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MCDM Framework for Optimal Supplier Selection of GMAW and GTAW Welding Equipment Using Fuzzy AHP and TOPSIS

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Abstract

The selection of suitable suppliers for welding machines for welding technics such as GMAW/GTAW is a critical decision in both industrial and educational sectors, directly impacting quality of product, operational efficiency, and long-term cost-effectiveness. This article presents a robust and systematic decision making framework for supplier selection by using combined MCDM techniques like- TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and FAHP (Fuzzy Analytic Hierarchy Process). By incorporating fuzzy logic into traditional AHP. The study is grounded in real-on field data collected through detailed surveys across industries and technical institutes in Chhattisgarh, India. Various selection parameters are considered for supplier selection such as performance, cost, reliability, after-sales service, safety, and documentation, by considering the different priorities between industrial and educational sectors. Subsequently, TOPSIS is employed to rank supplier alternatives based on their relative closeness to the ideal solution and FAHP minimizes judgmental fuzziness of human. The article further explores sector-wise differences and suggest suitable supplier for both industry and education sector. The integrated TOPSIS -FAHP framework not only bridges the gap between theory and practice but also provides high-impact recommendations for supply chain executives. The outcomes contribute to more transparent, objective, and context-aware supplier selection in the field of welding technology.

Keywords
Supplier selection, FAHP, TOPSIS, GMAW and GTAW.

1. Introduction
Supplier selection is inherently a multi-criterion decision-making (MCDM) problem involving both qualitative and quantitative factors. Key criteria often include price, technical capability, service quality, warranty, and supplier reputation. In the context of welding machine procurement, the selection of a reliable supplier is particularly critical. Welding machines—specifically GMAW (Gas Metal Arc Welding) and GTAW (Gas Tungsten Arc Welding) types—are indispensable in manufacturing and fabrication sectors such as automotive, railways, heavy machinery, shipbuilding, and infrastructure development. The performance and efficiency of these machines depend heavily on the quality of components like torches, wire feeders, power sources, and control systems. An incorrect supplier choice can

lead to frequent equipment breakdowns, substandard welds, high maintenance costs, and operational downtime, all of which can significantly impair productivity. Moreover, the value that welding machines bring to both industry and the education sector is substantial. in production industries, advanced welding machines enhance productivity, deliver consistent weld quality, and allow automation to support mass production. The machines also reduce material wastage, are energy efficient, and ensure workplace safety. In technical institutes such as polytechnics, ITIs, and engineering colleges, welding machines support technical training and skill development. Practical training on real machines allows students to gain employable skills to become industry-ready. As the performance driver of utmost importance, the optimal welding machine provider is a strategic necessity. This study proposes a sound decision-making model based on Fuzzy Analytic Hierarchy Process (FAHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to quantify and prioritize welding machine providers. The method integrates subjective expertise with quantifiable performance data collected through structured questionnaires from industrial customers and educational institutions in the state of Chhattisgarh.

1.1 Objectives

The main goal of this study is to create a strong, data-driven framework for the selection of GMAW/GTAW welding machine suppliers using Multi Criteria Decision Making (MCDM) techniques, specifically Fuzzy Analytic Hierarchy Process (FAHP) and TOPSIS. This framework aims to support effective, transparent, and technically informed procurement decisions in both industrial and educational sectors of the Chhattisgarh region by collecting real-time, empirical data from key stakeholders—such as industry professionals and educators—via structured surveys to understand the relative importance of various supplier selection criteria and then applying the Fuzzy Analytic Hierarchy Process (FAHP) for determining the weights of evaluation criteria, enabling the conversion of subjective linguistic judgments into a quantifiable fuzzy decision matrix then employing the TOPSIS method for ranking supplier alternatives choosing the greatest choice that is closer to the optimal solution based on how well they perform across all criteria.

2. Literature Review

Abima et al. (2022) is demonstrated comparative studies that shows the trade-offs between TIG and MIG welding machines. MIG dominates in speed and productivity, TIG provides accuracy and quality of weld. In the hybrid TIG-MIG welding methodology and Tesfaye, A. and Frederik, D. (2023) observed that simultaneous use of the two methods was found to lead to enhancements in tensile strength, ductility, and structural integrity beyond what the individual processes alone are capable of providing. These results support the need to understand machine aspects when suppliers are evaluated in particular working conditions. Do et al. (2024) applied FAHP-TOPSIS to evaluate academic staff performance in Vietnam, highlighting its ability to manage group decision-making and expert consensus. Ayhan (2013) applied FAHP to gear motor selection, closely mirroring welding machine selection due to similar evaluation criteria (torque, build quality, reliability). Nguyen et al. (2024) applied FAHP-TOPSIS in explosion protection systems, indicating its viability in high-risk equipment procurement. Do et al. (2024) used FAHP-TOPSIS to rank academic staff performance. Luyen and Thanh (2022) proposed a hybrid SERVQUAL-FAHP-TOPSIS for logistics provider evaluation. Helmy et al. (2021) applied FAHP to rank big data service providers. Their method managed qualitative factors like scalability, responsiveness, and reliability. The use of triangular fuzzy numbers provided precision in dealing with subjective assessments.

Chan et al. (2008) introduced FAHP for global supplier selection, integrating environmental considerations. Their criteria included green certifications and pollution control. Chan and Kumar (2007) presented a fuzzy extended AHP (FEAHP) using fuzzy synthetic extent methods. This model further improved consistency. Altinoz (2001) applied FAHP in the textile industry, incorporating quality, lead time, and flexibility. Hybrid FAHP-TOPSIS models are increasingly common due to their robust handling of both weight assignment and ranking. Rouyendegh and Saputro (2014) applied this model in a fertilizer company to handle supplier allocation. The integration with MCGP (Multi-Choice Goal Programming) added flexibility in order quantities. Liao and Kao (2011) used fuzzy TOPSIS with trapezoidal fuzzy numbers in the watch manufacturing sector. Their model supported supplier ranking under variable cost-quality trade-offs. Thus The studies under review collectively confirm the effectiveness of applying Fuzzy AHP to measure expert opinion and TOPSIS for ordered ranking of alternatives in multi-criteria contexts. Building upon these established methodologies, the current research proposes an integrated Fuzzy AHP–TOPSIS framework tailored specifically for the supplier selection of welding machines. The approach is grounded in real-world data collected from educational and industrial stakeholders, enhancing its applicability and decision support capabilities.

3. Methods

The methodological framework adopted in the study for the selection of suppliers of MIG/TIG welding machines using MCDM techniques. This study primarily adopts the FAHP along with the TOPSIS for decision-making and supplier ranking. The present study adopts a structured MCDM approach that integrates expert opinion and field data. The major steps in the methodology include:

1. Identification of criteria and alternatives.
2. Data collection through surveys.
3. Application of Fuzzy AHP to determine criteria weights.
4. Supplier ranking using TOPSIS.

To select the most suitable supplier for GMAW/GTAW welding machines for industrial and educational institutions in Chhattisgarh based on Six significant criteria were determined for supplier assessment: Price/Cost, Welding, Precision, Build Quality, After-Sales Service, Service Cost, Spare parts availability, Delivery time, Compliance with industry standards These were chosen through literature synthesis and interviews with experts. Also The five potential supplier brands examined in this study are: Megmeet, Ador, Panasonic, Relon, ESAB. They were chosen based on their presence in the local market and applicability to industrial and educational sectors (Figure 1).

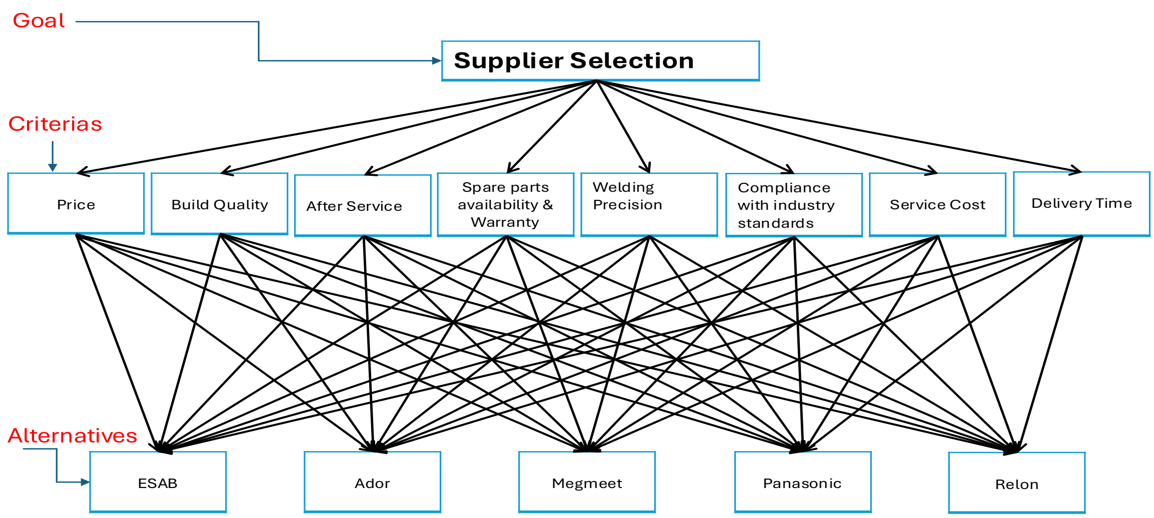

Figure 1. Supplier Selection Hierarchy

All pertinent aspects and sub-factors pertaining to the research topic must be integrated in order to develop the index system. A hierarchy derived from these identified factors forms the basis of the assessment index's structure. Subsequent tiers of components and sub-factors follow the top level, which stands for the primary goal. Additionally, this step involves breaking the problem down into its component parts according to common characteristics. Miller claims that the majority of decision-makers find it difficult to manage more than seven or nine things at once.

3.1 Fuzzy AHP

This section is present the overview of fuzzy AHP methodology. Equation (1) describes how fuzzy pairwise comparisons are used to generate a matrix $\tilde{A}$.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \dots & \tilde{a}_{2n} \\ \dots & \dots & \dots & \dots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & 1 \end{bmatrix} \qquad (1)$$

Where$\tilde{a}_{ij} = (l_{ij}, m_{ij}, n_{ij})$indicates the value of the fuzzy comparison between criteria I and J. The fuzzy weights for every criterion are then determined, as shown in Equations (2) and (3).

$$\tilde{r}_i = (\tilde{a}_{i1} \oplus \tilde{a}_{i2} \oplus \dots\dots \oplus \tilde{a}_{in})^{\frac{1}{n}} \quad \text{for i = 1,2………. n} \qquad (2)$$

$\widetilde{w}_i = \frac{\tilde{r}_i}{\tilde{r}_1 \oplus \tilde{r}_2 \oplus \ldots \ldots \oplus \tilde{r}_n}$ for i = 1,2………. n (3)

Here, $\tilde{r}_i$ denotes the geometric mean of fuzzy comparisons for criterion i, and $\tilde{w}_i$ represents the fuzzy weight corresponding to that criterion.

3.2 TOPSIS

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a commonly used approach in Multi-Criteria Decision-Making (MCDM). Introduced by Hwang and Yoon in 1981, the method is based on the concept that the most suitable alternative is the one with the shortest distance from the Positive Ideal Solution (PIS) and the greatest distance from the Negative Ideal Solution (NIS).

A decision matrix $X = X_{ij}$ is prepared based on the performance values of each alternative under each criterion.

$$X = \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ \dots & \dots & \dots & \dots \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix}$$

Where: X_{ij} represents the performance score of i^{th} alternative for jth criterion .

The decision matrix is normalized to remove the effects of different units and to make all criteria comparable.

$$\bar{X}_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}$$

Each normalized value $\bar{X}_{ij}$ is multiplied by the corresponding weight W_j of criterion j.

$V_{ij} = \bar{X}_{ij} * W_j$ Where: V_{ij} is the weighted normalized value of alternative i with respect to criterion j.

For benefit criteria: consider higher weighted normalized value, i.e. $V_J^+ = \text{maximum}\, V_{ij}$

For cost criteria consider lower weighted normalized value, i.e. $V_J^- = \text{minimum}\, V_{ij}$

Where: V_J^+: best value for criterion j and V_J^-: worst value for criterion j.

Distance from the Positive Ideal Solution (PIS): $S_i^+ = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_J^+)^2}$

Distance from the Negative Ideal Solution (NIS): $S_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_J^-)^2}$

The relative closeness coefficient CC_i or P_i is calculated for each alternative as: $CC_i = \frac{S_i^-}{S_i^+ + S_i^-}$

CC_i ranges from 0 to 1.Higher CC_i indicates that the alternative is closer to the ideal solution. Finally, alternatives are ranked in descending order of their closeness coefficient CC_i.The alternative with the highest CC_i is considered the best choice and The alternative with the lowest CC_i is considered the least preferred.

4. Data Collection

To support the application of FAHP and TOPSIS methods for supplier selection, primary data was collected through a structured questionnaire designed using Google Forms. The survey targeted stakeholders from both industrial areas and educational institutions in Chhattisgarh who have experience with MIG/TIG welding machines. To ensure a data-driven and technically grounded evaluation process, a comparative table was also developed based on publicly available specifications and field feedback regarding five leading MIG/TIG welding machine suppliers—ESAB, Panasonic, Adore, Megmeet, and Relon. The Table 1 includes detailed technical requirements as shown below.

Table 1. Supplier Selection Parameters and suppliers of GMAW/GTAW Welding Machines

	Criteria/Supplier	**Unit**	**ESAB**	**Panasonic**	**Ador**	**Megmeet**	**Relon**
1	Main Supply	V, Ph,Hz	415+/-10%, 3, 50	415+/-20%, 3, 50	415+/-10%, 3, 50	380+/-25%, 3,50	415+/-15%, 3,50
2	Rated input power	KVA	18.7	17.6	18.5	13.1	10
3	Rated input Current	A	26	26	30	34	25
4	Permitted load at 60% duty cycle		400	400	400		400
5	Permitted load at 100% duty cycle		300	300	310	400	310
6	Power factor		0.93	0.94-0.96	0.86	0.94	0.94
7	Efficiency at maximum current	%	85	60	85-93	91	85
8	Current range	A	20-400 / 25-350	20-400	15-400	3-400	3-401
9	Open circuit voltage	V	65	71	65	68	70
10	Dimensions	mm	997*420*913	550*330*600	530*360*700	280*530*630	565*306*432
11	Weight	kg	65	45	39	32	24
12	Enclosure		IP21S	IP23	IP21S	IP23S	IP21
13	Price	Rs.	115000	94300	95000	110000	70000
14	After Service (Ind.)	Rating Out of 5	3.532	3.306	3.629	3	3.096
	After Service (Edu.)		3.266	3.4	3.333	3.133	3.066
15	Welding Precision (Ind.)		3.58	3.387	3.629	2.983	2.967
	Welding Precision (Edu.)		3.333	3.466	3.6	3.266	3.2
16	Build Quality (Ind.)		3.5	3.451	3.435	2.854	2.903
	Build Quality (Edu.)		3.4	3.266	3.6	3.266	3.2
17	Service Cost (Ind.)		2.903	2.854	2.919	2.822	2.935
18	Delivery Time & Logistics(Both		4.5	3.5	5	3.5	4
19	Spare Parts Availability,Warranty		4.5	4	4.5	3.5	4
20	Industry Standards (Ind.)	As per std.	5	3	5	2	2

5. Results and Discussion

This section presents and discusses the outcomes of the proposed multi-criteria decision-making (MCDM) framework developed for the optimal selection of suppliers for GMAW and GTAW welding equipment. The integrated approach of Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was employed to effectively address the uncertainty and subjectivity inherent in expert judgment during supplier evaluation. Initially, Fuzzy AHP was applied to determine the relative importance of the identified evaluation criteria, including technical performance, cost, quality, service support, reliability, and supplier reputation. Table 2. (Industrial Sector) and Table 3. (Educational Sector) shows the ranking and Normalizing Weights values by aggregated fuzzy AHP pairwise comparisons via De-fuzzification after Fuzzy Geometric Mean Method between all the selection criteria based on responses from industrial and Educational experts. Each value is expressed as a Triangular Fuzzy Number(TFN). The rankings are calculated using the Fuzzy AHP method. It can be seen that the experts seem to put somewhat similar emphasis to the criteria, demonstrating that there exist some parameters guiding welding machines of what qualities matter the most.

Table 2. Final Criteria Weights (%) and Ranking by Fuzzy AHP for Industrial Sector

Criteria	Normalised value (%)	Rank
After Service	40.21	1
Price	30.14	2
Welding Precision	14.14	3
Build Quality	6.84	4
Cost of Service	4.48	5

Table 3. Final Criteria Weights (%) and Ranking by Fuzzy AHP for Educational Sector

Criteria	Normalised value (%)	Rank
After Service	50.7	1
Build Quality	23.83	2
Price	12.59	3
Welding Precision	6.84	4
Spare Parts availability & Warranty	4.69	5

Subsequently, TOPSIS was utilized to rank the alternative suppliers based on their relative closeness to the ideal solution. The normalized decision matrix, weighted by Fuzzy AHP-derived criteria weights, enabled a systematic comparison of suppliers. The results reveal a clear ranking order for both GMAW and GTAW equipment suppliers, demonstrating the robustness and applicability of the proposed framework in supporting rational and transparent decision-making. Table 4 shows Positive ideal and negative ideal solutions for industrial sector were determined to represent the best and worst possible performance levels, respectively. The separation distances of each supplier from the ideal solutions were calculated, and the closeness coefficient was used as the basis for ranking.

Table 4. Positive and Negative Ideal Solutions represents best and worst performance

	Price/cost	After service	Welding Precision	Build Quality	Service cost	Si+	Si-
ESAB	0.1580	0.1912	0.0682	0.0330	0.0201	0.0620	0.0317
Panasonic	0.1295	0.1790	0.0645	0.0326	0.0198	0.0380	0.0343
Ador	0.1305	0.1965	0.0691	0.0324	0.0203	0.0344	0.0459
Megmeet	0.1511	0.1624	0.0568	0.0269	0.0196	0.0661	0.0069
Relon	0.0962	0.1676	0.0565	0.0274	0.0204	0.0320	0.0620

In the final phase of the TOPSIS framework, alternatives are ranked according to their relative closeness values, as illustrated in the Figure 2 and Figure 3. Higher closeness values indicate better suitability, helping decision-makers identify the most appropriate supplier. This essential step ensures a thorough evaluation of all alternatives, thereby supporting well-informed decision-making.

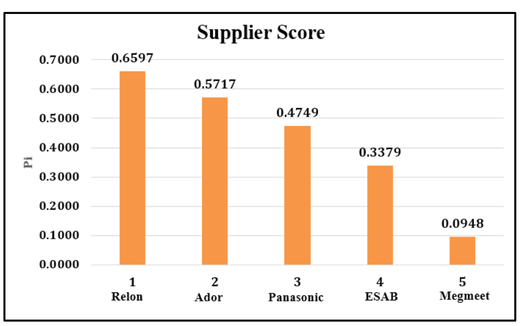

Figure 2. FAHP-TOPSIS Ranking for Industrial sector

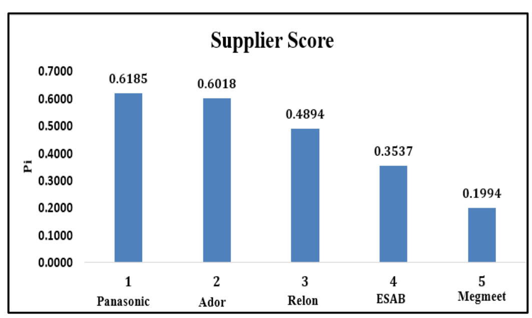

Figure 3. FAHP-TOPSIS Ranking for Educational sector

The final supplier rankings based on FAHP-TOPSIS analysis were determined separately for the education and industrial sectors. The rankings are summarized in the Table 5. These rankings reflect the sector-specific preferences and requirements. Panasonic was found most suitable for the education sector due to precision, safety features, and user-friendliness, while Relon was most favoured in the industrial sector owing to its cost-effectiveness and basic utility.

Table 5. Final Ranking based on Fuzzy AHP and TOPSIS

Final Rank for Education Sector			Final Rank for Industrial Sector		
Supplier	Pi	Rank	Supplier	Pi	Rank
Panasonic	0.6185	1	Relon	0.6597	1
Ador	0.6018	2	Ador	0.5717	2
Relon	0.4894	3	Panasonic	0.4749	3
ESAB	0.3537	4	ESAB	0.3379	4
Megmeet	0.1994	5	Megmeet	0.0948	5

6. Conclusion

This study presented an integrated FAHP–TOPSIS based multi-criteria decision-making framework for the optimal selection of suppliers for GMAW and GTAW welding equipment suppliers for two different application environments, namely the education sector and the industrial sector. The FAHP approach was employed to determine the relative importance of evaluation criteria under fuzzy expert judgments, while TOPSIS was applied to rank the alternative suppliers based on their closeness to the ideal solution. The results indicate noticeable differences in supplier performance across the two sectors. For the education sector, Panasonic achieved the highest closeness coefficient value of 0.6185, followed by Ador (0.6018) and Relon (0.4894), indicating that Panasonic provides the most suitable balance of performance attributes for academic and training environments. In contrast, for the industrial sector, Relon emerged as the top-ranked supplier with a closeness coefficient of 0.6597, followed by Ador (0.5717) and Panasonic (0.4749). These results suggest that Relon offers better suitability for industrial operational requirements such as productivity, continues production, robustness, and performance reliability. Suppliers ESAB and Megmeet consistently ranked lower in both sectors, with closeness coefficient values below 0.36 and 0.20, respectively, indicating comparatively weaker overall performance under the selected evaluation criteria. The comparative analysis demonstrates that supplier suitability varies depending on the operational context, highlighting the importance of sector-specific decision frameworks for equipment procurement. The proposed FAHP–TOPSIS approach effectively supports decision-makers by systematically incorporating multiple criteria and expert judgments into the supplier evaluation process.

Limitations

Despite the effectiveness of the proposed model, certain limitations exist. The criteria weights were derived from expert opinions, which may introduce subjectivity despite the use of fuzzy logic. Additionally, the analysis considered a limited number of suppliers and evaluation criteria, which may affect the generalizability of the results. Furthermore, the interdependence among criteria was not explicitly modelled in the present study.

Future Research Directions

Future studies may enhance the proposed framework by incorporating advanced decision-making techniques such as DEMATEL-ANP, Intuitionistic Fuzzy MCDM, or Type-2 fuzzy systems to capture complex relationships among criteria. Additionally, the integration of sustainability, sensitivity analysis, life-cycle cost, and energy efficiency parameters could provide a more comprehensive supplier evaluation model for modern manufacturing and educational applications.

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