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Enhancing Efficiency and Cost-Effectiveness: A Groundbreaking Bi-Algorithm MCDM Approach †

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Abstract: Numerous scholars have thoroughly studied the topic of choosing machines considering the progress and technological growth seen in machinery options. This scholarly investigation explores decision-making methods specifically designed to aid the selection of machines in manufacturing businesses. Additionally, this research emphasizes the need for decision-making frameworks in manufacturing facilities, highlighting the importance of smart machine selection strategies in those contexts. In this research, we show a dual-MCDM approach that includes DEX—decision experts—and the EDAS method that are popularly employed to solve decision-making problems in both academic and practical industries. Throughout the previous decade, business leaders and managers increasingly use MCDM solutions to overcome machine selection challenges. At this time, while various decision-support technologies and procedures have been developed and used, it is essential that we discuss the sequence of our study objectives and drive the proposed method for widening use in practical firms. In short, this research may be helpful as a literature review for MDCM studies and related topics. It will also help executives, engineers, and specialists determine which equipment or machines to create and increase product quality in manufacturing and industry.

Keywords: ship manufacturing; fabricating workshop; uncertainty model; machine selection; multicriteria decision making (MCDM); ship design selection

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1. Introduction

The field of manufacturing is vast and encompasses intricate products like automobiles, ships, boats, drafts, bearings and milling machines. It requires a deal of precision and expertise. Professionals from various domains have meticulously studied this landscape, contributing their valuable insights to decision-making methodologies. We are grateful for the technology and software that have ushered in a new era in machining products by combining scientific advancements with technological prowess.

These innovative tools play a role in improving design precision, evaluative abilities, compliance and construction oversight. Every aspect of their development, production and implementation is carefully planned to generate value. One essential component in manufacturing plants is the welding machine that serves as the linchpin for factory processes.

Take shipbuilding as an example—a domain where customized prototypes are created with attention to detail and incorporating technological advancements. The process of building a vessel can take from 24 to 36 months and requires collaboration among hundreds or even thousands of skilled professionals, from various disciplines. European shipyards are known for their standards in terms of quality, adherence to health and safety protocols and rigorous regulatory requirements. The safety and seaworthiness of each vessel greatly depend on the expertise and professionalism of the teams involved in its construction. With the advancement of production methods, automation has become a feature in parts of the process led by skilled individuals proficient in specialized technologies and tools. Companies have successfully integrated paradigms and techniques into their workshops to enhance competitiveness and maintain global leadership in key industries.

Real-life problems involve several parameters and trade-offs, all of which must be considered during decision making. As a result, this kind of decision making [1–6] is known as multicriteria decision making (MCDM), and it can be broken down into a variety of subcategories, including comparative/relative measurement methods, reference point methods, outranking methods and other methods (such as supremacy, max-min and min-max). The analytical hierarchical process, or AHP [5,7–10], is a relative measurement technique that can evaluate several options by considering qualitative and quantitative criteria.

MCDM divides problems into components. Once decisions are made regarding these parts, they are reassembled to reveal the picture of decision making. The criteria values can be either ordinal or cardinal. The information can be precise or somewhat ambiguous [10–12], decided in periods.

In today's world, the rise of multicriteria decision making methodologies has greatly empowered decision makers to tackle the complexities mentioned earlier. However, the challenge lies in choosing the aggregation method within the MCDM framework. In this context, the variety of options available poses a task requiring consideration by multiple criteria decision makers. Multicriteria decision making has seen growth in several fields in recent years. This progress encompasses three aspects: models that incorporate complex algorithms, procedural frameworks and selection paradigms; evaluation theories that establish assumptions about values or preferences supported by well-structured representations; and assessment methodologies covering various aspects such as elicitation, estimation and scaling of individual choices, utilities and subjective probabilities within multicriteria decision-making scenarios.

The practical application has been vital for adopting techniques, particularly in manufacturing. In this domain, decision makers face the task of selecting choices from a range of attribute-defined options. This approach brings together the foundations of MCDM with the demands of manufacturing environments. A wide range of decision-making techniques and approaches have developed over the years. Each is supported by a framework allowing for detailed investigations and tailored outcomes based on specific contexts. It is important to acknowledge that some methodologies are explicitly designed for problem domains and may not be applicable or transferable to situations. Therefore, choosing a decision-making methodology requires the consideration of various terms and factors, as each can significantly influence the effectiveness of the decision-making process. We utilized techniques such as AHP, COPRAS [10], TOPSIS [13], VIKOR [14,15], ELECTRE [5], DEMATEL [16], ANP [17], WASPAS [18], Entropy [3,8,18,19], DEA [20] assessment and evaluation tools [12,21,22] and others to scan the paper database for research papers related to DM methods.

The field of processes and machinery selection has always been a topic of interest in multicriteria decision making approaches. Our current work introduces a bifurcated method that cleverly combines the DEX (decision experts) and EDAS (evaluation based on distance from average solution) techniques. This innovative combination aims to provide a solution to the challenges involved in selecting machines for fabrication enterprises. The DEX technique stands out for its focus on involving domain experts. It is a strategy where expert insights come together to calculate weights and compare criteria. By integrating knowledge and experiential expertise, the DEX technique enhances the reliability and robustness of decision making thanks to the involvement of decision experts in the deliberation process.

Although not new, we chose the EDAS approach for our study due to its applicability and advantages over other MCDM methods, especially in cost estimation within the domain. Recognized for being user-friendly, effective and efficient in facilitating decisions, we seamlessly incorporate the EDAS method into our framework. This approach provides an accessible solution to selecting machines for fabrication establishments.

Our analysis focuses on a cutting-edge approach, explicitly emphasizing the fusion of the DEX technique with the EDAS approach. This fusion adds a dimension to the existing literature on machine selection and allows for a thorough evaluation of welding machines using qualitative and quantitative parameters.

Unlike studies comparing existing paradigms, our study provides an evaluative framework. This framework considers capacity, pricing considerations, welding speed and precise workpiece thickness. Although these selection criteria may seem straightforward, they are part of a methodology that effectively combines quantitative elements to address the challenges in selecting industrial machinery. The selection of industrial welding machines (welders) that combine DEX and EDAS [7,11,13,14,22–26] has been suggested in this study. The purpose of this study is to present an MCDM methodology for industrial machines selection that is straightforward, dependable and resilient while requiring a reduced number of calculations. No research has ever combined the DEX [8,19,27,28] and EDAS approaches to solve the machines selection challenge. There are three advantages to using the DEX method for calculating weights; (i) it consistently yields results, (ii) it requires bilateral comparisons compared to other MCDM methods and (iii) it simplifies the process for decision makers by facilitating the selection of the best and worst criteria and comparing them with others. The EDAS method was selected for evaluating the machines because it is an integrated approach that finds applications in various fields while being computationally more efficient than other MCDM methods like the CODAS, VIKOR and MOORA techniques that were analyzed, and their ranking outcomes were employed. A sensitivity analysis was conducted on these criteria. The results indicate that alternative options are susceptible to weight assignments and play a role in the selection process (refer to Table 1).

Table 1. Terms and welding methods.

Group 1: Arc Welding Techniques	Group 2: Gas Welding Techniques	Group 3: Resistance Welding Techniques	Group 4: Specialized Welding Processes
— Shielded Metal Arc Welding — Submerged Welding — Stud Welding	— TIG — MIG	— Spot Welding — Seam Welding — Projection	— Plasma — Laser — Thermit — Friction Stir — Multiple Pass — Tack Welds

2. Methods and Experiment

The ranking alternative involves selecting the best option from a list. It is fundamental to engineering, computer science and operation research that many MCDM methods have unique properties. Mathematical programming, gradient-based methods and metaheuristic algorithms [2,15,21,29–33] are popular. Optimization in decision making began with 19th century mathematicians and engineers, and calculus-based optimal approaches were first employed in engineering and physics [9,16,18,22,25,34]. They were not used in economics [19,31,35–39] or computer science [3,5,12,34,40–42] until the 20th century.

Several types of MCDM or decision-making methods [1,6,7,10,11,16,23,24,32,43–46] are presented in Table 2, each of which exhibits a distinct set of features. The following are examples of the most common types: (i) Mathematical programming: This approach uses a mathematical model to represent the problem and the constraints to solve the problem [24,34,44,47,48]. After that, the responses can be obtained by working through the mathematical equations. (ii) Techniques based on gradients: These procedures are predicated on using gradients, which are the directions of the most steeply ascending or descending slopes. Moving along the direction of the gradient is to find a local or global optimal [2] solution. (iii) The algorithm of metaheuristics: This approach is predicated on using metaheuristics, or rules of thumb, to direct the search for a solution [3,11,13,18,40,49,50]. These approaches are known as the metaheuristic algorithm. Iteratively enhancing an initial solution over time leads to the discovery of the solution.

Table 2. Related work.

Decision-Making Method	Hybrid/Mono	Application	Authors and Years
MCDM and Fuzzy logic MADM and Fuzzy	☑/☐ ☑/☐	-Environmental sustainability assessment -Investment alternatives for angel investors -Dombi operators (Heath Check) -Supplier selection -Not specific field	[35,47] [50] [51] [50] [52]
BPM and MACM	☑/☐	-Not specific field	[53]
AHPSort II and MOCM	☑/☐	-Automotive industry Quality control	[54]
-Multicriteria appraisal recommendation	☑/☐	-Diagnosis of thyroid nodules	[55]
Multicriteria group decision making (MCGDM)	☐/☑	-Cybersecurity problem -Health check system	[32] [20,46,48,56]
MADM	☐/☑	-General decision-making applications	[52,57–60]
MCDA	☐/☑	-Healthcare	[61]
TOPSIS-DEA	☑/☐	-Ranking efficient units	[62]
Human decision making or expert system	☐/☑	-Unexpected maintenance work at a factory that assembles engines for Ford Motor Company.	[63]
Fermatean fuzzy CRITIC-EDAS	☑/☐	-Selecting logistics providers	[24]
VIKOR and MCDM	☑/☐	-Healthcare	[15]
EDAS and MCDM	☑/☐	-Robot selection	[14]
Fermatean fuzzy CRITIC and EDAS	☑/☐	-Logistics providers -Distance education -Energies -Additive manufacturing	[7,11,23,24,26]
EDAS and PSO	☑/☐	-Optimal WEDM Parameters	[22]
EDAS and others	☑/☐	-Materials selection -Energy -Healthcare	[13,17,18,25]
VIKOR and others	☑/☐	-Supplier selection	[10,14,15]
Fuzzy and others	☑/☐	-Railway -Energies -Waste management -Supplier selection	[3–5,12,16,23,33,44,45,50,59]

In this study, our proposed method is presented in Figures 1–3 (DEX stage), and Figure 4 shows the flowchart of the whole proposed study process. This investigation shows a dual-MCDM approach that includes DEX—decision experts—and the EDAS method that are popularly employed to solve decision-making problems in academic and practical industries.

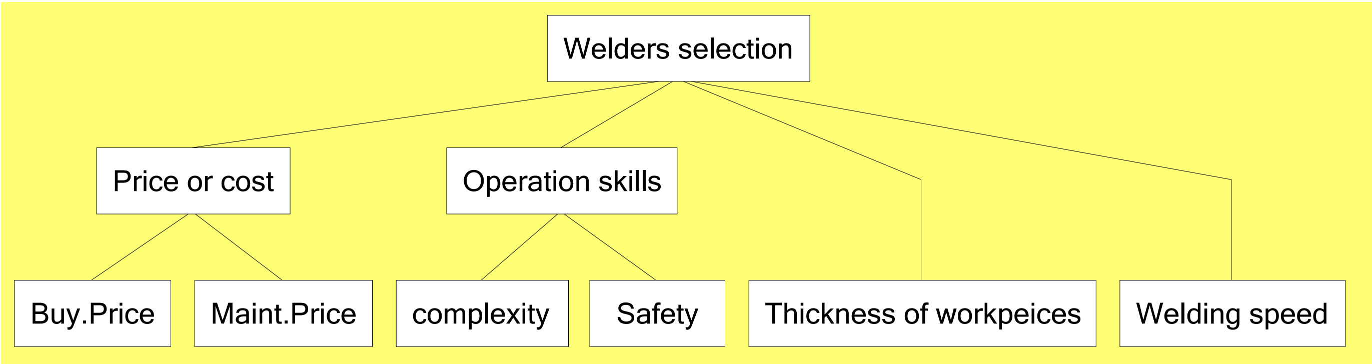

Figure 1. Tree of DEX for the attributes of the performance evaluation of welders.

Scales

Attribute	Scale
Welders selection	Unacc; Acc; Good; *Exc*
— Price or cost	high; medium; *low*
—— Buy.Price	high; medium; *low*
—— Maint.Price	high; medium; *low*
— Operation skills	bad; acc; good; *exc*
—— complexity	high; medium; *low*
—— Safety	small; medium; *high*
— Thickness of workpeices	big; medium; *small*
— Welding speed	low; medium; *fast*

Figure 2. Attribute and its descriptions and the proposed scales.

Function summary

Attribute	Items	Defined	Determined	Values
Welders selection	50/108	46.30	100.00	Unacc:49,Acc:46,Good:9,Exc:4
— **Price or cost**	9/9	100.00	100.00	high:5,medium:1,low:3
—— Buy.Price				
—— Maint.Price				
— **Operation skills**	9/9	100.00	100.00	bad:5,acc:1,good:2,exc:1
—— complexicty				
—— Safety				
— Thickness of workpeices				
— Welding speed				

Average weights

Attribute	Local	Global	Loc.norm.	Glob.norm.
Welders selection				
— **Price or cost**	33	33	30	30
—— Buy.Price	50	16	50	15
—— Maint.Price	50	16	50	15
— **Operation skills**	20	20	27	27
—— complexicty	50	10	50	14
—— Safety	50	10	50	14
— Thickness of workpeices	27	27	25	25
— Welding speed	20	20	18	18

Figure 3. Function summary of the attributes and the average weight.

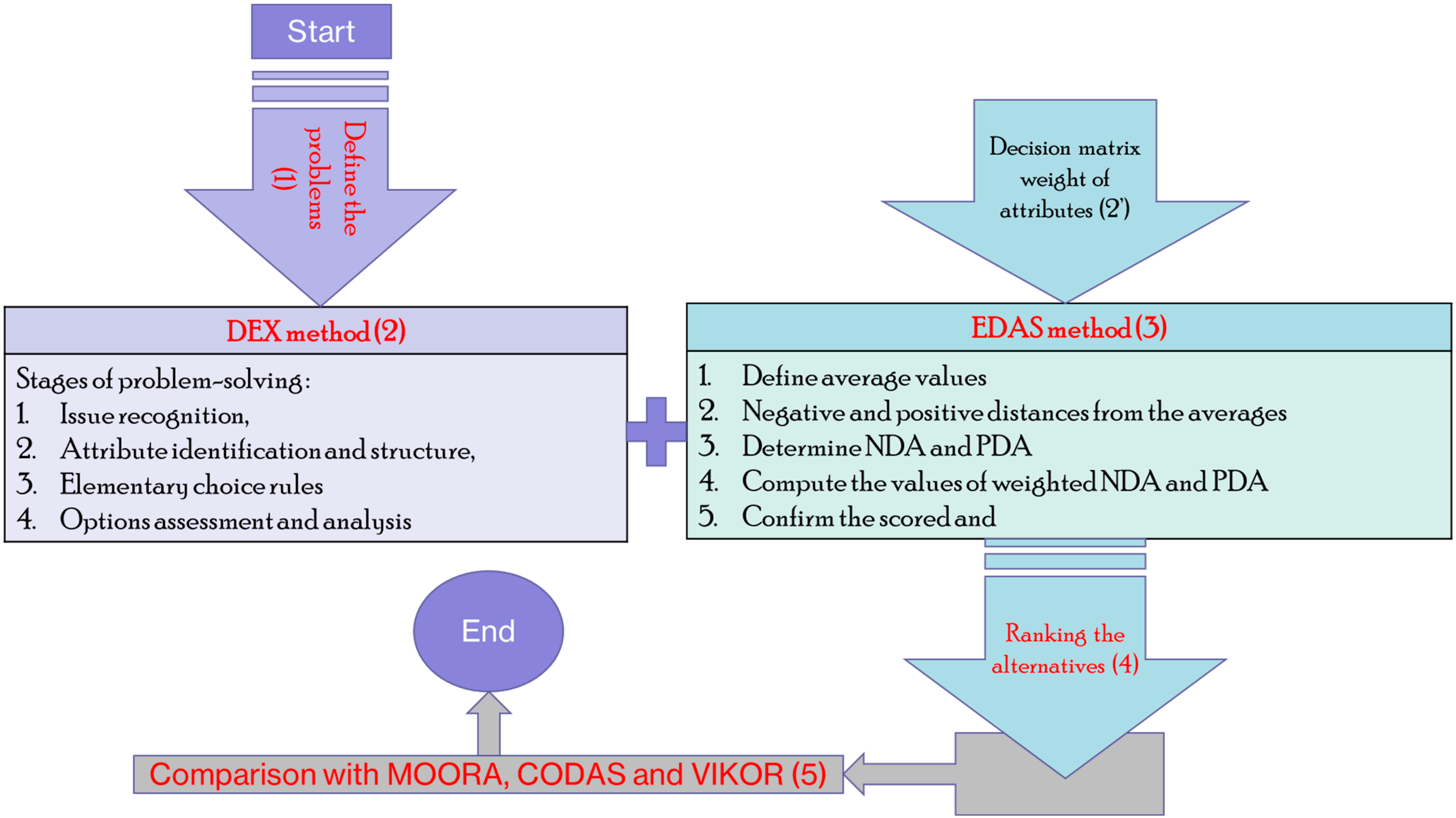

Figure 4. The flowchart of the study process.

2.1. Stage I: Decision Expert

DEX, which stands for decision expert, is a technique for modeling multicriteria decisions. The following characteristics set it apart: DEX follows a hierarchical structure; consequently, its multicriteria models comprise features arranged in a hierarchy. This concern is comparable to other MCDA approaches, such as the analytic hierarchy process (AHP)[9,10,39,58]

The heart of making decisions involves finding the choice that aligns perfectly with the goals of one or more decision makers. At the time, it requires organizing a list of options carefully ranked from the highest level of excellence to the lowest level of feasibility. These options include computer systems, potential job candidates, or in-vestment strategies, as shown in Figure 1. This approach is evident in some areas, which cover everything from personal preferences to complex fields like economics, management, strategic planning, and intricate medical issues. The complexity in situations often comes from the uncertainties surrounding defining and achieving objectives. It becomes more complicated with loosely defined alternatives influenced by various factors impacting decision-making paths.

Moreover, different decision makers may have conflicting priorities while facing resource limitations and time constraints. Decision makers can access methods and computational tools designed to understand and navigate complexity to overcome these challenges. The tools they have at their disposal include decision support systems, analytical methods of operations, research insights gained from management studies, the foundations of decision theory, and detailed analysis facilitated by decision analysis. A critical aspect of this framework is multi-attribute decision making (MADM), which involves breaking down the judgment challenge into smaller, more manageable subproblems. To accomplish this, decision makers identify the dimensions defining these sub-problems, such as attributes, performance factors and criteria, for evaluating alternatives [1,3,6,15,23,24,58,64]. A thorough and careful assessment, based on a purpose, combines worth across different options. This method serves as a tool to choose or prioritize the possibilities presented in Figures 2 and 3.

2.2. Stage II: Distance from Average Solution Assessment

The evaluation based on the distance from average solution (EDAS) technique is a modern MCDM approach that is both effective and time-saving. In this approach, the attractiveness of various options is determined by calculating their distances from a specific solution [5,7,9,11,21,22,25,39,44,48,51,64].

Step 1: Choose the essential criteria for the alternatives.

Step 2: Create the decision matrix (B), shown in Equation (1) below:

$$B = [B_{ij}] = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \dots & \dots & \dots & \dots \\ b_{n1} & b_{n2} & \dots & b_{nn} \end{bmatrix} \quad (1)$$

where B_{ij} is determined as the performance values of ith alternative concerning jth criteria.

Step 3: The average solution to the criteria is determined by the following equation (Equation (2)):

$$Mean = [Mean_j]_{1\times k} \quad (2)$$

Step 4: Calculate the matrix of PDA and NDA according to the benefit and expense criteria presented in Equations (3)–(6) as follows:

$$PDA = [PDA_{ij}]_{r\times k} \quad (3)$$

$$NDA = [NDA_{ij}]_{r\times k} \quad (4)$$

$$PDA_{ij} = \frac{\max(0, (b_{ij} - Mean_j))}{Mean_j} \quad (5)$$

$$NDA_{ij} = \frac{\max(0, (Mean_j - b_{ij}))}{Mean_j} \tag{6}$$

where PDA_{ij} and NDA_{ij} indicate the positive and negative distances of the ith alternative from the average solution in terms of the jth standard, respectively, if the jth criterion does not produce a favorable result.

Step 5: Define the weighted sum of PDA and NDA shown in Equations (7) and (8):

$$SP_i = \sum_{j=1}^{k} w_j PDA_{ij} \tag{7}$$

$$SN_i = \sum_{j=1}^{k} w_j NDA_{ij} \tag{8}$$

where w_j shows the criterion weight of the jth.

Step 6: Calculate SP and SN that are normalizing, shown in Equations (9) and (10) below:

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \tag{9}$$

$$NSN_i = \frac{SN_i}{\max_i(SN_i)} \tag{10}$$

Step 7: Calculate the appraisal score for the options using Equation (11):

$$AS_i = 0.5(NSN_i + NSP_i) \tag{11}$$

3. Results and Discussion

The first result of the DEX method presents its outcomes through graphs. We ap-appreciate the input from experts in assessing the suggested decision methodology, which led to a plan for prioritizing the design choices: WM 4, WM 2, WM 1, WM 3 and WM 5 (or the ranking presented as following WM 4 > WM 2 > WM 1 > WM 3 > WM 5). This result shows that the WM 4 machine plan is the best alternative. Figures 5–7 present the results of evaluations for the proposed alternatives in different charts and tables in detail.

Figure 8 illustrates the initial parameters used to evaluate all proposed alternatives in this study. The cost of purchasing welding and maintenance machines is presented relative to the average value of comparable features. Specifically, WM 1 represents a compact welding machine utilizing MIG welding technology, offering diverse capabilities. On the other hand, WM 2 showcases a medium-sized welding machine using Flux-Cored Arc Welding (FCAW). WM 3 denotes a welding machine that can be easily transformed into an arc welding machine. Additionally, WM 4 and WM 5 correspond to the TIG and laser welding machines, respectively. As depicted in Figure 8, the laser machine is the most expensive option, while the costs of WM 1 and WM 2 are the most economical.

Attribute	WM 1	WM 2	WM 3	WM 4	WM 5
Welders selection	Acc	Acc	Acc	Acc	Unacc
Price or cost	low	low	medium	medium	high
Buy.Price	medium	low	medium	medium	high
Maint.Price	low	low	medium	medium	high
Operation skills	good	good	good	good	bad
complexicty	low	low	low	medium	high
Safety	medium	medium	medium	high	high
Thickness of workpeices	big	big	medium	small	medium
Welding speed	medium	medium	low	medium	fast

Figure 5. Results of the evaluations for all alternatives.

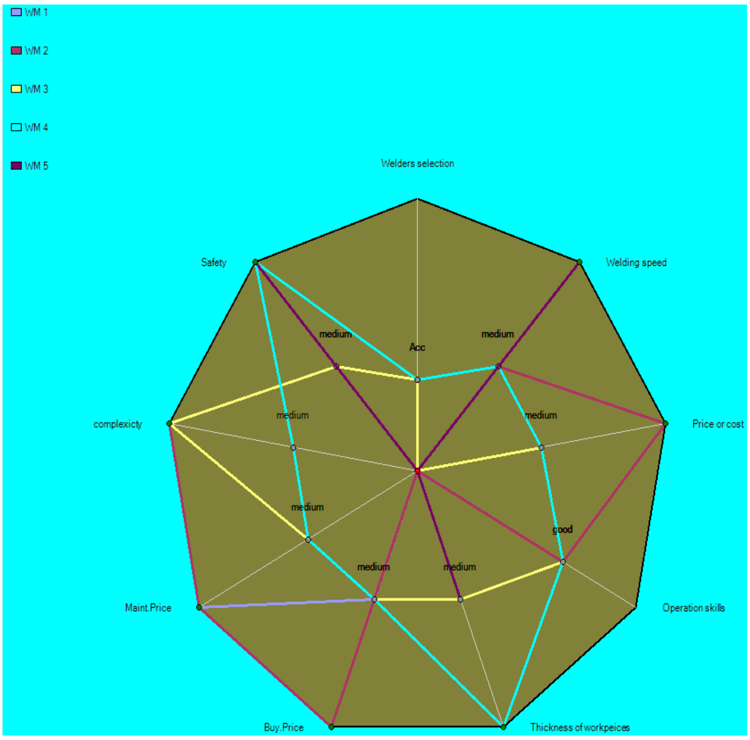

Figure 6. Results of the evaluations for alternatives in the radar grid.

Concerning the operating skills required for welding, each type of welding machine demands a distinct set of skills. This study introduces a classification of five skill levels ranging from 1 (highest) to 5 (lowest). Workers encounter significant challenges when operating welding machines assigned to skill level 1, making it a highly demanding task. The machining workpiece thicknesses for the respective welding machines, namely MW 1, MW 2, MW 3, MW 4 and MW 5, are represented by the values of 0.6, 3.2, 3.2, 0.25 and 0.5 mm, respectively.

Furthermore, the welding speed is addressed in this section, and different speed levels are proposed for the five welding machines: machines 1 to 5 have corresponding recommended speeds of 300, 400, 200, 250 and 750 mm.min^{-1}, respectively. It is recommended to select the average parameters for typical machines.

Tables 3 and 4 present the calculated results of the weighted sum of PAD standing by SP_i and the weighted sum of NDA, known as SN_i. These parameters are calculated based on the Equations (7) and (8).

Table 3. The weighted sum of PDA.

Alternatives/ Factors	Buying and Maintaining Price/Cost (US Dollars)	Operation Skill Level	The Thickness of the Metal Plate (mm^{-1})	Welding Speed (mm.min^{-1})	*SPi*
WM 1	0.20353822	0.140625	0.001256	0	0.34542
WM 2	0.26664777	0.140625	0	0.007895	0.41517
WM 3	0.18329553	0	0	0	0.1833
WM 4	0.18726469	0	0.353015	0	0.54028
WM 5	0	0	0.051508	0.146053	0.19756

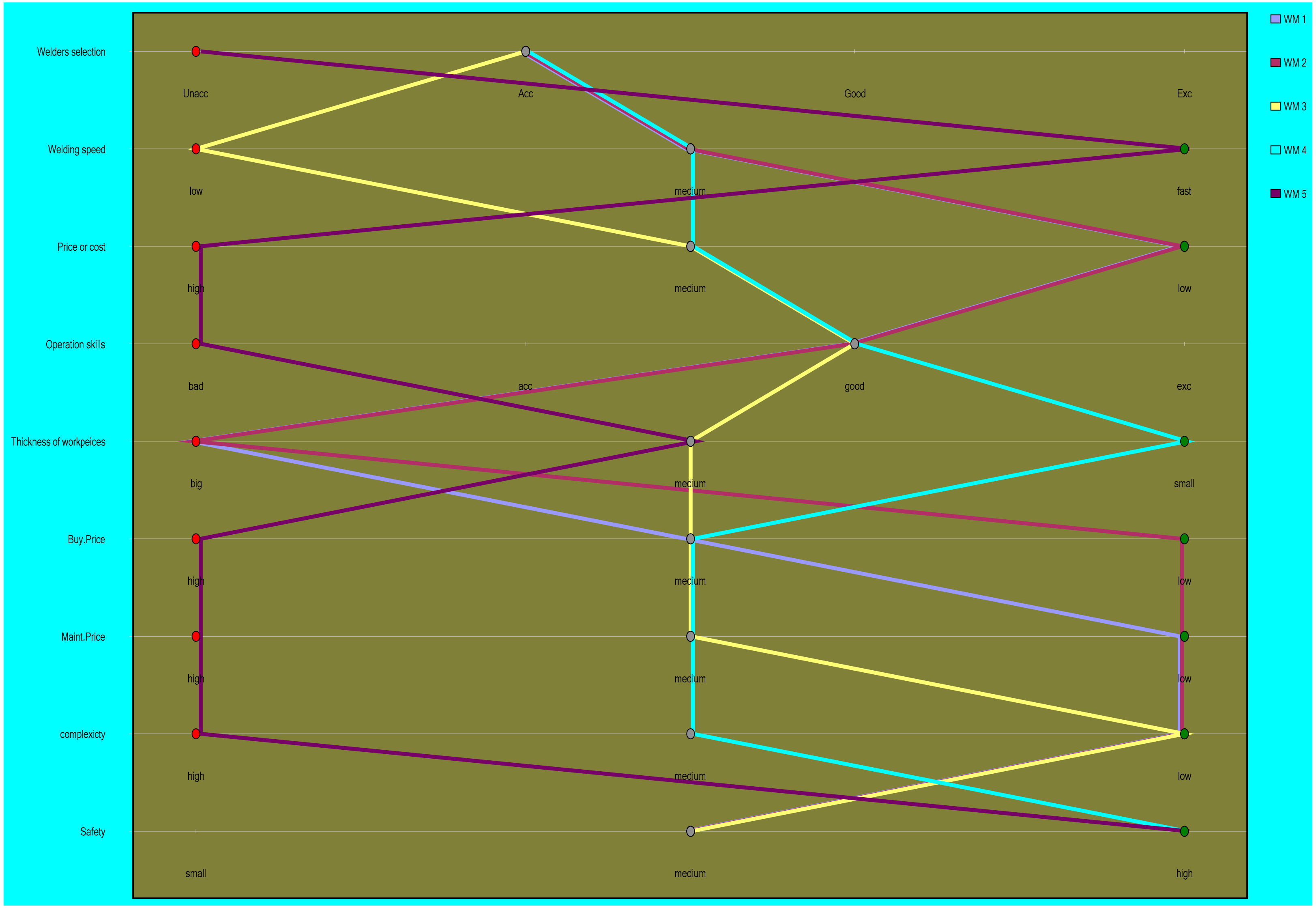

Figure 7. Results of the evaluations for welder options by employing the DEX method.

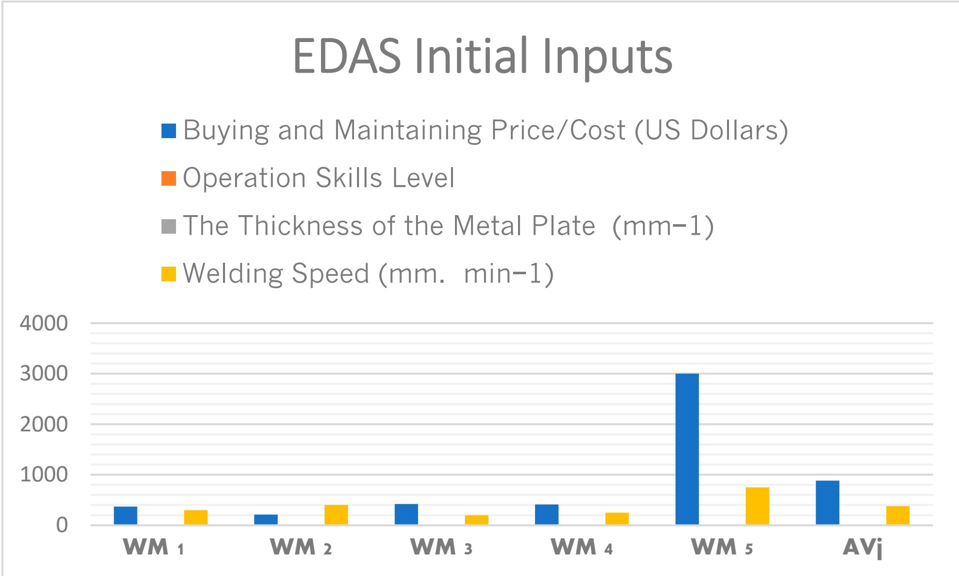

Figure 8. Initial inputs for EDAS evaluation.

Table 4. The weighted sum of NDA.

Alternatives/ Factors	Buying and Maintaining Price/Cost (US Dollars)	Operation Skill Level	The Thickness of the Metal Plate (mm^{-1})	Welding Speed ($mm.min^{-1}$)	SN_i
WM 1	0	0	0	0.031579	0.03158
WM 2	0	0	0.202889	0	0.20289
WM 3	0	0.015625	0.202889	0.071053	0.28957
WM 4	0	0.09375	0	0.051316	0.14507
WM 5	0.8407462	0.171875	0	0	1.01262

The weights that affect the factors that influence the selected welding machine options are as follows:

— Price/costs of buying and maintenance: 0.35;
— Skills required for operation: 0.25;
— The thickness of the metal plate (workpieces): 0.25;
— Welding speed: 0.15.

Table 5 provides the computed parameters, including NSP_i, NSN_i and AS_i, which are crucial for the synthesis and ranking of the alternatives. Additionally, Table 6 presents the ranking outcomes for the remaining options. The results clearly indicate that the proposed EDAS method ranks the alternatives as follows: WM 4 is identified as the best option, followed by WM 1 in second place and WM 2 in third place. WM 3 secures the fourth position, and finally, WM 5 is ranked as the least favorable option.

Table 5. Sorting the alternatives.

	$SP_i{}^{-1}$	$SN_i{}^{-1}$	$NSP_i{}^{-1}$	$NSN_i{}^{-1}$	$AS_i{}^{-1}$
WM 1	2.895030535	31.66666704	1.564126413	1.032188808	1.243672815
WM 2	2.408666382	4.928792575	1.301353689	1.250564317	1.275461398
WM 3	5.455670414	3.453431251	2.947588281	1.400477843	1.898794266
WM 4	1.850892952	6.893424059	1	1.167212533	1.077156737
WM 5	5.061749036	0.987536108	2.734760571	#NA	5.469561888

Table 6. Comparison of the results with the other methods.

	MOORA—Its Rank		VIKOR—Its Rank		CODAS—Its Rank		Our Proposed Method—Its Rank	
WM 1	0.24838	2	0.1582	4	0.18337	3	0.80407	2
WM 2	0.21146	3	0.2500	2	0.80819	1	0.78403	3
WM 3	0.09378	4	0.2500	2	−0.26798	4	0.52665	4
WM 4	0.26384	1	0.1875	3	0.19426	2	0.92837	1
WM 5	−0.08701	5	0.3500	1	−0.37147	5	0.18283	5

Table 6 and Figure 9 compare the options using various decision-making techniques, including our suggested method and MOORA, VIKOR and CODAS. The results aid in the decision-making process by placing the other options in order of performance.

According to our analysis using MOORA and our recommended approach, WM 4 stands out with two rankings, a first-place and third-place ranking. This result positions it at the top of the evaluation spectrum. On the other hand, WM 2 demonstrates performance as the runner-up in this context with first-place, second-place, and third-place rankings. In contrast, WM 5 consistently lags in all aspects, receiving fifth-place rankings, except for one first-place position according to the used method. This consistent under performance highlights the need for its irrelevance. Considering their weights and rankings, the remaining options are validated and supported without requiring lengthy analysis.

Here are the detailed comparison results: WM 4 < WM 2 < WM 1 < WM 3 < WM 5:

- WM1: MOORA rank—2; VIKOR rank—4; CODAS rank—3; our proposed method rank—2 (total score: 2 + 4 + 3 + 2 = 11);
- WM2: MOORA rank—3; VIKOR rank—2; CODAS rank—1; our proposed method rank—3 (total score: 3 + 2 + 1 + 3 = 9);
- WM3: MOORA rank—4; VIKOR rank—2; CODAS rank—4; our proposed method rank—4 (total score: 4 + 2 + 4 + 4 = 14);
- WM4: MOORA rank—1; VIKOR rank—3; CODAS rank—2; our proposed method rank—1 (total score: 1 + 3 + 2 + 1 = 7);
- WM5: MOORA rank—5; VIKOR rank—1; CODAS rank—5; our proposed method rank—5 (total score: 5 + 1 + 5 + 5 = 16).

These rankings demonstrate how our recommended strategy aligns with established methodologies like MOORA, VIKOR and CODAS. The consistent performance of WM 4 reaffirms its reliability and robustness as the choice across methods. It is important to note that these findings assist decision makers in selecting the solution based on the criteria and priorities of the problem at hand. Various decision-making techniques (MOORA, VIKOR, CODAS and our suggested method) are employed to evaluate and rank the alternatives in the comparison results presented in Table 6 and Figure 9. These techniques assess options using factors and generate rankings supporting decision making. The results indicate that WM 4 consistently outperforms all approaches. It attains the highest ranking in MOORA, third place in VIKOR, second in CODAS, and first in our suggested technique. This outcome indicates that WM 4 is a contender and one of the best choices. However, across all methods, WM 5 consistently receives low ranks. In VIKOR, it is ranked first, while it ranks fifth in CODAS, MOORA and our proposed method. These rankings imply that WM 5 is not an option and should be disregarded. The rankings of the remaining choices, WM 1, WM 2 and WM 3, vary across techniques. For example, CODAS ranks WM 2 as the best choice, VIKOR ranks it as second, while our suggested approach ranks it third, and MOORA positions it third as well. These findings indicate that WM 2 shows promise as an option, given its high ranking in the CODAS and VIKOR methodologies.

Notably, the rankings produced by these methodologies offer decision makers helpful information for choosing the best option. Following the precise criteria and priorities of the decision-making problem, the rankings show the benefits and drawbacks of each solution.

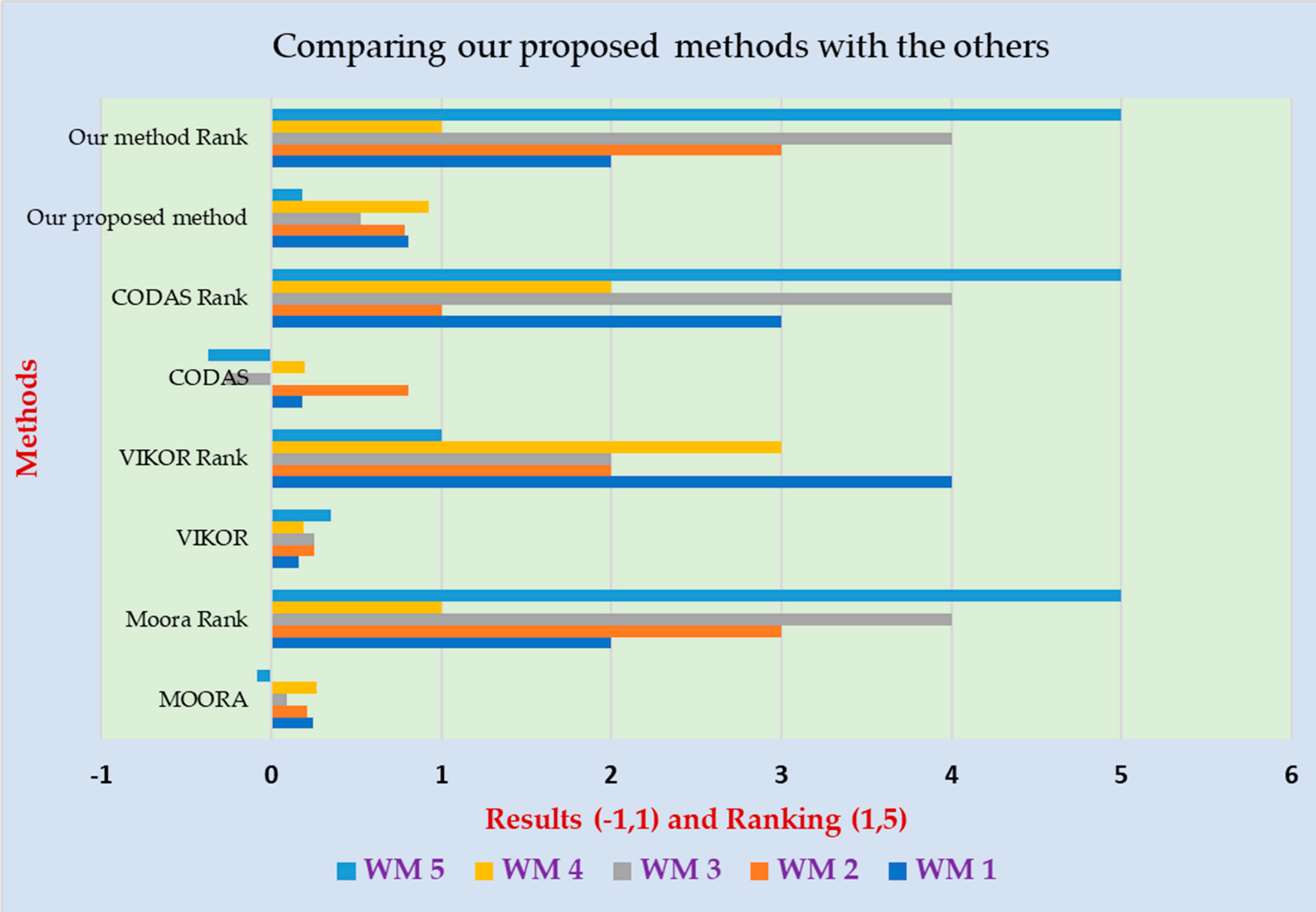

Figure 9. Comparing the results of our proposed method with the others.

Making assessments requires a thorough understanding of the alternatives, which decision makers can achieve by considering the rankings from various approaches. Our suggested method compares favorably to the rankings achieved using well-known techniques, increasing its validity and offering more evidence to support decision making.

In essence, the comparative findings shown in Table 6 and Figure 9 show how well various approaches work for assessing and rating the options. These findings provide decision makers with a valuable tool for the selection process, enabling them to make decisions based on the precise goals and standards of the choice problem.

4. Conclusions

4.1. Conclusions

The selection of welding machines in practical industries can be effectively carried out using the DEX approach integrated with the EDAS technique. This approach considers essential factors such as operating capacity, costs, welding speed and the precise thickness of the workpiece. The ranking results obtained from the proposed approach align well with established methods, enhancing its reliability and robustness. It is simple to observe that the suggested EDAS method is as follows: The best alternative is WM4, which was classified first (by MOORA and our proposed method), second (by CODAS) and third in VIKOR. WM 2 and WM 1 take second and third place, respectively. The final two options are WM 5, the worst-case scenario, with three fifth-place rankings and one first-place ranking (WM5 consistently ranks lower in all methodologies, indicating rejection), and WM 3, with the fourth-place potential selection.

There are several key advantages of the proposed approach. First, it employs a consistent weight derivation process, ensuring a reliable basis for decision making. Second, it requires fewer pair-wise comparisons, reducing the complexity and cognitive burden on decision makers. Third, it is user-friendly, providing an easily understandable framework for decision making. Finally, the proposed approach entails lower computing expenses, making it more efficient and accessible.

The dual-MCDM approach, specifically the DEX-EDAS method, enables the rating of welding machines based on both qualitative and quantitative factors. This comprehensive approach is a valuable tool for decision makers, offering practical solutions to issues with relatively simple selection criteria for industrial ranking alternatives.

4.2. Limitation of the Study

The suggested dual-MCDM methodology incorporating DEX and EDAS approaches for welding machine selection has some drawbacks. First, decision makers attribute weights and performance values to drive the proposed technique. Quality inputs determine correctness and reliability. Thus, data biases or mistakes may affect decision making and alternative rankings. Second, the method presupposes that decision-making criteria are static. The requirements may change in real life, necessitating continuous appraisal and adjustment. Dynamic decision contexts may limit the suggested method's adaptability and usefulness. Thirdly, the proposed technique may struggle with uncertainty and imprecision. The EDAS technique accommodates distance-based calculations.

4.3. Proposed Further Research

As a direction for future research, fuzzy TOPSIS and EDAS can be employed to incorporate fuzzy environments and draw weights more effectively. Expanding the work in this direction would enhance the applicability of the proposed approach and its ability to handle more complex decision scenarios. Decision-making techniques could be used to improve current studies on sustainable development. The dual-MCDM is discussed concerning sustainable development disciplines by [65,66]. In the mentioned references, dual-MCDM solves complicated decision-making issues in various contexts. Future research of enhancing dual-MCDM could be used to examine sustainable decision making in planning for renewable energy, waste management, mitigating climate change and choosing machines, equipment or renting offices. These tendencies can help academics develop novel applications and long-term decision-making frameworks.

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