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# TOPSIS and VIKOR approaches to machine tool selection

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This paper mainly focuses to compare the different multiple criteria decision making (MCDM) methods such as TOPSIS and VIKOR Method for selection of alternative industrial welding machine. Both the methods are based on an aggregating function that represents closeness to the ideal solution. VIKOR method is based on linear normalization whereas TOPSIS method used vector normalization to eliminate the units of criterion functions. A solution obtained by TOPSIS method has the shortest distance from the ideal one and farthest from the negative ideal solution. VIKOR method helps to determine a compromise solution that gives a maximum group utility for the majority and minimum for opponents. In this paper, rank obtained by TOPSIS and VIKOR are compared by the help of SDI (statistical design institute) software tool.SDI tool software has also been used for obtaining the results and thus the result obtained is being compared with the result of TOPSIS and VIKOR. The correlation coefficient was calculated with the help of MINITAB software to measure the rank coefficient between VIKOR and TOPSIS.

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## Introduction

Decision-making is a logical human judgment process for identifying and choosing alternatives based on the values and preferences of the decision maker that mostly applied in the managerial level of the concerned department of the organization. Recently, decision-making has gained immense popularity in industries because of their global competitiveness and to survive successfully in respective market place. Therefore, decision-making plays a vital role especially in purchase department for reducing material costs, minimizing production time as well as improving the quality of product or service. But, in today's real life problems, decision-makers generally face lot of confusions, ambiguity due to the involvement of uncertainty and subjectivity in complex evaluating criterions of alternatives. To deal such kind of vagueness in human thought the title 'Decision-Making in Fuzzy Environment' has focused into the emerging area of research associated with decision sciences. In order to tackle such kind of problems, Rao R.V. [1] introduced fuzzy sets contributed to the field of MCDM and called fuzzy Multi-Criteria Decision Making (FMCDM) approach. Today's, it has been observed that, FMCDM has gained immense popularity in the real life applications. Zavadskas and Kaklauskas [2] developed a method of multiple criteria complex proportional assessment of projects for determining the priority and the utility degree of alternatives. In the period of 1996–2011, Lithuanian as well as foreign scientists has been applying the original or expanded method for solving different engineering as well as management multi-attribute problems. Usual crisp TOPSIS as developed by Hwang and Yoon [3] and fuzzy TOPSIS has been mostly applied in construction management for ranking of construction technological alternatives, selecting of resource-saving decisions, accepting other technological or facility management decisions. Yen and Chang [4] apply a new fuzzy multi criteria decision making approach for evaluating decision alternatives involving subjective judgments made by a group of decision makers was presented. Jakimavicius and Burinskiene [5] have evaluated road design and transport systems. In some papers the application of extended TOPSIS has been analyzed by Zavadskas et al.[6] the methodology for measuring the accuracy of determining the relative significance of alternatives as a function of the criteria values was developed Attempts using extended TOPSIS method with different distance approaches were published,

Opricovic [7-9] was developed Compromise ranking method VIKOR .The present method was compared with TOPSIS methods by Opricovic and Tzeng [8]. According to Opricovic and Tzeng, the values normalized by vector normalization and applied in TOPSIS may depend on the evaluation unit. Moreover, these two methods introduce different aggregating functions for ranking. Therefore, the authors of the current paper also applied the VIKOR method for ranking redevelopment alternatives of derelict buildings Antucheviciene and Zavadskas [10]. The VIKOR-F method has been developed to solve fuzzy multi criteria problem with conflicting and no commensurable criteria Opricovic [9]. Keeping this in mind, this paper introduces innovative decision methodologies for an evaluation cum selection policy analysis, based on theory of multi-criteria decision-making-tools theory. However, combination of VIKOR with some other MCDM methods has been more often applied and handling of a proper MCDM technique has been discussed. Selection of proper methods considering their advantages and disadvantages in qualitative manner was analyzed by Ginevicius and Zubrecovas [11, 12] .TOPSIS and VIKOR were applied for evaluating of environment of enterprises by Ginevicius et al.[13] . The TOPSIS and VIKOR methods have been used in the literature as multi criteria tools in selection among various alternatives considering multiple criteria by Rao [14] and Zammori et al. [15].

## Methodology

### Topsis method

TOPSIS method was firstly developed by Hwang and Yoon in 1981. The basic approach of this method is choosing an alternative that should have the shortest distance from the positive ideal solution and the farthest distance from negative ideal solution. The positive ideal solution maximizes the benefit criteria and minimizes conflicting criteria, whereas the negative ideal solution maximizes the conflicting criteria and minimizes the benefit criteria. For the calculation of TOPSIS values, we have to go through the following steps.

**Step 1**:- In the first step, we have to determine the objective and to identify the attribute values for each alternative.

**Step 2:-** This step involves the development of matrix formats. The row of this matrix is allocated to one alternative and each column to one attribute. The decision making matrix can be expressed as:

$$D = \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \cdots & x_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn} \end{bmatrix}$$

**Step 3:-** Then using the above matrix to develop the normalized decision matrix with the help of the formula given below:

$$_{ij}{*}=Xij/\sqrt{\sum_{i=1}^{n}(Xij^2)})$$

**Step 4:-** Depending upon the relative importance of different attributes obtain weight for each attributes using the formula given below and the sum of the weights should be 1.

$$W_j=V_j/\sum_{i=1}^{m} Vj \& \sum_{j=1}^{m} Wj= \mathbf{1}$$

Where $V_j$ is the variance of each attribute which can be calculated by the formula given as

$$V_j=(1/n)\sum_{i=1}^{n}(X_{ij}^{*} - X_{ijmean}^{*})^2$$

**Step 5:-** Then obtain the weighted normalized matrix $V_{ij}$ by multiplying Wj with all the values Xij.*such as

$$V_{ij}= W_j X^*_{ijS}$$

**Step 6:-** This step determines the ideal (best) and negative ideal (worst) solutions. The ideal and negative ideal solution given as:

a) The Ideal solution

$$A^+ = \{V_1^+ \ldots\ldots\ldots\ldots\ldots\ldots\ldots, V_m^+ \}=\{(\max v_{ij}|j\in I'),(\min v_{ij}|j\in I'')\}$$

b) The negative ideal solution

$$A^- = \{V_1^- \ldots\ldots\ldots\ldots\ldots\ldots\ldots V_m^- \} =\{(\min v_{ij}|j\in I'),(\max v_{ij}|j\in I'')\}$$

Here,
I' = {j=1, 2 …………n|j }: Associated with the beneficial attributes .
I'' = {j=1, 2 …………n|j }: Associated with non-beneficial adverse attributes.

**Step 7:-** Obtain separation (distance) of each alternative from the ideal solution and negative ideal solution which is given by the Euclidean distance given by the equations.

$$D_i^+=\sqrt{\sum_{j=1}^{m}(V_{ij} - V_j^+)2} \qquad i=1\ldots\ldots\ldots\ldots\ldots\ldots\ldots n.$$

$$D_i^+=\sqrt{\sum_{j=1}^{m}(V_{ij} - V_j^-)^2} \qquad i=1\ldots\ldots\ldots\ldots\ldots\ldots\ldots n.$$

**Step 8:-** Calculate the relative closeness to the ideal solution of each alternative which is given by the formula:-

$$C_i^*=C_i^-/(C_i^- + C_i^+), \quad i=1\ldots\ldots\ldots\ldots\ldots\ldots\ldots n.$$

**Step 9:-** A set of value is generated for each alternative. Choose the best alternative having largest closeness to ideal solution. Arrange the alternative as an increasing order of $C_i^*$.

### Vikor method

VIKOR also known as Compromise Ranking Method is a possible solution that is closest to the ideal solution and the meaning of compromise is agreement generated by mutual concession. The calculation of VIKOR values, we go through the following steps: Till step 4 is same that of TOPSIS method as given above.

**Step 5:-** Obtain the value of the criterion function for all the alternative $f_{ij}$. $f_{ij}$, is the jth criterion function of $X_i$ alternative .

Here,
i=1,2,….,n : the number of alternatives.
j=1,2,….,m: the number of criteria.

**Step 6:-** Obtain the maximum criterion function $f_j^*$ and the minimum criterion function $f_j^-$, where j = 1. . . . . . m.

$$f_j^*= f_{ij}=\max [(f_{ij} )| i = 1, 2, .......,n] .$$

$$f_j^-= f_{ij}=\min [(f_{ij}) | i = 1, 2, ........,n] .$$

**Step 7:-** Calculate the utility measure and regret measure for all the alternatives given as:

a) Utility measure

$$S_i = \sum_{j=1}^{m} w_j(f_j^+ - f_{ij})/(f_j^+ - f_i^-)$$

b) Regret measure

$$R_i={}^{\max}{}_j[W_j(f_j^* - f_{ij}) / ( f_j^* - f_j\text{-}) ]$$

**Step 8**:- calculate the value of VIKOR index for each alternative expressed as follows:

$$Q_i= v(S_i- S^*)/(S^- - S^*)+ (1 - v)(R_i- R^*)/(R^- - R^*)$$

Where,

$Q_i$ represents the VIKOR index value of ith alternative. I=1,2,……,n.

$S^{*} = S_i = \min [(S_i) \mid i = 1, 2, . . .… . . . ,n]$

$S^{-} = S_i = \max [(S_i) \mid i = 1, 2, . . .… . . . ,n]$

$R^{*} = R_i = \min [(R_i) \mid i = 1, 2, . . . .... . ,n]$

$R^{-} = R_i = \max [(R_i) \mid i = 1, 2, . . . ... .. . ,n]$

v is introduced as a weight for the strategy of maximum group utility, whereas (1-v) = weight of the individual regret. The solution obtained by $\min_j S_j$ is with a maximum group utility (majority rule), and the solution obtained by $\min_j R_j$ is with a minimum individual regret of the opponent. Normally, the value of v is taken as 0.5. However, v can take any value from 0 to 1.

**Step 9**:- Rank the alternatives, sorting by the values $S_i$, $R_i$, and $Q_i$. The results are three ranking lists. Propose as a compromise solution the alternative $A^{(1)}$, which is the best ranked by the measure $Q_i$ (minimum), if the following two conditions are satisfied:

a.) Acceptable advantage: $Q[A^{(2)} - Q^{(1)}] \geq DQ$, where DQ = 1⁄(J - 1), and $A^{(2)}$ = alternative with second position on the ranking list by $Q_i$;

b.) Acceptable stability in decision making: The alternative $A^{(1)}$ must also be the best ranked by $S_i$ and/or $R_i$. This compromise solution is stable within a decision-making process, which could be the strategy of maximum group utility (when v > 0.5 is needed), "by consensus" (v is approximately 0.5), or with veto (v < 0.5).

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

c.) Alternative $A^{(1)}$ and $A^{(2)}$ if only condition 2 is not satisfied, or

d.) Alternatives $A^{(1)}$,$A^{(2)}$, K, $A^{(m)}$ if condition 1 is not satisfied, in which $A^{(m)}$is determined by the relation $Q[A^{(m)} - QA^{(1)}] < DQ$ for maximum n; the positions of these alternatives are "in closeness."

## Problem specification:- Case study

**Company profile**

Passive Infra specializes in Manufacturing of Structural Steels in India, and has developed a strong presence in supplying Fabricated & Galvanized Steel Structures to various companies involved in infrastructural projects. Backed by the international standards certification ISO 9001:2000 awarded for its manufacturing facility located in Haryana on the Delhi Border, the company is now growing in reputation and business, poised for occupying a prominent place among top steel fabricating companies in India.

Equipped with a perfect blend of state-of-the-art machines and man-power, the company enjoys a clear edge over others in delivering jobs that are totally in sync with the specifications of the clients. The manufacturing facilities passive Infra comprise of hot dip galvanizing, welding process, powder coating, sand blasting, and painting processes, apart from a well stocked tool room & in-house lab-testing, which is also available for chemical & physical testing of products at the company's manufacturing plant.

The company's operations are backed by a sound infrastructure and a world-class manufacturing facility certified for international Standards of Quality ISO 9001:2008. The vast production facilities spread over 5, 34, 000 sq. ft. of area on the outskirts of Delhi in Haryana are installed to fabricate and galvanize 48,000 tons of Steel every year.

**Data given**

The company's operations are backed by a sound infrastructure and a world-class manufacturing facility, and machines used in ARC welding machine, MIG welding machine, robotic arm CNC cutting m/c,3D drilling m/c, milling m/c ,etc.

In this paper, we have studied and compared FP 100 ARC welding machine, FP 235 ARC welding machine, FP 260 MIG welding machine, FP 130 MIG welding machine.

**TOPSIS Method**

For the calculation of TOPSIS values, we have to go through the following steps.

Step 1:-

In the first step, we have to determine the objective and to identify the attribute values for each alternative.

Attribute value (criteria):-

Input voltage e($V_i$ )

Output voltage ($V_o$)

Maximum welding capacity (M)

Cost (C)

Alternative value or M/c

FP 100 ARC Welding machine ($M_1$).

FP 235 ARC Welding machine ($M_2$).

FP 260 MIG Welding machine ($M_3$).

FP 130 MIG Welding machine ($M_4$).

Step 2:-

This step involves the development of matrix formats. The row of this matrix is allocated to one alternative and each column to one attribute. The decision making matrix can be expressed as in Table 1.

Step 3:-

Then using the above matrix to develop the normalized decision matrix with the help of the formula given below as shown in Table 2.

**Table 1** Matrix Making

| Alternative/Criteria | Input voltage $V_i$ | Output voltage $V_o$ | Welding capacity M | Cost C |
|---|---|---|---|---|
| $M_1$ | 120V | 27V | (3/16)inch | 252$ |
| $M_2$ | 230V | 20V | (1/2)inch | 642$ |
| $M_3$ | 230V | 26V | (5/8)inch | 784$ |
| $M_4$ | 120V | 18V | (1/4)inch | 585$ |

**Table 2** Normalized decision Matrix

| Alternative/criteria | Input voltage $V_i$ | Output voltage $V_o$ | Welding capacity M | Cost C |
|---|---|---|---|---|
| $M_1$ | 0.3271 | 0.5852 | 0.2182 | 0.2105 |
| $M_2$ | 0.6269 | 0.4334 | 0.5819 | 0.5363 |
| $M_3$ | 0.6269 | 0.5634 | 0.7274 | 0.6550 |
| $M_4$ | 0.3271 | 0.3901 | 0.2909 | 0.4887 |

Step 4:-

$V_j$ is the variance of each attribute which can be calculated by the formula given as in Table 3.

Depending upon the relative importance of different attributes obtains weight for each attributes using the formula given below and the sum of the weights should be 1 as shown in Table 4.

Step 5:-

Then obtain the weighted normalized matrix $V_{ij}$ by multiplying $W_j$ with all the values $X_{ij}^*$ such as given in Table 5.

Step 6:-

This step determines the ideal (best) and negative ideal (worst) solutions. The ideal and negative ideal solution given below and shown in Table 6:

Step 7:-

Obtain separation (distance) of each alternative from the ideal solution and negative ideal solution which is given by the Euclidean distance given by the equations and results are shown in Table 7.

Step 8:-

Calculate the relative closeness to the ideal solution of each alternative which is given by the formula and are shown in Table 8.

Step 9:-

A set of value is generated for each alternative. Choose the best alternative having largest closeness to ideal solution. Arrange the alternative as an increasing order of $C_i^*$.

$M_2$ is the best alternative having largest closeness to ideal solution.

**VIKOR method**

The calculation of VIKOR values, we go through the following steps: Till step 4 is same that of TOPSIS method as given above.

Step 5:-

Obtain the value of the criterion function for all the alternative $f_{ij}$. $f_{ij}$,is the jth criterion function of $X_i$ alternative.

Step 6:-

Obtain the maximum criterion function $f_j^*$ and the minimum criterion function $f_j^-$, as shown in Table 9 and 10.

Step 7:-

Calculate the utility measure and regret measure for all the alternatives given as in Table 11 and 12.

Step 8:-

Calculate the value of VIKOR index for each alternative. Normally, the value of v is taken as 0.5.

Step 9:-

Rank the alternatives, sorting by the values $Q_i$. The alternative $M_2$, which is the best ranked by the measure $Q_i$ (minimum) as in Table 13.

**Table 3** Variance of each attribute

| | $V_i$ | $V_o$ | M | C |
|---|---|---|---|---|
| $V_j$ | 0.0225 | 0.0069 | 0.0433 | 0.0266 |

**Table 4** Weight of different attributes

| | $V_i$ | $V_j$ | M | C |
|---|---|---|---|---|
| $W_j$ | 0.2266 | 0.0695 | 0.4360 | 0.2679 |

**Table 5** Weight normalized matrix

| Alternative/criteria | Input voltage $V_i$ | Output voltage $V_o$ | Welding capacity M | Cost C |
|---|---|---|---|---|
| $M_1$ | 0.0741 | 0.0406 | 0.0951 | 0.0563 |
| $M_2$ | 0.1420 | 0.0301 | 0.2537 | 0.1436 |
| $M_3$ | 0.1420 | 0.0391 | 0.3171 | 0.1755 |
| $M_4$ | 0.0741 | 0.0271 | 0.1268 | 0.1309 |

**Table 6** Ideal positive and Ideal negative solutions

| | $V_i$ | $V_j$ | M | C |
|---|---|---|---|---|
| $A^+$ | 0.1420 | 0.0406 | 0.2537 | 0.0563 |
| $A^-$ | 0.0741 | 0.0271 | 0.0951 | 0.1755 |

**Table 7** Distance from ideal positive and ideal negative

| | $M_1$ | $M_2$ | $M_3$ | $M_4$ |
|---|---|---|---|---|
| $D_j^+$ | 0.1725 | 0.0879 | 0.1350 | 0.1627 |
| $D_j^-$ | 0.1199 | 0.1754 | 0.2325 | 0.0549 |

**Table 8** Relative closeness to ideal solution

| | $M_1$ | $M_2$ | $M_3$ | $M_4$ |
|---|---|---|---|---|
| $C_J^*$ | 0.4100 | 0.6661 | 0.6326 | 0.2516 |

**Table 9** Maximum criteria function

| | $V_i$ | $V_o$ | M | C |
|---|---|---|---|---|
| $F_j^*$ | 0.6269 | 0.5852 | 0.7274 | 0.2105 |

**Table 10** Minimum criteria function

| | $V_i$ | $V_o$ | M | V |
|---|---|---|---|---|
| $F_j^-$ | 0.3271 | 0.3901 | 0.2182 | 0.6550 |

**Table 11** Utility measure

| | $M_1$ | $M_2$ | $M_3$ | $M_4$ |
|---|---|---|---|---|
| $S_i$ | 0.6626 | 0.3748 | 0.2757 | 0.8374 |

**Table 12** Regret measure

| | $M_1$ | $M_2$ | $M_3$ | $M_4$ |
|---|---|---|---|---|
| $R_i$ | 0.4360 | 0.1963 | 0.2679 | 0.3737 |

**Table 13** VIKOR index

| | $M_1$ | $M_2$ | $M_3$ | $M_4$ |
|---|---|---|---|---|
| $Q_i$ | 0.8444 | 0.0882 | 0.1493 | 0.8700 |

## Results and discussion

Both the TOPSIS and VIKOR methods were utilized in finding the ranking of welding machine using variances and weights as given above. By TOPSIS method, using the relative closeness coefficient ranking was found to be in the order $M_2$, $M_3$, $M_1$, and

$M_4$. In VIKOR, by observing the VIKOR index value, ranking was done as $M_2$, $M_3$, $M_1$, and $M_4$. Hence, for selection of Welding machine, both the results affirmed machine $M_2$. It clearly satisfies all the attributes like Input voltage ($V_i$), Output voltage ($V_o$), Maximum welding capacity (M), and Cost of each machine(C). Final ranking in both the methods was found to be same. Both the methods provided same preferential-ordered solution to this problem, VIKOR stood out the best reducing computation time and providing desirable result.

### Discussion by SDI (Statistical Design Institute) Tool

By mathematical modeling the ranks for machines are in the order $M_2$, $M_3$, $M_1$, $M_4$ but when modeling is done with the help of SDI tool as shown in Fig 1, the order of preference changes to $M_3$, $M_2$, $M_1$, $M_4$.

By both mathematical modeling and SDI tool the values of machines M2 and M3 are very close to each other so we just have to look after for these machines to check out the best among them.

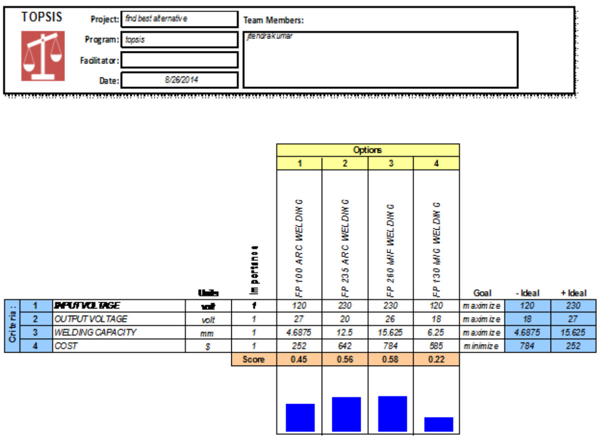


**Fig. 1** Result by SDI tool

### Correlation Coefficient (MINI TAB)

In this correlation coefficient screenshot the values of M1 and M4 score 1 and '*' so we have to closely look after these machines for calculation, and M2 and M3 score 1 and '*' so these two machines are also closely looked after for measurement as shown in Fig 2.

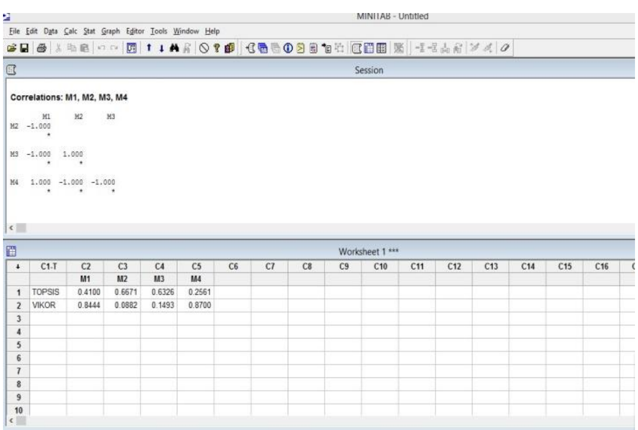


**Fig. 2** Correlation coefficient for machine

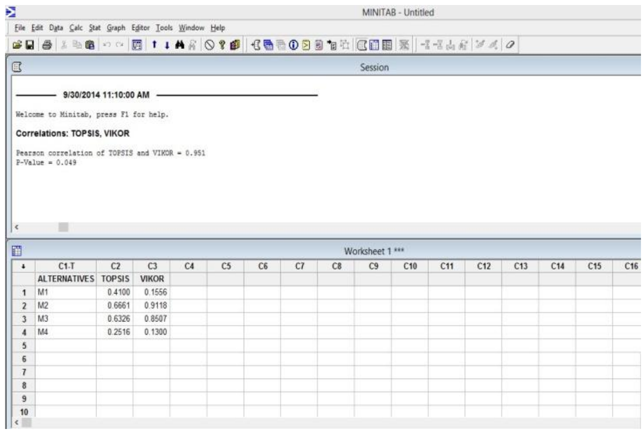


**Fig. 3** Correlation Coefficient for method (TOPSIS and VIKOR)

The above Fig. 3 clearly depicts the correlation coefficient between TOPSIS and VIKOR. Here, p-value is 0.049 which is less than 0.05 which clearly indicates that TOPSIS and VIKOR method highly correlates with each other.

## Conclusion

This paper shows that two popular multi-criteria decision making algorithms such as TOPSIS and VIKOR for solution quality when applied to a benchmarking problem in industrial welding machine selection. With the help of normalized decision matrix methods we estimate criteria weights so that human judgment can be avoided by assigning weights to different attributes. The results show that one of the welding machine is the highest ranked by both methods. Being the highest ranked alternative by the TOPSIS method indicates that this machine is the best in terms of the ranking index. In addition, being the highest ranked alternative by the VIKOR method indicates that it is the closest to the ideal solution, and to be as close as possible to the ideal is the rationale of human choice. Both the methods result in same preference of selecting an industrial welding machine. But VIKOR method stands out to be the best due to elegant method and computational easiness. As discussed above, TOPSIS method indicates that alternative $M_2$ is the best in terms of the ranking index $C_j^*$. In addition, being the highest ranked alternative by the VIKOR method indicates that is the closest to the ideal solution.


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### Notes and References


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