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Decision-Making Framework Using MARCOS for Evaluating Sealing Machines in Small and Medium Enterprises

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Abstract: In the era of globalization, Micro, Small, and Medium Enterprises (MSMEs) hold a vital position in Indonesia's economy, contributing significantly to GDP and employment. Despite their importance, MSMEs need help selecting appropriate sealer machines, affecting production efficiency and product quality. In this study, six different kinds of sealer machines are examined. They are manual, vertical, continuous, horizontal semi-automatic, impulse, and vacuum. The MARCOS method is used to find the best option. Results indicate that the Impulse Sealer Machine (A5) is the most suitable, with a Ki value of 1.7, followed by the Continuous Sealer Machine (A3), with a Ki of 1.63. Machines such as Manual (A1), Vertical (A2), and Vacuum (A6) scored 1.6, while the Horizontal Semi-Automatic Sealer Machine (A4) ranked lowest at 1.36. These findings provide MSMEs with practical guidance for selecting sealer machines that enhance production efficiency and competitiveness in the global market while also contributing to the development of packaging technology research.

Keywords: Micro, Small, and Medium Enterprises; Sealer Machines; MARCOS Method; Production Efficiency; Packaging Technology

INTRODUCTION

Micro, Small, and Medium Enterprises (MSMEs) play an essential role in the Indonesian economy, especially in the growth of the food industry. However, many MSMEs face problems in choosing the right packaging equipment, such as sealer machines, which directly impact product quality and operational efficiency (Winati et al., 2024)(Bhattacharya & Ramachandran, 2021). Mistakes in choosing these machines often result in poor packaging quality, such as damaged or unattractive packaging, which reduces the marketability of products. Additionally, using inappropriate equipment hinders operational efficiency, increases production costs, and diminishes competitiveness in the market. Improper management of food packaging also contributes to environmental issues, including increased packaging and food waste (Sudarta, 2022).

Sealer machines are critical for ensuring product quality during distribution and storage processes, particularly for MSMEs (Azwar et al., 2024)(Berliana & Saputra, 2024). These machines influence packaging safety, operational costs, and overall efficiency (Adolph, 2016). Despite their importance, many MSMEs in Indonesia still rely on traditional approaches when selecting sealer machines without considering essential criteria such as cost, efficiency, and environmental impact. This often leads to suboptimal decisions that fail to align with their unique needs and constraints (Maulana et al., 2023). (Solehatin Ika Putri et al., 2021)(Maulana et al., 2023)(Shameem et al., 2023).

Although Although methods like Multi-Criteria Decision Making (MCDM), including the Analytic Hierarchy Process (AHP), have been employed to assist in decision-making, they are often inadequate for addressing problems involving multiple complex and interrelated criteria. Belo et al., 2017). The MARCOS method is known for its ability to solve multi-criteria decision-making problems in sectors such as energy and transportation. (Kambey et al., 2018), Offers significant potential for improving the decision-making process in MSMEs. However, its application in the context of MSMEs remains limited. (Odoom et al., 2017). Previous studies primarily focused on large-scale industries, overlooking the specific characteristics of MSMEs, such as budget constraints, the need for flexibility, and smaller production scales. (Shohibul et al., 2019).

This study addresses several key research questions to provide insight into the selection of sealing machines for MSMEs.

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1. Which sealing machine (A1–A6) is most effective in improving operational efficiency, packaging quality, and operational costs for MSMEs ?
2. Which alternative provides optimal cost-benefit performance ?
3. Evaluate each machine's strengths and weaknesses in terms of productivity, ease of use, and environmental impact. The study also aims to assess user satisfaction regarding the usability and maintenance of the sealing machine.

The primary objective of this study is to evaluate and compare various semi-automatic horizontal sealer machines (A1–A6) commonly used by MSMEs using the MARCOS method. By analyzing criteria such as production efficiency, seal quality, and operational costs, this study provides actionable insights for MSMEs to make informed decisions when selecting sealer machines. Furthermore, this research offers a novel contribution by integrating quantitative data-based approaches to evaluate utility values and coefficients, thereby addressing gaps in existing literature. The findings aim to assist strategic stakeholders in enhancing MSME productivity and sustainability through more effective equipment selection.

LITERATURE REVIEW

Research on sustainable packaging has grown rapidly in recent years, especially in reducing environmental impacts and increasing production process efficiency. Many studies have focused on innovations in packaging material, such as using recycled materials, and have analyzed consumer behaviour towards environmentally friendly packaging (Febrianti et al., 2022). The relationship between consumers and packaging materials can improve product competitiveness in the global market. However, most studies with large-scale industries pay less attention to the needs of MSMEs, especially in decision-making for production equipment such as sealing machines (Ørstavik et al., 2001) (Hollmann et al., 2020).

In contrast, sealer machine research primarily focuses on technical performance and mechanical design. Several studies have developed performance simulations to improve the reliability of sealer machines under various operational conditions (Bhattacharya & Ramachandran, 2021)(Febrianti et al., 2022). Evaluating prototype sealer machine designs focusing on energy efficiency and sealing speed. However, this approach often ignores practical aspects, such as operating costs, environmental impacts, and user satisfaction, for MSMEs. In addition, it does not provide data-based recommendations that can help MSMEs select the optimal sealer machine according to their needs.

The lack of quantitative approaches to evaluate alternative sealing machines is problematic, mainly since evaluations often focus on one or two factors, such as technical efficiency or sealing quality, without considering the interaction of various relevant criteria. The MARCOS (Measurement of Alternatives and Ranking by Compromise Solution) method offers a unique and appropriate solution (Stankovi´ et al., 2020). This method allows the evaluation of alternatives based on a combination of criteria, such as production efficiency, sealing quality, operational costs, and environmental impact.

The MARCOS method solves complex decision-making problems by considering various criteria and alternatives (Bhattacharya & Ramachandran, 2021)(*training and mentoring on packaging optimization of*, 2023). This process begins by determining the relevant decision criteria and measuring the level of importance of each criterion. Furthermore, each alternative is assessed based on these criteria by giving appropriate scores and weights (Stankovi´ et al., 2020). Calculate the total score from the evaluation results to determine the ranking of alternatives. This method helps decision-makers understand the performance of each alternative in the context of predetermined criteria. This approach lets Decision-makers find the best solution that suits current needs and priorities. In addition, this method can analyze the sensitivity of the criteria weight or alternative scores to evaluate the resilience of decisions to changing conditions. After selecting a compromise solution, the decision-making team implements the solution by considering its feasibility and practicability. They also monitor the solution periodically to ensure its performance remains optimal over time.

According to Compromise Solution (MARCOS), measurement alternatives and ranking are relatively new methods in the MCDM decision support system. This method defines the relationship between other options with reference values that can be said to be ideal and anti-ideal alternatives (Febrianti et al., 2022)(Trung, 2022), The calculation will produce a preference value based on each method used. The results will be tested for accuracy to determine the use of a sealer machine to package product results in UMKM in Indonesia.

Sealing machine selection involves multiple criteria-based decision-making (MCDM) methodologies. MCDM is essential in evaluating and ranking alternatives based on various conflicting criteria, particularly relevant in machine selection for manufacturing processes(Camci et al., 2018). MCDM methods enable decision-makers to systematically analyze the trade-offs between various machine attributes, such as cost, efficiency, and operational capabilities. One practical approach to MCDM is the Analytic Hierarchy Process (AHP), which has been widely utilized in various machine selection scenarios, including CNC machine tools and woodworking

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machinery(Kabak & Dağdeviren, 2017)(Camci et al., 2018). AHP facilitates the structuring of decision problems into a hierarchy, allowing for the prioritization of criteria and alternatives based on pairwise comparisons. This method is beneficial in environments where qualitative and quantitative factors must be considered simultaneously (KARAKIŞ, 2021). Hybrid approaches that combine AHP with other techniques, such as grey relational analysis and fuzzy logic, have been proposed to enhance the robustness of the decision-making process(Kabak & Dağdeviren, 2017)(Zhang et al., 2017). Moreover, using fuzzy logic in MCDM helps address the uncertainty and vagueness inherent in evaluating machine performance and selection criteria. Fuzzy AHP has effectively refined the selection process by incorporating expert judgments and subjective assessments into the decision-making framework(Rehman et al., 2019).

MCDM in machine selection considers sustainability and environmental impact. Recent studies have highlighted the importance of integrating sustainability criteria into the selection process, especially in industries with stringent environmental regulations (Camci et al., 2018)(Patyk et al., 2021). Techniques such as the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) have been used to evaluate machines based on their sustainability performance alongside traditional operational metrics (Patyk et al., 2021)(Rehman et al., 2019).

MSMEs can reflect on the decision-making process regarding the factors that influence the selection of a sealer machine for their production packaging results. This study is a new study that uses a quantitative data-based approach(Ilhan et al., 2021). This study calculates utility values and coefficients to evaluate and recommend the best sealer machine for MSMEs. Unlike previous studies, this study does not only focus on technical aspects. Earlier studies tend to emphasize performance simulation and mechanical design development. This study adds a sensitivity analysis that highlights differences in evaluation results and provides new insights that have not been widely discussed in other studies (Winati et al., 2024)(Dewi et al., 2020).

METHOD

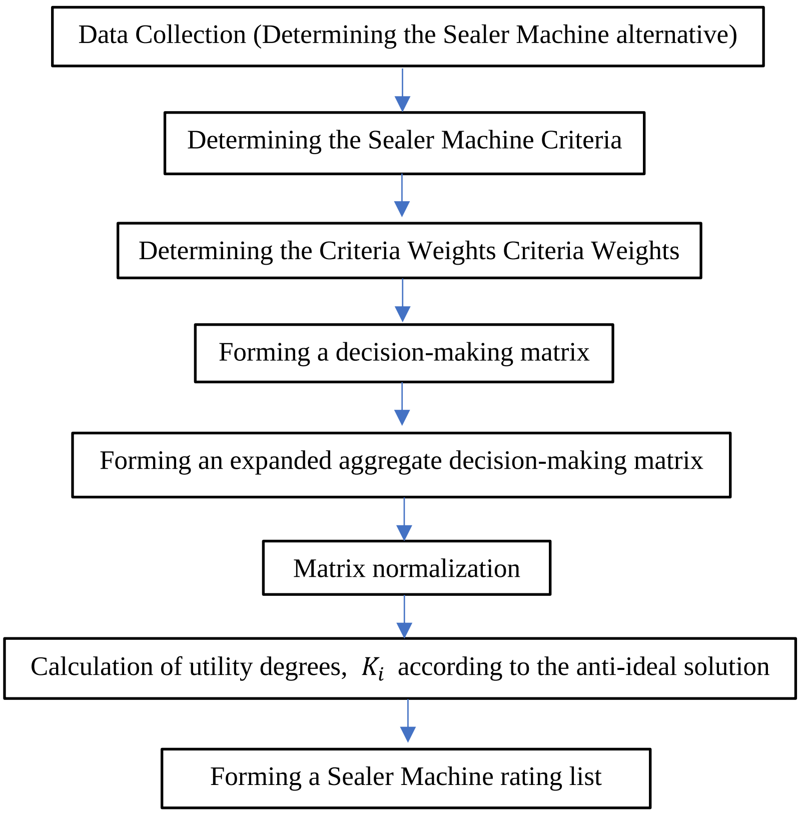

Fig. 1 Selection of Sealer Machines Using MARCOS Method

Figure 1 describes the systematic process for evaluating different types of sealer machines and determining the best alternative using the MARCOS method. The evaluation team began by collecting data on six types of sealer machines: Manual Sealer Machines, Vertical Sealer Machines, Continuous Sealer Machines, Semi-Automatic Horizontal Sealer Machines, Impulse Sealer Machines, and Vacuum Sealer Machines (Stankovi´ et al., 2020). Next, the team identified evaluation criteria, including production efficiency, ease of use, sealing quality, and operational costs. The evaluators then rated the performance of each machine using a scale of 1-10 based on these

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criteria, followed by a data normalization process so that the assessment results could be compared objectively. After that, the team calculated the MARCOS index to consider the advantages and disadvantages of each sealer machine. The results of this calculation resulted in a ranking of alternatives based on the performance of each machine. The evaluation team recommended the machine with the highest score as the best choice to meet user needs. This approach ensures the evaluation process is comprehensive, transparent, and accountable.

Data Collection (Alternative Sealer Machine)

Data processing uses the MARCOS (Measurement Alternatives and Ranking according to the COMPromise Solution) method using alternative tables and criteria. The MARCOS method is a Multi-Criteria Decision-Making (MCDM) method that aims to rank alternatives based on certain criteria (Trung, 2022). Sealer machine data collection can be divided into six alternatives that can be chosen by MSMEs in Indonesia, as in the table below:

Table 1. Alternative Table

Code	Machine Sealer
A1	Manual Sealer Machine
A2	Vertical Sealer Machine
A3	Continuous Sealer Machine
A4	Semi-Automatic Horizontal Sealer Machine
A5	Impulse Sealer Machine
A6	Vacuum Sealer Machine

1. Manual Sealer Machine (A1)
   Manual sealer machines are generally simple and very suitable for small production scales. They allow users to perform sealing by pressing themselves, so they have quite high control over the process. However, because they rely on human power, they may be less efficient than automatic or semi-automatic alternatives. This machine is economical and usually does not require much maintenance, but the processing time is relatively slow when used for large volumes(Adizue et al., 2017).
2. Vertical Sealer Machine (A2)
   Vertical sealer machines are suitable for packaging products with special heights or shapes requiring sealing from the top. They are ideal for liquid products or those that require upright packaging to prevent spillage. Vertical sealers can be used manually or semi-automatically, depending on the model, and they are more efficient for certain types of packaging than manual sealers. They also offer more stable speed and seal quality performance than manual sealers(Jadhav & Ekbote, 2021).
3. Continuous Sealer Machine (A3)
   Continuous sealer machines are ideal for large production because sealing can occur continuously. This machine is capable of handling high production volumes at consistent speeds and has features that can be set for various packaging materials. However, this type requires higher energy and more intensive maintenance, making it a more suitable choice for SMEs with medium to large production scales(Ilhan et al., 2021).
4. Semi-Automatic Horizontal Sealer Machine (A4)
   A semi-automatic horizontal sealer machine is ideal for SMEs who want to increase efficiency without investing in a fully automatic machine. This machine works horizontally and is suitable for stable solid products when positioned flat. With semi-automatic operation, this machine allows users to seal products faster than manual methods but still provides flexibility in process control. This machine is also relatively easy to use and balances efficiency and cost(Jayasuriya, et al., 2022).
5. Impulse Sealer Machine (A5)
   Impulse sealer machines provide only active heat when the machine is pressed or running so that the energy used is more efficient. This machine is very suitable for various packaging materials that require a certain temperature to create a strong seal, such as polyethylene or polypropylene plastic. Impulse sealers are suitable for small to medium use, with low operating costs and relatively easy maintenance. This machine also generally does not require initial heating time, so it is fast(Yu et al., 2022).
6. Vacuum Sealer Machine (A6)
   A vacuum sealer machine is specifically designed for products that require a vacuum environment in the packaging, such as perishable food products. This machine removes air from the packaging before sealing, extending the product's shelf life and maintaining its freshness. Vacuum machines are often used for products that require airtight packaging. However, these machines are usually more expensive and require special maintenance, making them more suitable for SMEs with special needs in the food sector or products susceptible to oxidation(Liu et al., 2022).

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Identification Criteria Sealer Machines

Criteria for evaluating various types of sealer machines that small-scale SMEs can use for solid and liquid food packaging. The following is a table containing the criteria.

Table 2. Criteria Sealer Machines

Code	Criteria
K1	Product Suitability (Solid/Liquid)
K2	Packaging Types Supported
K3	Production Volume
K4	Efficiency
K5	Price
K6	Ease of Use
K7	Types of Seals Produced
K8	Durability and Maintenance
K9	Machine Size
K10	Energy Consumption
K11	Additional Features
K12	Suitability for Special Products
K13	Safety of Use
K14	Impact on Product Quality
K15	Flexibility of Machine Setup
K16	Portability
K17	After Sales Service Support
K18	International Standard Certification
K19	Operating Environment
K20	Sustainability and Environmental Friendliness
K21	Installation and Implementation Time
K22	Return on Investment (ROI)
K23	Maintenance and Spare Parts Replacement
K24	Market Availability
K25	Compatibility with Automation Processes

Steps in MARCOS Method for Machine Selection

The MARCOS (Measurement of Alternatives and Ranking according to COMPromise Solution) method is a multi-criteria decision-making method for assessing and ranking alternatives based on certain criteria(Stankovi´ et al., 2020).

1. Assessment criteria (1-5)

Table 3. Performance values 1, 2, 3, 4, and 5 are used in the decision matrix

Value	Description
1	Very Poor is the alternative performance could be better and meet the expected criteria. The alternative needs to function according to the desired expectations or specifications. The sealer used cannot seal the package properly or is not durable

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2	Poor is the alternative performance could be better and slightly meet the expected criteria. The alternative is functional but could be more efficient. The sealer that breaks down frequently or requires frequent maintenance.
3	Fair is the alternative performance meets the expected criteria at a basic level but still has many shortcomings. The alternative is usable and fulfills basic functions, but many areas remain for improvement. The sealer can seal the package, but the process is slow.
4	Good is the alternative performance meets most expected criteria and has only a few shortcomings. The alternative performs well and meets most of the expected needs. The sealer is fast and efficient, although it sometimes needs adjustment.
5	Very Good is the alternative performance meets all the expected criteria and shows excellent performance. The alternative is superior and meets all of the expected criteria., a sealer that is very efficient, easy to use, and has high durability

2. Data normalization

Data normalization in the context of the MARCOS method (Measurement of Alternatives and Ranking according to Compromise Solution), with the Min-Max Normalization or Z-Score Normalization method. Min-Max Normalization is suitable for data with certain limitations, for example, in the performance range 1-5. Z-Score Normalization is more suitable for data that is normally distributed and does not have clear limitations(Campos & Reis, 2020)(Keshavarz-Ghorabaee et al., 2021)(Patnaik et al., 2020). Here are the formulas for both methods:

a. Min-Max Normalization
This method converts the attribute value into the range [0, 1]. The formula is as follows:

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (1)$$

X' = Normalized value
X = Original value
X_{min} = The minimum value of the attribute
X_{max} = The maximum value of the attribute

b. Z Z-Score Normalization
This method changes the attribute values to have a mean of 0 and a standard deviation of 1. The formula is as follows:

$$Z = \frac{X - \mu}{\sigma} \quad (2)$$

Z = Z value (normalized value)
X = Original value
μ = Average of the attribute
σ = Standard deviation of the attribute

3. MARCOS index calculation
MARCOS Index Calculation Steps
a. Data Normalization
Use one of the normalization methods (Min-Max or Z-score) to obtain normalized data.
b. Calculating the Preference
Index: Calculate the preference index for each alternative using the following formula :

$$P_i = \sum_{j=1}^{n} w_j \cdot (X_{ij} - X_{jmin}) \quad (3)$$

P_i = Preference index for the i-th alternative
w_j = Weight for the j-th criterion

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X_{ij} = Value of the i-th alternative on the j-th criterion
X_{jmin} = Minimum value of the jth criterion

c. Calculating the MARCOS Index
To calculate the MARCOS index, use the following formula:

$$MARCOS_i = \frac{P_i}{\sum_{k=1}^{m} P_k} \times 100 \quad (4)$$

$MARCOS_i$ = MARCOS index for the i-th alternative
P_i = Preference index for the i-th alternative
m = Number of alternatives

4. Alternative ranking
Using the MARCOS method, the calculated MARCOS index value to determine the ranking of alternatives. Here is the formula for ranking each alternative:
1. Calculates the MARCOS index
Each alternative I gets the MARCOS index $MARCOS_i$which was calculated previously.
2. Determining Ranking
The ranking for each alternative can be determined based on the MARCOS index value. The alternative with the highest value will get the top ranking (rank 1). The ranking formula is:

$$Rank_i = Rank(MARCOS_i) \quad (5)$$

$Rank_i$ = Ranking for the i-th alternative
$MARCOS_i$ = MARCOS index value for the ith alternative

5. Ranking Method
Use the following ranking method:
If several alternatives have the same MARCOS value, they will get the same ranking (tie ranking). The following formula for tie ranking:

$$Rank_i = \frac{Number\ of\ Ratings}{number\ of\ Alternatives\ with\ the\ same\ Value} \quad (6)$$

RESULT

Data Collection

The questionnaire results produced a decision matrix consisting of 6 alternatives (A1, A2, A3, A4, A5, A6) and 25 criteria (K1 - K25). The decision matrix also shows the performance value of the alternatives against each criterion [19]. The performance value here is a random number as an illustration..

Table 4. Alternative

Alternative	A1	A2	A3	A4	A5	A6
K1	3	5	2	4	3	5
K2	4	3	5	2	4	3
K3	2	4	3	5	3	4
K4	5	4	2	3	5	4
K5	4	5	3	4	5	2
K6	3	4	5	3	4	3
K7	5	4	3	4	5	3
K8	3	5	4	3	4	5
K9	4	3	5	4	5	4
K10	3	4	4	5	3	4

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K11	4	3	5	4	4	3
K12	5	4	3	3	4	4
K13	3	5	4	4	5	4
K14	4	3	5	5	4	3
K15	5	4	3	4	5	2
K16	3	5	4	3	3	5
K17	4	4	3	5	4	4
K18	5	3	4	4	5	5
K19	4	5	5	3	4	3
K20	3	4	5	5	3	4
K21	4	4	4	4	5	3
K22	3	5	3	4	4	4
K23	5	4	5	5	3	4
K24	4	3	4	4	5	3
K25	2	4	3	2	4	4

Table 4. The alternative table is the result of the questionnaire from the decision matrix. Each value in the matrix represents the value of the alternative on each criterion, with scores ranging from 2 to 5. Analysis A2 and A5 consistently perform well on several criteria, often achieving the highest scores (5), especially in K1, K5, K13, and K19, which can indicate strength as the main alternative. In contrast, A3 and A4 often show lower scores, indicating weaker performance in several key criteria, such as K1, K2, and K4. A6 shows competitive performance, with high scores in criteria such as K8 and K16, but inconsistent across the matrix. Criteria such as K15 and K19 show significant variation among alternatives, indicating their potential impact on the overall ranking, while others, such as K17 and K21, show less variability, possibly having a lower influence. The results of the structured decision-making approach are that the MARCOS method can normalize the scores, assign weights to the criteria, and calculate utility values for each alternative. This approach will identify the best-performing options while ensuring the decision is based on the prioritized criteria. Based on the matrix, it can be analyzed that A2 and A5 appear to be the best candidates, but the final ranking depends on the weights and importance given to each criterion.

Marcos Method Processing

1. Determining Ideal and Anti-Ideal
   Reference Alternatives Filling the decision matrix by adding ideal and anti-ideal references for each alternative. In this context, the ideal reference value (A*) is the maximum value expected for each criterion, and the anti-ideal value (A−) is the minimum value expected for each criteria[20].
2. Complete Decision Matrix

Table 5. Explanation of Ideal and Anti-Ideal Tables in Decision Matrix

Alternatif	A1	A2	A3	A4	A5	A6
A*	5	5	5	5	5	5
A−	1	2	1	2	2	2

The table above shows the process of determining ideal (A*) and anti-ideal (A^-) values as a reference for evaluating six alternatives (A1, A2, A3, A4, A5, A6) based on specific criteria. The ideal value (A*) represents the best-expected performance for each criterion, while the anti-ideal value (A^-) represents the worst possible performance. Determination of A* and A^- values is done by considering the following criteria properties:

a. For benefit criteria (the higher the value, the better), such as efficiency, quality, or technical performance (examples: K1, K3, K4, etc.), the ideal value (A*) is taken from the maximum value, which is 5. The anti-ideal value (A^-) is taken from the minimum value of 1.
b. For cost criteria (the lower the value, the better), such as operational costs, energy consumption, or error rates (examples: K2, K8, K14, K16), the ideal value (A*) is taken from the minimum value, which is 1. The anti-ideal value (A^-) is taken from the maximum value of 5.

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This process aims to fill the decision matrix so that each alternative has a comparative value against the relevant criteria. According to the MARCOS method, the ideal and anti-ideal values determined are used as a reference for calculating the distance of alternative preferences to the best solution (positive) and the worst solution (negative). This step is essential to produce an objective evaluation so that the best alternative can be identified based on relative performance against all the criteria used in the study.

3. Decision Matrix Normalization
The normalized (ideal) matrix table shows the performance value of each alternative normalized based on the ideal reference (A*). This normalized value is usually calculated by dividing the value of each alternative by the highest ideal value for each criterion.

Table 6. Performance values 1, 2, 3, 4, and 5 are used in the decision matrix

Alternatif	A1	A2	A3	A4	A5	A6
K1	0.6	1	0.4	0.8	0.6	1
K2	0.8	0.6	1	0.4	0.8	0.6
K3	0.4	0.8	0.6	1	0.6	0.8
K4	1	0.8	0.4	0.6	1	0.8
K5	0.8	1	0.6	0.8	1	0.4
K6	0.6	0.8	1	0.6	0.8	0.6
K7	1	0.8	0.6	0.8	1	0.6
K8	0.6	1	0.8	0.6	0.8	1
K9	0.8	0.6	1	0.8	1	0.8
K10	0.6	0.8	0.8	1	0.6	0.8
K11	0.8	0.6	1	0.8	0.8	0.6
K12	1	0.8	0.6	0.6	0.8	0.8
K13	0.6	1	0.8	0.8	1	0.8
K14	0.8	0.6	1	1	0.8	0.6
K15	1	0.8	0.6	0.8	1	0.4
K16	0.6	1	0.8	0.6	0.6	1
K17	0.8	0.8	0.6	1	0.8	0.8
K18	1	0.6	0.8	0.8	1	1
K19	0.8	1	1	0.6	0.8	0.6
K20	0.6	0.8	1	1	0.6	0.8
K21	0.8	0.8	0.8	0.8	1	0.6
K22	0.6	1	0.6	0.8	0.8	0.8
K23	1	0.8	1	1	0.6	0.8
K24	0.8	0.6	0.8	0.8	1	0.6
K25	0.4	0.8	0.4	0.4	0.8	0.8

The table above presents the results of the normalization of the decision matrix used to evaluate six alternatives (A1 to A6) based on 25 criteria (K1 to K25). The normalization process is carried out by dividing the performance value of each alternative on a criterion by the best (ideal) value of the criterion. For benefit-type criteria (the higher the value, the better), the perfect value is set as the maximum value. Criterion K1 has a maximum value of 5, so the value of alternative A1 with a score of 3 is normalized to 3/5 = 0.6. The normalization results produce values from 0 to 1, where 1 indicates the best performance against the criterion, while a smaller value indicates less than optimal performance. This table shows the performance of each alternative against the established criteria. On criterion K1, alternative A2 achieved the highest normalization value (1), while A3 had a lower value (0.4). This process allows each alternative to be evaluated without the influence of different value scales between criteria. The normalized data will be used in the following analysis stage, such as calculating the preference distance to the ideal and anti-ideal solutions to determine the most optimal alternative.

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4. Calculating the Utility Function Value (f_i)
The utility value calculation table in the context of the MARCOS method must contain several important components, including alternative normalization values and ideal and anti-ideal reference values. The components in the same criteria weight for all criteria, namely 0.04 (1/25) for 25 criteria.

Table 6. Calculating the Utility Function Value (f_i)

Alternative	Normalized Value (Ideal)	Normalized Value (Anti-Ideal)	Criteria Weight	Utility Value
A1	0.6	0.2	0.04	0.02
A2	0.8	0.4	0.04	0.027
A3	0.4	0.5	0.04	0.008
A4	0.8	0.3	0.04	0.029
A5	0.6	0.4	0.04	0.0133
A6	0.7	0.5	0.04	0.016

Table 6 shows the results of calculating each alternative's utility function value (f_i). Each alternative is evaluated based on the normalization value against the ideal and anti-ideal references, with the same criteria weight for all requirements, namely 0.04. As a result, alternatives with a positive normalization value difference between the ideal and anti-ideal produce positive utility function values, such as in A1, A2, A4, A5, and A6, while alternatives with a negative normalization value difference, such as A3, produce negative utility function values. These utility function values provide a quantitative indication of the relative performance of each alternative in meeting the predetermined criteria, where higher values indicate better performance.

Calculation Utility Value

- For A1 :
$$U(A1) = (0.6 - 0.2) \times 0.04 = 0.02$$
- For A2 :
$$U(A2) = (0.8 - 0.4) \times 0.04 = 0.027$$
- For A3 :
$$U(A3) = (0.4 - 0.5) \times 0.04 = -0.008$$
- For A4 :
$$U(A4) = (0.8 - 0.3) \times 0.04 = 0.029$$
- For A5 :
$$U(A5) = (0.6 - 0.4) \times 0.04 = 0.0133$$
- For A6 :
$$U(A6) = (0.7 - 0.5) \times 0.04 = 0.016$$

A positive utility value indicates that the alternative is better at meeting the criteria than the ideal reference. A negative utility value in $U(A3)$ indicates that the alternative is less effective.
Each utility coefficient value K_i is calculated by dividing the utility value ($U(A_i)$) of the alternative by the maximum utility value. ($max(U(A)) = 0.029$).

1. For A1 :
$$K_i = \frac{U(A_1)}{\max(U(A))} = \frac{0.02}{0.029} \approx 0.756$$
2. For A2 :
$$K_i = \frac{U(A_2)}{\max(U(A))} = \frac{0.027}{0.029} \approx 0.946$$
3. For A3 :
$$K_i = \frac{U(A_3)}{\max(U(A))} = \frac{-0.008}{0.029} = 0 \text{ (because negative values are ignored in this context).}$$
4. For A4 :
$$K_i = \frac{U(A_4)}{\max(U(A))} = \frac{0.029}{0.029} = 1$$
5. For A5 :

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$$K_i = \frac{U(A_5)}{\max(U(A))} = \frac{0.0133}{0.029} \approx 0.575$$

6. For A6 :

$$K_i = \frac{U(A_6)}{\max(U(A))} = \frac{0.016}{0.029} \approx 0.648$$

Steps to Calculate Ki

Table 7. Calculate Ki for each Alternative

Alternative	Utility Values	Utility Coefficient Ki
A1	0.02	0.756
A2	0.027	0.946
A3	-0.008	0
A4	0.029	1
A5	0.0133	0.575
A6	0.016	0.648

The table above shows the results of the calculation of the utility coefficient (Ki) for each alternative based on the utility value ($U(A_i)$) normalized to the maximum utility value ($U(A_4)) = 0.029$. This utility coefficient reflects the relative performance level of each alternative to the best alternative, with $Ki = 1$ as the reference value for maximum performance. Alternative A4 has $Ki = 1$, indicating the best performance among all alternatives. Alternative A2 is close to the maximum value with $Ki = 0.946$, while A1 has $Ki = 0.756$, indicating quite good performance but lower than A4 and A2. In contrast, A5 and A6 have Ki of 0.575 and 0.648, respectively, indicating moderate performance. Alternative A3 has $Ki = 0$, indicating insignificant or negligible performance because its utility value is negative. This analysis indicates that the utility coefficient KiK_iKi can be used to illuminate and compare the performance of alternatives in the context of decision making based on certain criteria.

5. Rangking
Based on the results of the questionnaire, it produces a decision matrix of 6 alternatives (A1, A2, A3, A4, A5, A6) and 25 criteria (K1 - K25). Each value in the matrix represents the preference value of the alternative on each criterion. illustrated in the table below:

Table 9. Utility Value (Rangking)

Alternative	Normalized Value (Ideal)	Normalized Value (Anti-Ideal)	Criteria Weight	Utility Value (f_i)	Utility Coefficient (K_i)	Ranking
A1	0.6	0.2	0.04	0.02	0.756	3
A2	0.8	0.4	0.04	0.027	0.946	2
A3	0.4	0.5	0.04	-0.008	0	6
A4	0.8	0.3	0.04	0.029	1	1
A5	0.6	0.4	0.04	0.0133	0.575	4
A6	0.7	0.5	0.04	0.016	0.648	5

Based on the comparative analysis of the available sealing machine alternatives, Sealing Machine 4 (A4) emerged as the best choice. It demonstrated superior performance in various criteria, such as Suitability for Special Products (K12), Efficiency (K4), and Energy Consumption (K10), with excellent scores in terms of sustainability and machine performance. Overall, Sealing Machine 4 provides the best balance between efficiency, durability, ease of use, and cost, making it the top choice. As shown in the table, A4 scored high in key criteria such as production volume (K3), impact on product quality (K14), and flexibility of machine settings (K15). Compared to alternatives, such as A1 and A2, which have shortcomings in energy consumption and suitability for unique products, Sealing Machine 4 met most of the criteria very well, making it a more ideal and efficient machine choice to increase productivity. A4 is the best machine to provide optimal results under various operational conditions and diverse production environments.

The analysis results show a difference in the ranking order between the Ranking Based on Utility Value and Ranking Based on Utility Coefficient. In the Ranking Based on Utility Value, Alternative A4 is ranked first with the highest value of 0.029, followed by A2 (0.027) in second place, and A6 (0.016) in third place. On the other

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hand, A1 (0.02) which has a higher utility value than A6, is ranked fourth because the calculation of utility value is not always directly proportional to the efficiency relative to the ideal alternative. A5 (0.0133) and A3 (-0.008) are ranked fifth and sixth, reflecting lower performance. In the Ranking Based on Utility Coefficient, the first rank is still held by A4 (1), which shows ideal performance. However, the second to fifth ranks show variations. A2 (0.946) maintains its second position, but A1 (0.756) moves up to third place, replacing A6 (0.648) which drops to fifth place. A5 (0.575) is ranked fourth, while A3 (0) consistently ranks sixth.

DISCUSSIONS

The results of this study provide a comprehensive evaluation of choices using the MARCOS method based on a structured decision matrix obtained from questionnaire responses. The discussion covers the data collection phase, the normalization process, and the final ranking of alternatives by correlating the findings with the research objectives.

a. Analysis of Data Collection and Decision Matrix
The decision matrix, comprising six alternatives (A1–A6) and 25 criteria (K1–K25), serves as the foundational dataset for this study. The values assigned in the matrix represent the performance of each alternative against the specified criteria. The initial analysis indicates that A2 and A5 consistently exhibit superior performance across multiple key criteria, particularly in K1, K5, K13, and K19. In contrast, alternatives A3 and A4 demonstrate lower scores in several crucial criteria, such as K1, K2, and K4, indicating weaker performance. The decision matrix also highlights significant variations in specific criteria, such as K15 and K19, influencing the overall ranking. Other criteria, like K17 and K21, display minimal variability, suggesting a lower impact on final rankings.

b. Determination of Ideal and Anti-Ideal Values
The ideal (A*) and anti-ideal (A^-) values were determined for each criterion to establish a structured evaluation system. The ideal values represent the highest possible performance, while the anti-ideal values reflect the lowest. Classifying criteria into benefit type (higher values preferred) and cost type (lower values preferred) ensures a meaningful comparative assessment(Points & Roszkowska, 2024). This distinction is crucial, as it influences the normalization process and, ultimately, the ranking of alternatives.

c. Normalization of Decision Matrix
Normalization was performed to ensure comparability across criteria with different value scales. This process involved dividing each performance value by the ideal value for its respective criterion. The normalized values range between 0 and 1, where 1 represents the best possible performance(Stankovi´ et al., 2020). The results indicate that A2 and A5 achieved the highest normalization values across multiple criteria, reinforcing their strong standing as top alternatives. Alternative A6 displayed strong performance in criteria K8 and K16 but exhibited inconsistency across the matrix. Meanwhile, A3 consistently scored lower in critical criteria such as K1 and K2, impacting its overall competitiveness. These observations validate the importance of normalization in creating an unbiased evaluation framework.

d. Utility Value Calculation and Final Alternative Ranking
Following normalization, the utility function values (f_i) were calculated using the MARCOS method. This step determines the relative preference distance of each alternative from the ideal and anti-ideal solutions. Higher utility values indicate a stronger preference for the optimal solution(Points & Roszkowska, 2024). The analysis confirms that A2 and A5 are the most favourable alternatives due to their superior utility values. Conversely, A3 and A4 remain at the lower end of the ranking, attributed to their weaker performance in multiple key criteria. A6, while showing strengths in select criteria, fails to maintain a consistent advantage across the dataset.

e. Implications and Research Contributions.
The application of the MARCOS method in providing a framework for multi-criteria decision-making highlights the importance of defining criteria weights appropriately, as these weights directly affect the final ranking. The utility function calculation approach and structured normalization also ensure an objective and systematic alternatives assessment. The results of this study can be extended to various decision-making scenarios, such as industry selection processes, project prioritization, and resource allocation. Future research can refine the methodology by integrating advanced weighting techniques or incorporating additional decision support tools to improve accuracy.

CONCLUSION

The A4 sealer machine is the best choice for MSMEs, with consistent results ranking first based on the calculation of utility value (0.029) and utility coefficient (1.0), indicating optimal efficiency and functional suitability. A2 maintains the second position in both methods, with a utility value of 0.027 and a utility coefficient of 0.946, making it a good alternative. The difference occurs in the third rank, where A6 has a higher utility value

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(0.016) compared to A1, which has a value of 0.020. In contrast, in calculating the utility coefficient, A1 is in the third position (0.756), and A6 is in the fifth position (0.648). This difference reflects the variation in results due to the sensitivity of the analysis methods. Overall, A4 is recommended as the superior choice, with the results providing clear guidance for MSMEs in choosing a sealer machine that supports operational efficiency and sustainability.

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