks of different alternatives.

Calculation of Weight

Table 1. Relative attribute matrix [8]

Attribute	Ra	F	P	TL	MRR	Vb
Ra	1	3	3	1	2	1
F	1/3	1	1	1/3	2/3	1
P	1/3	1	1	1/3	2/3	1
TL	1	3	3	1	2	1
MRR	1/2	2/3	2/3	1/2	1	1
Vb	1	1	1	1	1	1

Table 1 tabulates the pairwise attribute matrix. The above matrix of attributes is then normalized by following the steps above mentioned in the AHP methods to obtain the weights of different criteria. The normalized matrix is first found by calculating the sum of each column and dividing the attribute value with the resultant and then for finding the weights we find the average of each row which gives us the respective weights of criteria.

The normalized matrix is shown in Table 2.

Table 2. Normalized matrix of attributes

Attribute	Ra	F	P	TL	MRR	Vb
Ra	0.24	0.31	0.31	0.24	0.27	0.17
F	0.08	0.10	0.10	0.08	0.09	0.17
P	0.08	0.10	0.10	0.08	0.09	0.17
TL	0.24	0.31	0.31	0.24	0.27	0.17
MRR	0.12	0.07	0.07	0.12	0.14	0.17
Vb	0.24	0.10	0.10	0.24	0.14	0.17

The weights of the above mentioned criteria are [8]: - $W_{Ra}=0.25112$, $W_F=0.100191$, $W_P=0.100191$, $W_{TL}=0.251964$, $W_{MRR}=0.14141$, $W_{Vb}=0.155122$.

Table 3 shows the performance matrix for various parameters.

Table 3. Performance matrix for various machining parameters [8]

SL. No	v	f	A	Ra	F	P	TL	MRR	Vb
1	30.09	0.12	1.49	0.530	1030.054	5.526	16.866	5261.882	0.096
2	27.33	0.13	1.49	0.560	1115.502	5.416	16.008	5235.061	0.089
3	30.43	0.12	1.49	0.532	1039.400	5.629	16.258	5408.290	0.097
4	26.78	0.13	1.49	0.570	1149.028	5.452	15.454	5321.004	0.088
5	26.77	0.13	1.50	0.563	1129.193	5.366	16.186	5178.547	0.087
6	27.34	0.13	1.48	0.556	1096.056	5.335	16.583	5109.348	0.089
7	29.83	0.12	1.49	0.534	1042.257	5.539	16.597	5296.115	0.095
8	29.82	0.12	1.46	0.535	1027.040	5.470	16.828	5203.697	0.096
9	30.09	0.12	1.45	0.531	1007.984	5.429	17.164	5133.786	0.097
10	30.23	0.12	1.49	0.530	1029.089	5.546	16.782	5287.359	0.096
11	27.44	0.13	1.47	0.556	1087.822	5.321	16.615	5088.652	0.090
12	27.26	0.13	1.48	0.568	1135.683	5.488	15.322	5361.867	0.089
13	30.43	0.12	1.49	0.532	1037.794	5.621	16.320	5395.907	0.097
14	29.80	0.12	1.49	0.540	1062.479	5.625	15.937	5435.633	0.095
15	28.04	0.13	1.49	0.558	1112.254	5.532	15.574	5382.670	0.091
16	06.77	0.14	1.50	0.573	1161.547	5.501	15.123	5399.943	0.087
17	28.39	0.12	1.49	0.542	1067.003	5.397	16.968	5140.209	0.091
18	28.35	0.13	1.49	0.557	1110.184	5.581	15.386	5444.730	0.092
19	27.33	0.13	1.47	0.556	1089.506	5.309	16.655	5074.630	0.089
20	27.44	0.13	1.49	0.560	1113.793	5.428	15.969	5249.625	0.089

SOLUTION**A) PROMETHEE II**

By the help of calculated weights and all the above data available for different alternatives and criteria we apply the aforementioned steps of PROMETHEE II to get the rank of all the alternatives. The step by step solution by PROMETHEE II involves a very large number of mathematical calculations so programs in C++ were written for each step and the results of each step were used to determine the final ranking.

Firstly the performance matrix was normalized by using the formula mentioned in the above step of PROMETHEE II. The normalized matrix obtained is given in Table 4: -

Table 4. Normalized matrix for performance matrix

SL. No	Ra	F	P	TL	MRR	Vb
1	1.0000	0.8563	0.3219	0.8540	0.5059	0.1000
2	0.3023	0.2998	0.6656	0.4336	0.4334	0.8000
3	0.9535	0.7954	0	0.5561	0.9015	0
4	0.0698	0.0815	0.5531	0.1622	0.6657	0.9000
5	0.2325	0.2107	0.8219	0.5208	0.2808	1.0000
6	0.3953	0.4265	0.9189	0.7153	0.0938	0.8000
7	0.9070	0.7768	0.2812	0.7222	0.5984	0.2000
8	0.8837	0.8759	0.4969	0.8354	0.3487	0.1000
9	0.9767	1.0000	0.6250	1.0000	0.1598	0
10	1.0000	0.8626	0.2594	0.8128	0.5748	0.1000
11	0.3953	0.4801	0.9625	0.731	0.0379	0.7000
12	0.1163	0.1684	0.4406	0.9750	0.7761	0.8000
13	0.9535	0.8059	0.0250	0.5865	0.8681	0
14	0.7674	0.6451	0.0125	0.3988	0.9754	0.2000
15	0.3488	0.3300	0.3031	0.2210	0.8323	0.6000
16	0	1.0000	0.4000	0	0.8789	1.0000
17	0.7209	0.6157	0.7250	0.904	0.1772	0.6000
18	0.3721	0.3345	0.1500	0.1289	1.0000	0.5000
19	0.3953	0.4691	1.0000	0.7506	0	0.8000
20	0.3023	0.311	0.6281	0.4145	0.4728	0.8000

Thereafter the steps above mentioned in PROMETHEE II are followed to calculate the pairwise difference values and then calculation of preference function is done which is used to determine the weak preference index value and the strong preference index value which are then used to calculate the total preference index. This total preference index is used to obtain the entering flow, the leaving flow and hence the total flow which determines the rank.

Thus the final ranking obtained by use of PROMETHEE II is shown in Table 5.

Table 5. Overall rank of alternatives

ALTERNATIVE	LEAVING FLOW	ENTERING FLOW	OVERALL FLOW	RANK
1	1	0.30012	0.69988	1
2	0.270739	0.379159	-0.10842	17
3	0.416673	0.387398	0.02927	8
4	0.342504	0.509657	-0.16715	20
5	0.325576	0.418347	-0.09277	15
6	0.317332	0.380388	-0.063056	11
7	0.367062	0.332294	0.0347687	6
8	0.380352	0.36595	0.0143927	9
9	0.476963	0.434062	0.0429006	4
10	0.420473	0.35509	0.0654633	2
11	0.318043	0.395404	-0.077361	13
12	0.432067	0.384244	0.0478233	3
13	0.414422	0.379836	0.034585	7
14	0.373501	0.386939	-0.01343	10
15	0.29542	0.407612	-0.112192	18
16	0.463996	0.541576	-0.0775	14
17	0.383366	0.345427	0.03793	5
18	0.334804	0.45108	-0.116277	19
19	0.333699	0.40532	-0.0716	12
20	0.269908	0.377069	-0.10176	16

Therefore according to PROMETHEE II the best optimum machining parameters are that of pertaining to Alternative 1.

B) VIKOR

All the steps mentioned above are followed to obtain the best optimum values of cutting speed, feed and depth and rank the other available alternatives according to their performance. Here also the weights calculated by the AHP method are used to calculate the normalized values and also used in the further steps as stated above. The number of calculations is less in comparison to the PROMETHEE II method so there is no requirement of any programme. All the calculations are done by hand and the main values are used in the ranking process. First of all the values are calculated for the required parameters to obtain the rank of the alternatives and these values are used for further steps and calculations.

Table 6. $W_j * [(x_{ij})_{max} - x_{ij}] / [(x_{ij})_{max} - (x_{ij})_{min}]$

SL. No	Ra	F	P	TL	MRR	Vb
1	0.2511	0.0858	0.0322	0.0368	0.0699	0.0155
2	0.0759	0.0300	0.0667	0.1427	0.0801	0.1241
3	0.2394	0.0797	0	0.1118	0.0139	0
4	0.0175	0.0082	0.0554	0.2111	0.0473	0.1396
5	0.0584	0.0210	0.0823	0.1207	0.1017	0.1551
6	0.0993	0.0427	0.0921	0.0717	0.01281	0.1241
7	0.2278	0.0778	0.0281	0.0700	0.0568	0.031
8	0.2219	0.0878	0.0497	0.0415	0.0921	0.0155
9	0.2453	0.1001	0.0626	0	0.1188	0
10	0.2511	0.0864	0.026	0.0472	0.0601	0.0155
11	0.0993	0.0481	0.0964	0.0678	0.1361	0.1086
12	0.0292	0.0168	0.0441	0.2274	0.0317	0.1241
13	0.2394	0.0807	0.0033	0.1042	0.0817	0
14	0.1927	0.0646	0.0012	0.1514	0.0035	0.0310
15	0.0876	0.0330	0.0304	0.1963	0.0237	0.0930
16	0	0.1000	0.0400	0.2519	0.0171	0.1551
17	0.1810	0.0617	0.0726	0.0242	0.1164	0.0930
18	0.0934	0.0335	0.0150	0.2195	0	0.0760
19	0.0993	0.0470	0.1001	0.0628	0.1414	0.1241
20	0.0759	0.0312	0.0629	0.1475	0.0745	0.1241

Table 7. Overall rank of alternatives

ALTERNATIVE	E_i	F_i	P_i	RANK
1	0.4913	0.2511	0.8969	18
2	0.5195	0.1427	0.4626	2
3	0.4448	0.2394	0.7909	13
4	0.4791	0.2111	0.7096	11
5	0.5393	0.1551	0.5397	5
6	0.558	0.1551	0.5621	6
7	0.4915	0.2278	0.7966	16
8	0.5085	0.2219	0.7914	14
9	0.5268	0.2453	0.9143	19
10	0.4863	0.2511	0.8909	17
11	0.5563	0.1361	0.4780	3
12	0.4733	0.2274	0.7731	12
13	0.4463	0.2394	0.7927	15
14	0.4444	0.1927	0.5887	7
15	0.4640	0.1963	0.6277	8
16	0.5642	0.2519	0.9874	20
17	0.5489	0.1810	0.6631	9
18	0.4374	0.2195	0.6961	10
19	0.5747	0.1414	0.5229	4
20	0.1561	0.1475	0.0492	1

Table 6 is used to tabulate the data calculated by following the first step mentioned in the above process and Table 7 shows the overall rank of the alternatives.

Hence the best alternative according to VIKOR method is Alternative 20.

6.2 Implementation of MCDM methods for selection of a warehouse Location.

An efficient strategic investment decision is required for the selection of a warehouse location for maximum business profitability. In a business model, one of the important decision making process of the logistic administrators is decision for the location of the distribution centre. After a lot of research a business model with four different alternative warehouses are specified. For the warehouse location, the evaluation criteria are explained as follows in such a way that the criteria based on cost, capacity and customer related to the prospect of sector and business is covered.

- Unit price (UP): It is one of the most important factors in determining the storage of goods in warehouse. If the unit price is less the probability of choosing that location over others increases.
- Stock holding capacity (SHC): This should not be very high which will cause wastage of extra space nor should it be very small. The capacity should be somewhat in the middle level to satisfy this criterion for the decision maker.
- Average distance to shops (ADS): If the presentation period of goods is reduced it provides an important advantage in competition for retail sector businesses. The main aim of a decision maker should always be to choose such a location which will provide the company a good access to the shops when they run out of products from their rival business. If the distance to shops is less it will be in the advantage of the company.
- Average distance to main suppliers (ADM): Minimizing this criterion will also help in good business for the company.
- Movement flexibility (MF): The movement flexibility is decided by the evaluation of architectural and layout factors of the warehouse location which tells about the total storage space in the warehouse and other conformity factors. Thus alternative warehouse locations are evaluated based on 0-4 scale (really bad, bad, average, good and really good).

So the beneficial attributes (higher is better) are stock holding capacity and movement flexibility and the non-beneficial attributes are unit price, average distance to shops and average distance to main suppliers. Table 8 shows all the attributes pertaining to different criteria.

The importance weights of criteria in the decision problem are, $\{W_{UP}, W_{SHC}, W_{ADS}, W_{ADM}, W_{MF}\} = \{0.29, 0.35, 0.15, 0.15, 0.06\}$.

Table 8. Performance values of warehouse alternatives [9]

ALTERNATIVE	Unit price (\$/m ²)	Stock holding capacity (unit)	Average distance to shops (kilometre)	Average distance to main suppliers (kilometre)	Movement flexibility
A	7	100	20	14	3
B	10	120	8	10	1
C	8	150	12	12	2
D	6	180	16	13	4

SOLUTION**A) PROMETHEE II**

By the help of calculated weights and all the above data available for different alternatives and criteria we apply the aforementioned steps of PROMETHEE II to get the rank of all the alternatives.

Again the normalized matrix was calculated by the aforementioned formula and tabulated in Table 9.

Table 9. Normalized matrix

ALTERNATIVE	UP	SHC	ADS	ADM	MF
A	0.75	0	0	0	0.67
B	0	0.25	1.00	1.00	0
C	0.50	0.63	0.67	0.50	0.33
D	1.00	1.00	0.33	0.25	1.00

Thus the final ranking obtained by use of PROMETHEE II is shown in Table 10.

Table 10. Overall rank of alternatives

ALTERNATIVE	LEAVING FLOW	ENTERING FLOW	OVERALL FLOW	RANK
A	0.348533	0.759683	-0.41115	4
B	0.488333	0.723917	-0.235583	3
C	0.498267	0.37695	0.121317	2
D	0.82425	0.298833	0.525417	1

Therefore warehouse D is ranked the best in the list.

B) VIKOR

All the steps mentioned above are followed to obtain the best warehouse location. Here also the weights calculated by the AHP method are used to calculate the normalized values and also used in the further steps as stated above. Table 11 is used to tabulate the data calculated by following the first step mentioned in the above process.

Table 11. $W_j * [(x_{ij})_{max} - x_{ij}] / [(x_{ij})_{max} - (x_{ij})_{min}]$

ALTERNATIVE	UP	SHC	ADS	ADM	MF
A	0.2175	0	0	0	0.402
B	0	0.8750	0.1500	0.1500	0
C	0.1450	0.2190	0.1000	0.0500	0.1980
D	0.2900	0.3500	0.0500	0.3750	0.0600

After calculating this further steps are followed and the final rank is tabulated in Table 12.

Table 12. Overall rank of alternatives

ALTERNATIVE	E_i	F_i	P_i	RANK
1	0.2577	0.402	0.1396	1
2	0.3875	0.875	0.6226	4
3	0.55905	0.2188	0.2847	2
4	0.7870	0.375	0.6190	3

6.3 Cutting tool material selection using PROMETHEE II and VIKOR methods.

In this modern era of metal working industry, a series of materials, like high speed steel, ceramic materials, diamond, carbide tool etc. are used as cutting tools. Because of a variety of conditions and requirements, for all the machining applications, a single cutting tool cannot be used. Each and every cutting tool material has its own characteristics and properties that make it best for a specific machining application. For selection of a cutting tool material it is important to go through all the physical properties of the material available. Thus, it is always desirable that the most appropriate cutting tool material for a specific application with the desired physical properties for high machining performance be selected. Here a list of 19 cutting tool materials has been made which are to be chosen on the basis of 10 different criterions.

Table 13. Cutting tool material selection criteria [10]

Properties of cutting tool materials (criteria)	Symbol
Density (gm/cc)	C ₁
Hardness (HK)	C ₂
Yield tensile strength (MPa)	C ₃
Modulus of elasticity (GPa)	C ₄
Compressive strength (MPa)	C ₅
Shear strength (MPa)	C ₆
Charpy impact strength (J)	C ₇
Thermal conductivity (W/mK)	C ₈
Coefficient of linear thermal expansion (µm/m-°C)	C ₉
Tool material cost (USD/kg)	C ₁₀

Table 13 shows different criteria and their symbols.

Table 14. Cutting tool material alternatives [10]

Cutting tool materials	Symbol
Powder metal tool steel (AISI A11)	A ₁
Oil quenched tool steel (AISI O2)	A ₂
Cobalt-free super high speed steel	A ₃
Air-hardened tool steel (ASTM A2)	A ₄
Tool steel (ASTM A6)	A ₅
Shock-resisting tool steel (ASTM S7)	A ₆
Tungsten-molybdenum high speed steel (W-Mo)	A ₇
Sintered reaction bonded silicon nitride	A ₈
Titanium carbide	A ₉
Cermet	A ₁₀
Tungsten carbide	A ₁₁
Mono-tungsten carbide	A ₁₂
Stellite (cast cobalt alloy)	A ₁₃
Sialon	A ₁₄
Cubic boron nitride (CBN)	A ₁₅
Alumina (99.9% pure)	A ₁₆
Synthetic polycrystal diamond	A ₁₇
Synthetic single crystal diamond	A ₁₈
Hot pressed silicon nitride	A ₁₉

Table 14 tabulates various alternatives available and their symbols.

Here the non-beneficial attributes are C₉ and C₁₀ and the rest of the attributes are beneficial.

Table 15. Decision matrix for cutting tool material [10]

SL. No	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀
A ₁	7.40	754	1975	220	2190	1684	65.00	22.00	11.40	1.65
A ₂	7.61	624	1751	140	1890	1492	105.00	39.00	10.30	1.25
A ₃	8.17	908	2228	235	3145	1899	18.00	46.00	10.67	9.70
A ₄	7.86	822	2090	207	2357	1782	678.00	26.00	14.00	1.90
A ₅	7.83	788	2012	207	2200	1715	407.00	14.70	13.01	5.30
A ₆	7.83	677	1874	207	1976	1597	16.90	28.50	12.40	2.15
A ₇	8.14	826	2065	208	3000	1760	23.00	37.00	11.30	10.85
A ₈	3.30	2550	128	310	1035	410	0.10	42.00	3.10	400.00
A ₉	4.94	1800	237	451	3475	756	1.24	17.00	7.70	18.00
A ₁₀	14.95	1276	1324	600	6150	4219	1.35	60.00	4.60	78.60
A ₁₁	15.00	1387	415	690	4975	1324	1.34	98.00	6.50	60.00
A ₁₂	15.70	1167	316	696	2683	1008	1.27	82.00	5.20	65.00
A ₁₃	8.77	803	379	243	2300	1210	1.25	8.40	11.47	87.50
A ₁₄	3.25	1959	381	345	3450	1216	1.07	19.00	3.50	557.00
A ₁₅	8.60	5000	481	850	6900	1532	0.50	13.00	4.80	864.00
A ₁₆	9.36	1700	276	370	3000	879	0.10	30.00	5.43	152.12
A ₁₇	4.00	7000	1472	953	6700	4688	0.10	1200	3.80	1300.00
A ₁₈	3.80	8000	1794	1050	6900	5713	0.20	1500	4.80	1500.00
A ₁₉	3.20	2730	501	310	3450	1612	.012	39	10.71	337.00

The weights of different criteria are $\{W_1, W_2, W_3, W_4, W_5, W_6, W_7, W_8, W_9, W_{10}\} = \{0.0232, 0.0716, 0.0549, 0.038, 0.0248, 0.0424, 0.2227, 0.2939, 0.0212, 0.2023\}$.

SOLUTION

A) PROMETHEE II

By the help of calculated weights and all the above data available for different alternatives and criteria we apply the aforementioned steps of PROMETHEE II to get the rank of all the alternatives. Table 16 shows the normalized matrix values.

Table 16. Normalized matrix of the decision matrix

SL. No	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀
A ₁	0.3360	0.0176	0.8795	0.0879	0.1969	0.2400	0.6187	0.0091	0.2385	0.9997
A ₂	0.3530	0	0.7729	0	0.1458	0.2040	1.0000	0.0205	0.3394	1.0000
A ₃	0.3970	0.0385	1.0000	0.1044	0.3598	0.2130	0.1706	0.0252	0.3055	0.9944
A ₄	0.3728	0.0268	0.9343	0.0736	0.2254	0.2587	0.6454	0.0118	0	0.9996
A ₅	0.3704	0.0222	0.8971	0.0736	0.1604	0.2238	0.1602	0.0134	0.1468	0.9973
A ₆	0.3704	0.0072	0.8314	0.0736	0.1604	0.2238	0.1602	0.0134	0.1468	0.9994
A ₇	0.3952	0.0274	0.9224	0.0747	0.3350	0.2546	0.2183	0.0192	0.2477	0.9936
A ₈	0.0008	0.2611	0	0.1868	0	0	0	0.0225	1.0000	0.7339
A ₉	0.1392	0.1594	0.0519	0.3418	0.4160	0.0652	0.0109	0.0058	0.578	0.9888
A ₁₀	0.9400	0.0884	0.5695	0.5056	0.8721	0.7183	0.0119	0.0346	0.8624	0.9484
A ₁₁	0.9440	0.1034	0.1367	0.6044	0.6718	0.1724	0.0118	0.0601	0.6881	0.9608
A ₁₂	1.0000	0.0736	0.0895	0.6110	0.2810	0.1128	0.0012	0.0493	0.8073	0.9575
A ₁₃	0.4456	0.0247	0.1195	0.1132	0.2157	0.1508	0.0092	0	0.2321	0.9425
A ₁₄	0.0040	0.1810	0.1205	0.2253	0.4118	0.1519	0.0038	0.0071	0.9630	0.6291
A ₁₅	0.4320	0.5934	0.1681	0.7802	1.0000	0.2116	0.0004	0.0031	0.8440	0.4243
A ₁₆	0.4928	0.1459	0.0705	0.2527	0.3350	0.0884	0	0.0145	0.7862	0.8993
A ₁₇	0.0640	0.8644	0.6400	0.8934	0.9659	0.8067	0	0.7989	0.9358	0.1334
A ₁₈	0.0480	1.0000	0.7933	1.0000	1.0000	1.0000	0.0009	1.0000	0.8440	0
A ₁₉	0	0.2855	0.1800	0.1868	0.4118	0.2267	0.0002	0.0205	0.3018	0.7760

After following all the steps of the method we get the final ranking as shown in Table 17.

Table 17. Overall rank of alternatives

ALTERNATIVE	LEAVING FLOW	ENTERING FLOW	NET FLOW	RANK
A ₁	0.1444222	0.0846284	0.059735	5
A ₂	0.2257	0.084145	0.141555	3
A ₃	0.072532	0.0947689	-0.0222369	9
A ₄	0.153508	.0861185	0.0673895	4
A ₅	0.098929	0.0966934	0.00223649	6
A ₆	0.0548962	0.108657	-0.0537605	13
A ₇	0.0729946	0.0956567	-0.0226621	10
A ₈	0.281694	0.149718	-0.121549	18
A ₉	0.241383	0.034107	-0.109969	17
A ₁₀	0.8857510	0.922679	-0.0036928	7
A ₁₁	0.0613371	0.0110261	-0.0489236	12
A ₁₂	0.0522038	0.118428	-0.0066245	8
A ₁₃	0.011451	0.1424	-0.130949	19
A ₁₄	0.0256708	0.134462	-0.0108791	16
A ₁₅	0.083299	0.114256	-0.0309651	11
A ₁₆	0.0258236	0.128918	-0.103094	14
A ₁₇	0.355548	0.0733479	0.2822	2
A ₁₈	0.441397	0.0682254	0.373171	1
A ₁₉	0.0272658	0.130803	-0.103537	15

Thus the best alternative of cutting tool material according to PROMETHEE II is A₁₈.

B) VIKOR

All the steps mentioned above are followed to obtain the best cutting tool material. Here also the weights calculated by the AHP method are used. Since the number of calculations are less no programming is required. Table 18 is used to tabulate the data calculated by following the first step mentioned in the above process.

Table 18. $W_j * [(x_{ij})_{max} - x_{ij}] / [(x_{ij})_{max} - (x_{ij})_{min}]$

SL. No	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀
A ₁	0.0079	0.0013	0.0483	0.0034	0.0049	0.0102	0.1378	0.0027	0.0051	0.2022
A ₂	0.0082	0	0.0424	0	0.0036	0.0086	0.2227	0.0060	0.0072	0.2023
A ₃	0.0092	0.0029	0.0549	0.0039	0.0089	0.0119	0.0380	0.0074	0	0.2022
A ₄	0.0086	0.0017	0.0493	0.0028	0.0056	0.0190	0.1437	0.0035	0	0.2022
A ₅	0.0086	0.0017	0.0493	0.0028	0.0049	0.0104	0.0862	0.0012	0.0018	0.2018
A ₆	0.0086	0.0005	0.0456	0.0028	0.0040	0.0095	0.0357	0.0039	0.0031	0.2022
A ₇	0.0092	0.0021	0.0506	0.0028	0.0083	0.0107	0.0486	0.0056	0.0053	0.2010
A ₈	0	0.0200	0	0.0071	0	0	0	0.0066	0.0212	0.1485
A ₉	0.0032	0.0122	0.0028	0.0129	0.0103	0.0028	0.0024	0.0017	0.0123	0.2000
A ₁₀	0.0218	0.0068	0.0313	0.0192	0.0216	0.0305	0.0026	0.0102	0.0183	0.1919
A ₁₁	0.0219	0.0079	0.0075	0.0230	0.0167	0.0073	0.0026	0.0177	0.0146	0.1937
A ₁₂	0.0232	0.0056	0.0049	0.0232	0.0070	0.0048	0.0025	0.0145	0.0171	0.1937
A ₁₃	0.0103	0.0018	0.0016	0.0043	0.0064	0.0020	0	0.0049	0	0.1907
A ₁₄	0	0.0456	0.0092	0.0296	0.0248	0.0064	0	0.0009	0.0204	0.1273
A ₁₅	0.0100	0.0456	0.0092	0.0296	0.0248	0.0089	0	0.0009	0.0179	0.0858
A ₁₆	0.0114	0.0112	0.0039	0.0096	0.0083	0.0003	0	0.0042	0.0167	0.1819
A ₁₇	0.0015	0.0662	0.0351	0.0339	0.0239	0.0342	0	0.2348	0.0198	0.0269
A ₁₈	0.0011	0.0716	0.0435	0.0380	0.0248	0.0424	0	0.2939	0.0179	0
A ₁₉	0	0.0219	0.0099	0.0071	0.0102	0.0096	0	0.0060	0.0064	0.1570

Table 19. Overall rank of alternatives

ALTERNATIVE	E_i	F_i	P_i	RANK
A ₁	0.4238	0.2022	0.0587	1
A ₂	0.5010	0.2227	0.1185	5
A ₃	0.3448	0.2012	0.5040	17
A ₄	0.3015	0.2022	0.4453	12
A ₅	0.3687	0.2018	0.5392	18
A ₆	0.3159	0.2022	0.4656	13
A ₇	0.3442	0.2010	0.5027	15
A ₈	0.2034	0.1485	0.1776	6
A ₉	0.2606	0.2000	0.3882	10
A ₁₀	0.3605	0.1919	0.5039	16
A ₁₁	0.3370	0.1944	0.4768	14
A ₁₂	0.2965	0.1937	0.4178	11
A ₁₃	0.1843	0.1907	0.2520	8
A ₁₄	0.1963	0.1273	0.1167	4
A ₁₅	0.2327	0.0858	0.0684	2
A ₁₆	0.2475	0.1819	0.3202	9
A ₁₇	0.4763	0.2348	0.7705	19
A ₁₈	0.5382	0.2939	0.1000	3
A ₁₉	0.2272	0.1570	0.2317	7

Table 19 is used to tabulate the overall rank of the available alternatives and it is found that the best alternative is A₁.

6.4 Use of a MCDM approach for selection of suppliers in auto industry

In selection of a supplier various criteria are to taken into account, so we require a MCDM approach to determine which supplier will meet our requirements best according to the criteria values set by us. Here we encounter various issues related to supplier selection in an auto industry. The various criteria involved in decision making process are: -

- (C₁) PPM (Part per million) customers: It measures the number of parts returned per million by the customer.
- (C₂) Quality: The quality of goods provided by the suppliers.
- (C₃) Price/ cost: The cost which the enterprise pays for the goods.
- (C₄) Standardization: The extent of pre-set standards followed by the company during the manufacturing process.
- (C₅) Service: The support and service provided by a supplier after sales of the product.
- (C₆) Flexibility: The extent to which the supplier is able to cope up with the change in demand of the customer.
- (C₇) On time delivery: The time taken by the supplier to supply the parts.

Here the criteria C₁ and C₃ are non-beneficial and the attributes pertaining to other criteria are beneficial.

The weight calculated by AHP method are {W₁, W₂, W₃, W₄, W₅, W₆, W₇} = {0.376, 0.155, 0.062, 0.208, 0.059, 0.037, 0.099}.

Table 20. Performance matrix of alternatives [11]

ALTERNATIVE	C₁	C₂	C₃	C₄	C₅	C₆	C₇
S₁	0.475	0.435	0.479	0.542	0.379	0.571	0.600
S₂	0.425	0.446	0.524	0.475	0.525	0.452	0.585
S₃	0.552	0.543	0.325	0.313	0.500	0.452	0.432
S₄	0.535	0.396	0.465	0.570	0.422	0.356	0.596

The performance matrix of alternatives is tabulated in Table 20.

SOLUTION

A) PROMETHEE II

By the help of calculated weights and all the above data available for different alternatives and criteria we apply the aforementioned steps of PROMETHEE II to get the rank of all the alternatives.

The normalized values are first calculated and tabulated in Table 21.

Table 21. Normalization matrix

ALTERNATIVE	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇
S ₁	0.606	0.265	0.226	0.891	0	1.000	1.000
S ₂	1.000	0.340	0	0.630	1.000	0.446	0.912
S ₃	0	1.000	1.000	0	0.829	0.446	0
S ₄	0.134	0	0.307	1.000	0.294	0	0.976

Overall rank of the alternatives after various calculations is tabulated in Table 22 which shows the best alternative is S₁.

Table 22. Overall rank of alternatives

ALTERNATIVE	LEAVING FLOW	ENTERING FLOW	OVERALL FLOW	RANK
S ₁	0.602977	0.410119	0.192585	1
S ₂	0.623036	0.59021	0.032826	3
S ₃	0.61489	1	-0.38511	4
S ₄	0.639329	0.479903	0.159425	2

B) VIKOR

All the steps mentioned above are followed to obtain the best cutting tool material. Table 23 is used to tabulate the data calculated by following the first step mentioned in the above process.

Table 23. $W_j * [(x_{ij})_{max} - x_{ij}] / [(x_{ij})_{max} - (x_{ij})_{min}]$

ALTERNATIVE	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇
S ₁	0.228	0.041	0.014	0.185	0	0.037	0.099
S ₂	0.376	0.053	0	0.131	0.059	0.017	0.090
S ₃	0	0.155	0.062	0	0.049	0.017	0
S ₄	0.050	0	0.019	0.208	0.017	0	0.097

Table 24. Overall rank of alternatives

ALTERNATIVE	E _i	F _i	P _i	RANK
S ₁	0.604	0.228	0.527	3
S ₂	0.726	0.376	1.000	4
S ₃	0.283	0.155	0	1
S ₄	0.391	0.208	0.242	2

Table 24 clearly shows that S₃ is the best alternative available by this process.

7. Conclusion

This thesis explains the two MCDM methods namely PROMETHEE II and VIKOR clearly and the solution of four engineering problems from different fields gives a clear cut idea on the diverse applications of these two MCDM methods. Both methods follow different algorithm so the results obtained by both algorithms are different.

8. Bibliography

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