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A NOVEL HYBRID APPROACH TO FLUID SELECTION IN DECISION-MAKING DESIGNED FOR THE MANUFACTURING ENVIRONMENT

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Abstract
Today, selecting the right cutting fluids is essential in an industrial setting. Better tool life and outstanding surface quality are provided by the intended cutting fluid. This study suggested a novel decision support system for choosing various cutting fluids in a production setting. Three studies were selected from the literature for this particular scenario. The optimal settings for this research were identified using four normalization procedures and fifteen different multi-criteria decision-making techniques. A novel hybrid criterion weighing approach was put out in terms of criteria for weighting. The Spearman correlation test was used to compare the ranks that were obtained. The suggested approach yielded consistent results in terms of ranks when compared to the findings in the literature ($p < 0.05$).

Keywords:
Multi-criteria decision making (MCDM); manufacturing; decision support system; cutting fluid selection; tool life.

I. Introduction
The choice of coolants in the conventional approach is determined by cost, quality, and functional requirements. Since the number of laws and regulations governing industrial and environmental safety is increasing, the usage of coolants causes serious cost challenges for manufacturing enterprises. Many fluids are used in the manufacturing sector for lubrication and cutting[1]. Better tool life and outstanding surface quality are further benefits of the coolant. Friction phenomena generate heat during machining operations. The impact of the heat generated raises surface roughness and tool wear while reducing the dimensional accuracy of the workpiece [2-4]. Thus, the best coolant choice is essential as it reduces expenses and environmental risks while boosting the effectiveness of the machining process [5-6]. Most people agree that selecting a cutting coolant is a multi-criteria decision-making (MCDM) dilemma. In earlier research, scientists have selected appropriate cutting fluids for material removal procedures using a variety of MCDM techniques [7]. An online coolant assessment tool called CFEST was proposed by Sutherland et al. [8] and can provide information about coolants' safety, cost, and other characteristics. Using the Analytical Hierarchy Process (AHP), Sun et al. [9-10] evaluated the performance of grinding fluids in a two-grade fuzzy synthetic decision-making system.A technique for choosing the ideal coolant was devised by Rao and Gandhi [11] using a matrix approach and digraph. A multi-purpose approach to decision-making for coolant selection was put forth by Tan et al. [12]. A program for optimizing the coolant selection process based on human safety and environmental impact was suggested by Meciarova and Stanovsky [3]. To select an appropriate lubricant, Abhang and Hameedullah [13] employed the AHP and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approaches. The matrix approach and Chi-square statistics were utilized by Kumar and Prasad [14] to resolve the coolant selection issue. The weighted aggregated sum product assessment (WASPAS) method was employed by Chakraborty and Zavadskas [15-16] to choose the coolant.The best cutting fluid has been selected by Jagadish and Ray [16] taking into

account quality, cost, and environmental risks. In their investigation, the hybrid criterion decision-making approach of AHP/VIKOR was employed. The optimal coolant was chosen by Jagadish and Ray [17] using multi-purpose optimization based on the simple ratio analysis (MOOSRA) technique to reduce environmental risk and expense while enhancing surface quality. This work suggests a novel way for reducing fluid selection that uses a variety of criterion weighting, normalization, and decision-making techniques to remove the findings' reliance on MCDM techniques. Furthermore, it attempts to address the drawbacks by combining subjective and objective approaches with the criterion weights. This study assessed and compared the outcomes of fifteen distinct MCDM models as well as three cutting fluid selection issues. Four distinct normalization methods were used to assess each decision-making model.

II. Methodology:

Fifteen distinct MCDM strategies and four distinct normalization procedures were employed in the study to choose various cutting fluids. The methods' specifics are listed below.

Normalization methods:

Equation for normalized method is given as:

Max. weighting formula is given below (Eq. 1)

$$x_{ij}=\frac{a_{ij}}{a_j^{max}} \text{ for benefit} \quad (1)$$

Here i is the number of alternatives, j is number of criteria

x_{ij} is normalized value of jth criteria of ith alternative

a_{ij} is value for jth criteria of ith alternative

Sum weighting formula is given by equation-2

$$x_{ij}=\frac{a_{ij}}{\sum_{i=1}^{m} aij} \text{ for benefit} \quad (2)$$

Max-Min weighting formula is given by equation-3

$$x_{ij}=\frac{a_{ij}-a_j^{Min}}{a_j^{Max}-a_j^{Min}} \text{ for benefit} \quad (3)$$

Vector weighting formula is given by equation-4

$$x_{ij}=\frac{a_{ij}}{\sqrt{\sum_{j=1}^{n} a_{ij}^2}} \text{ for benefit} \quad (4)$$

Multi-criteria decision making (MCDM) techniques:

These techniques are briefly described. 2.2a SAW (simple additive weighting): SAW is an MCDM technique that involves giving each choice a total value that is weighted according to the relative importance of the related assessment criterion and each associated with the option [18].

SAW (simple additive weighting): SAW is an MCDM technique that involves weighting each option according to the relative importance of the appropriate evaluation criterion and assigning a sum of values to each option that is linked with that criterion [19].

MOORA (Multi-objective optimization on the basis of ratio analysis) (MOORA ratio system (MOORA RS) and MOORA reference point (MOORA RP)): Because it considers and evaluates every objective while also considering all relationships between options and objectives, the MOORA methodology outperforms other approaches. Rather than using subjectively weighted normalization, the approach makes use of non-subjective and non-directional values [20].

VIKOR (VIsekriterijumsko KOmpromisno rangiranje): A popular approach for ranking and selection issues as well as performance reviews is the VIKOR technique. By consensus, the strategy's weight in this study is 0.5. 2.2d Complex Proportional Assessment System (COPRAS): Compared to other MCDM strategies like AHP, VIKOR, and TOPSIS, the COPRAS method is simpler.

TOPSIS (technique for order of preference by similarity to ideal solution) (TOPSIS Euclidean, TOPSIS Sity Cab, TOPSIS–Inf (Min): Using optimal metrics, TOPSIS is a strategy that enables the best option among the possibilities. The study's 0.5 indifference threshold is used.

D'IDEAL (displaced ideal method): In D'IDEAL approach, the better system should have less distance from ideal.

MABAC (Multi-attributive border approximation area comparison): The main idea behind the MABAC technique is that choices are evaluated based on how far away their criteria functions are from the boundary proximity area. Put otherwise, the creation of a boundary proximity field occurs. After that, the criteria functions are computed for every alternative, and the separation between them and the boundary proximity area is established. Ultimately, the possibilities are listed and the best option is chosen by calculating the criteria distances .

ORESTE (organisazion, RangEment ot SynTEze dedonnecs relationnelles): One ranking system that takes into account the relationship between seniority, importance, and preference is called ORESTE. The ORESTE approach has been applied to a limited number of choice issues, although being less popular than other outranking techniques like ELECTRE, PROMETHEE, etc.. The indifference coefficient in this investigation is 0.05. The coefficient of preference association is 1.4. The decision-maker's coefficient is equal to 0.5. Non-linear projection, or Lp, is made. The analysis makes use of a variety of Lp values, including Lp (p = 1 Average (Mean), = -1-Medium Harmonic, = 2-Mean Square, and inf.)

III. Proposed method:

The entropy technique was used in this work to determine weights, which were derived by integrating weights previously found in the literature. Figure 1 shows the suggested method's flowchart. A new hybrid methodology was developed using fifteen different MCDM techniques and four different normalization methods. After adding up each ranking, an aggregate ranking was produced.

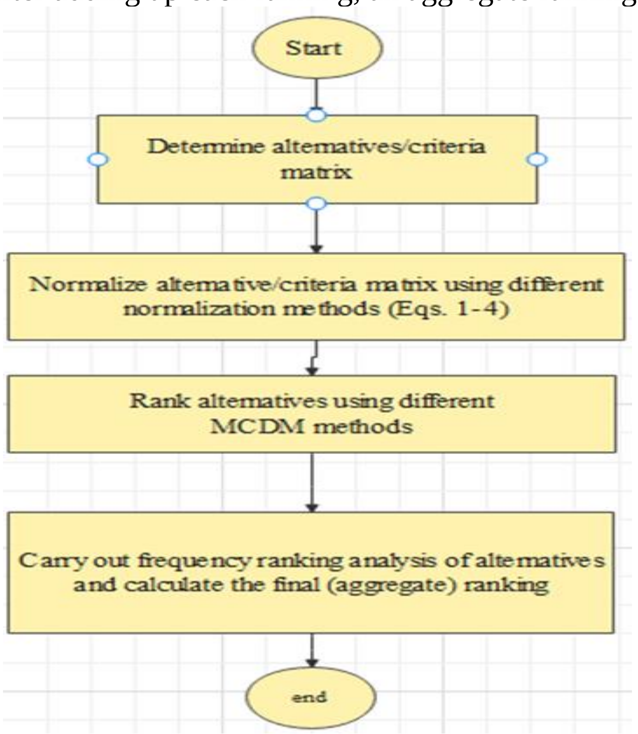

Figure-1 Flowchart of proposed method

Table-1 Decision matrix of Tiwari and shram study [18]

Alternative code	**Lubrication cooling condition**	**Nose Wear (C_1)(mm)**	**Flank Wear (C_2)(mm)**	**Feed force (C_3)(N)**	**Cutting force (C_4)(N)**	**Surface roughness $(C_5)(\mu m)$**
A_1	SCF-II (8%EP)	0.1505	0.1789	439.6	635.15	3.47
A_2	SCF-II (12%EP)	0.1681	0.1881	423.8	627.4	3.93
A_3	CCF-II (8%EP)	0.1311	0.1532	401.5	629.32	3.04
A_4	CCF-II (12%EP)	0.1616	0.1963	495.03	668.12	3.78
A_5	CMCF	0.2339	0.1949	544.89	663.26	3.75
A_6	CSSCF	0.2094	0.2346	523.94	615.05	4.01
A_7	Dry Cutting	0.5357	0.51	271.16	503.15	3.3

SCF-II (8% of EP): sunflower-based cutting fluids with 8% of EP additive.
SCF-II (12% of EP): sunflower-based cutting fluids with 12% of EP additive.
CCF-II (8% of EP): canola-based cutting fluids with 8% of EP additive.
CCF-II (12% of EP): canola-based cutting fluids with 12% of EP additive.
CMCF: commercial mineral-based cutting fluid. CSSCF: commercial semi-synthetic cutting fluid.
Determining the proper weight of importance for each criterion is a crucial challenge for multicriteria decision-making, as each criterion has a distinct priority in this type of decision-making and it is not believed that all of them have equal weights. Two categories can be made out of the several approaches to criterion weights that have been put forth in the literature. These techniques are both objective and subjective. Subjective techniques only take decisionmakers' preferences into account when setting weights. Subjective procedures make it easy to bring up prejudice and bias. The weights are determined by objective procedures, which do not take the decision-maker's preferences into account and instead use the available data. Since many real-life difficulties make it difficult to establish reliable subjective significance weights, using objective weights is more advantageous [34]. As a result, in this study, subjective weightings were combined with the entropy method, an objective weighting technique. To compare the outcomes, the Spearman correlation test was applied. It is a nonparametric statistical measure that is employed to assess the degree of reliance between two variables. A specific instance of Pearson's product-moment correlation coefficient is the Spearman's rank correlation coefficient (q). The sample data must match the order of the two variables (Y and X) in order to calculate the q value.When Pearson's assumptions are not fulfilled, the Spearman correlation coefficient (q) is utilized to measure the linear relationship between two continuous variables instead of Pearson correlation. The linear link between two ordinal variables or a sequential and continuous variable is referred to as the Spearman correlation coefficient [35]. It is fair to compare the consistency of these rankings using this test because of these reasons.

IV- Results:

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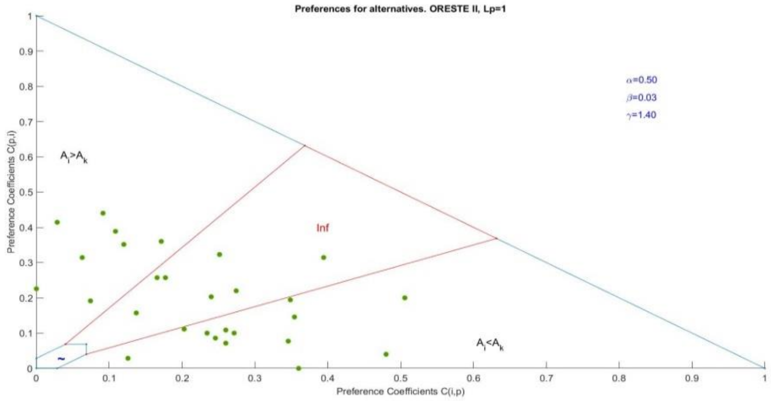

Figure-2 Preferences for alternatives, ORESTE II, For Lp = 1

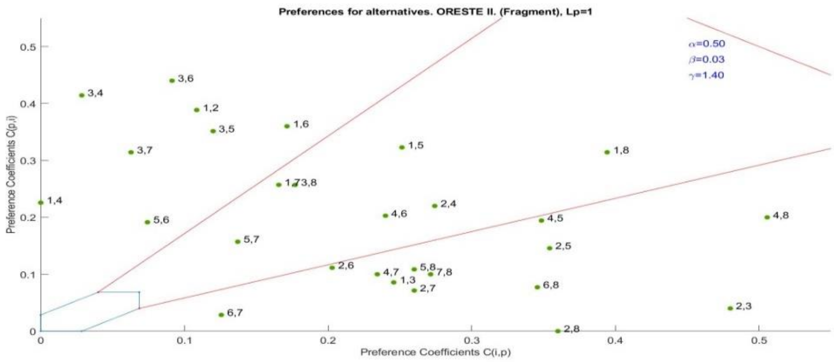

Figure-3 Preferences for alternatives, Fragment, For Lp = 1

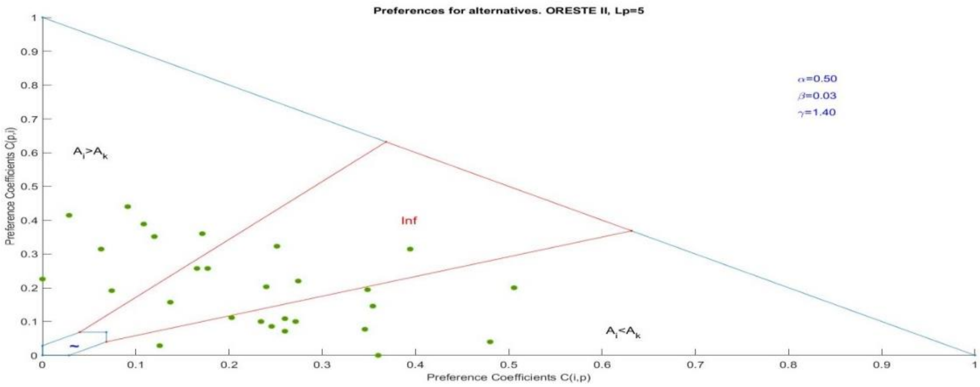

Figure-4 Preferences for alternatives, ORESTE II, For Lp = 5

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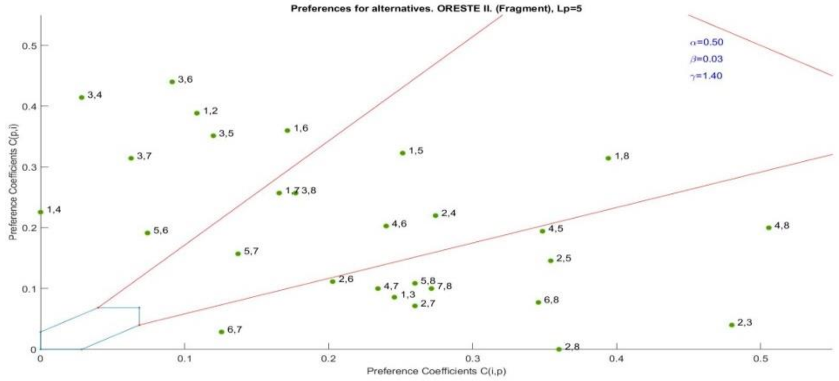

Figure-5 Preferences for alternatives, ORESTE II,(Fragment) For $Lp = 5$

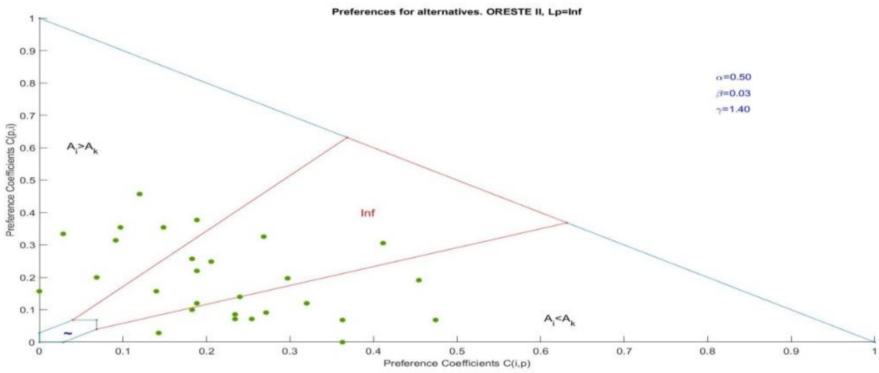

Figure-6 Preferences for alternatives, ORESTE II, For $Lp = \infty$

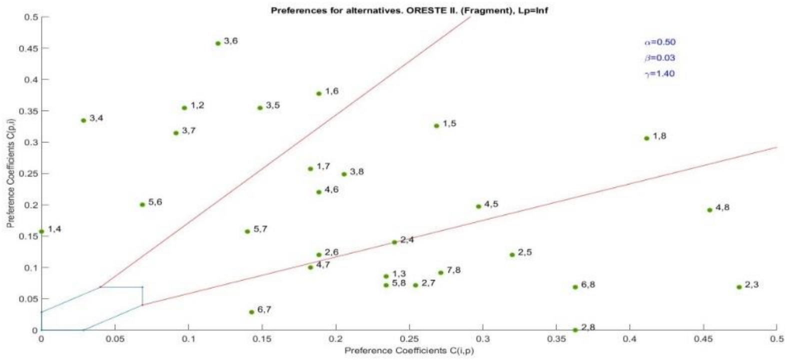

Figure-7 Preferences for alternatives, ORESTE II, (Fragment) $Lp=\infty$

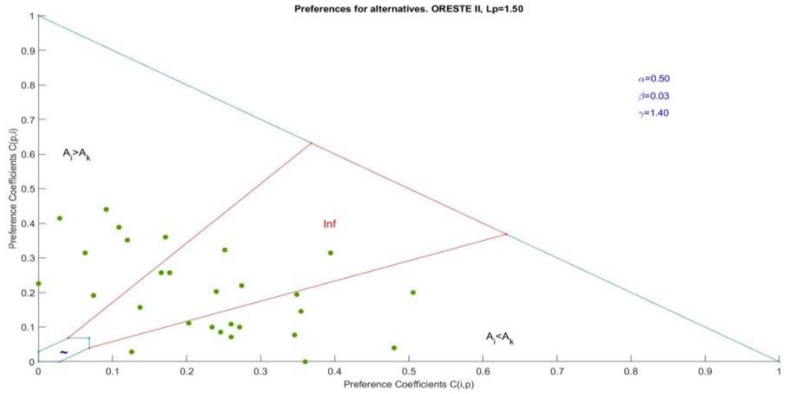

Figure-8 Preferences for alternatives, ORESTE II, For $Lp = 1.5$

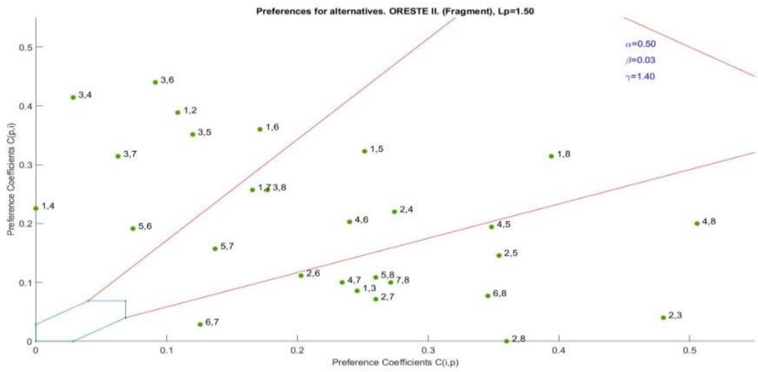

Figure-9 Preferences for alternatives, Fragment, For $Lp = 1.5$

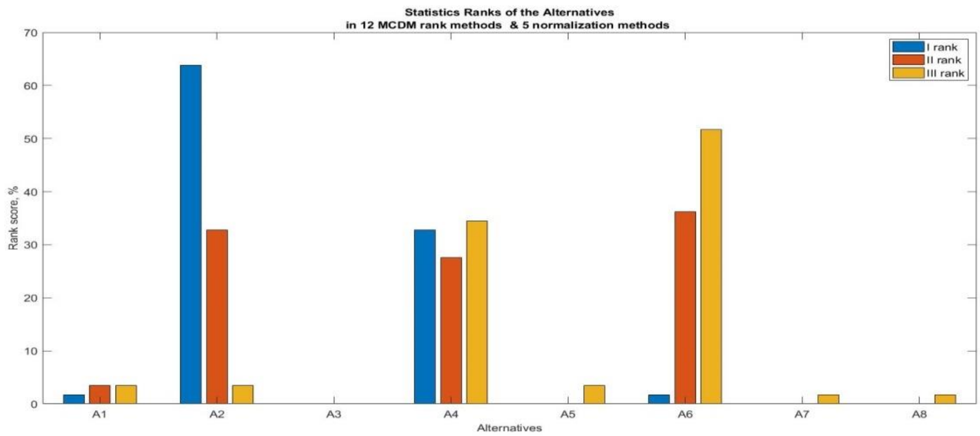

Figure -10 Statistics of ranks of the alternative in 12 MCDM ranking Method & 5 normallization method

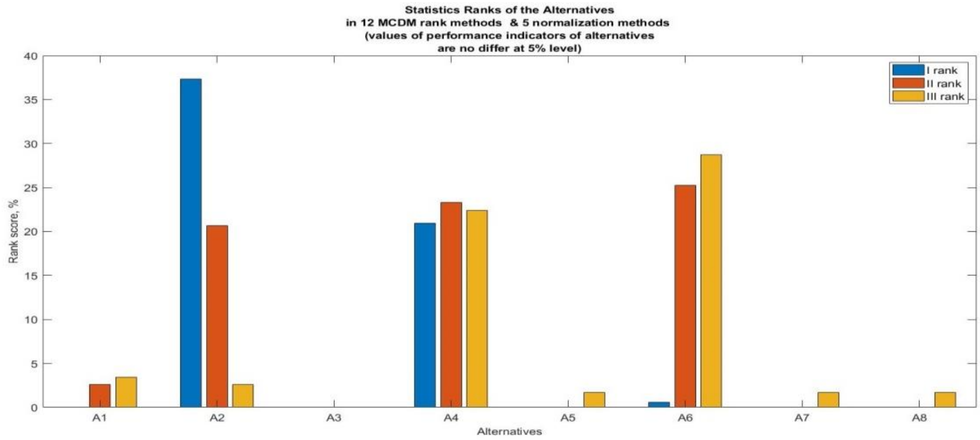

Figure- 11 Statistics of ranks of the alternative in 12 MCDM ranking Method & normallization method (values of Preferences indicator of alternatives are not differ at 5% level)

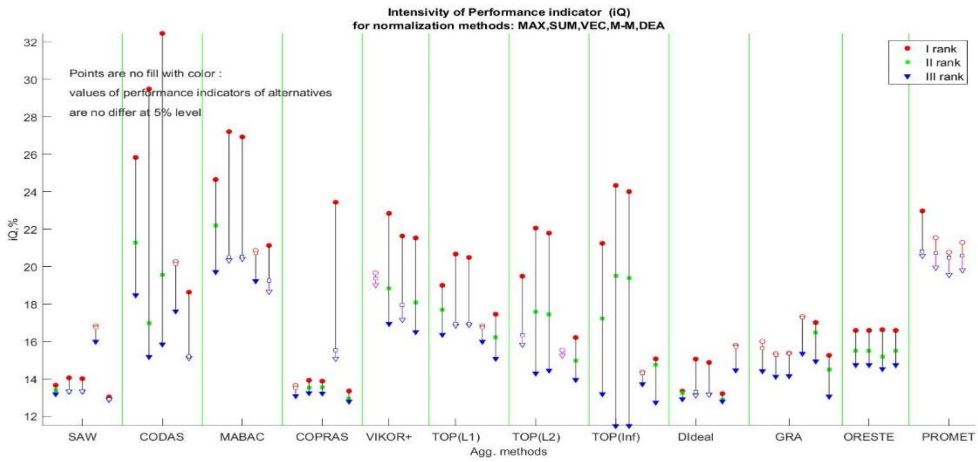

Figure- 12 Intensivity of Preferences indicator for normalization method: MAX, SUM, VEC, M-M, DEA

V- Conclusions:

A novel cutting fluid selection decision assistance system was put forth in this study. Three distinct cutting fluid selection issues were selected for this context from the literature. The best cutting conditions for these investigations were identified using fifteen distinct MCDM approaches and four different normalizing strategies. In addition to the weights established in the literature, a novel hybrid approach was employed for the purpose of weighting criteria. The Spearman correlation test was used to compare the ranks that were obtained. There was consistency in the results ($p<0.05$). The study aids operators and manufacturers in their decision-making when choosing cutting fluids for use in manufacturing settings. Future research can employ several criterion weighing techniques, such as Level Based Weight Assessment and Best-Worst. Given the results, a thorough sensitivity analysis may be carried out.

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