Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

Enhanced Root Assessment Method for Multi-Criteria Decision Making: An Improved Framework for Robust Alternative Ranking

Aditya Lapu Kalua[1*], **Angreine Kewo**[2], **Susi Hendartie**[3], **Yampi R Kaesmetan**[4]

[1]Faculty of Mathematics and Natural Sciences, Sam Ratulangi University, Manado, Indonesia
[2]Departement of Management Engineering, Technical University of Denmark, Lyngby, Denmark
[3]Departement of Information System, STMIK Palangkaraya, Palangkaraya, Indonesia
[4]Departement of Informatics Engineering, Universitas Uyelindo, Kupang, Indonesia

Keywords:
Enhanced Root Assessment Method; Multi-Criteria Decision Making; Comparative Analysis; Ranking; Sensitivity Analysis;

ABSTRACT

Multi-Criteria Decision Making (MCDM) methods are widely used to address complex decision problems involving multiple alternatives and criteria with different characteristics. However, ranking outcomes may be sensitive to normalization mechanisms, criterion weights, and aggregation processes, particularly when benefit and cost criteria are evaluated simultaneously. This study proposes the Enhanced Root Assessment Method (ERAM), an improved root-based MCDM framework designed to provide a more structured and balanced evaluation of alternative performance while improving ranking stability. ERAM integrates modified normalization, weighted normalization, positive and negative aggregation, Relative Benefit-Penalty Balance, and an Enhanced Root Assessment Index to construct the final preference measure. The proposed method is evaluated using a new store location selection dataset comprising eight alternatives and six criteria. Its performance is examined through comparative analysis with SAW, WASPAS, GRA, and MOORA, together with sensitivity analysis using ±0.05 changes in criterion weights. The results show that ERAM maintains a stable ranking structure under weight variations and achieves a strong Spearman correlation of 0.9286 with the reference ranking, exceeding WASPAS (0.9048) and SAW, GRA, and MOORA (0.8810). These findings demonstrate that ERAM can produce consistent rankings while maintaining robustness against moderate changes in criterion importance. Therefore, ERAM provides a structured and robust framework for multi-criteria ranking problems involving heterogeneous criteria and uncertain decision preferences.

Publication Dates:
Online First Date:
November 16, 2026

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma
Published Date:
March 20, 2027
Corresponding Author:
Aditya Lapu Kalua
Sam Ratulangi University, Indonesia
Kampus UNSRAT Bahu, Manado, North Sulawesi, Indonesia
Email: adityalapu.kalua@unsrat.ac.id

I. Introduction

The development of Multi-Criteria Decision Making (MCDM) has become an important part of supporting decision-making processes in various complex problems that involve many alternatives and criteria[1]–[3]. In practice, each alternative can have different performance levels for a number of criteria that have different characteristics, measurement units, value ranges, and levels of importance. These differences make it impossible to directly compare the values of each criterion because one criterion might be the higher the better (benefit), while another criterion might be the lower the better (cost). Therefore, the normalization process becomes an important step in MCDM to convert the original values of each criterion into a uniform and comparable scale, without losing the relative relationships between alternatives[4], [5]. Normalization allows information from various criteria with different scales and characteristics to be processed consistently during both the weighting and ranking stages, making the evaluation results of alternatives more objective, structured, and usable as a basis for making more accurate decisions.

Criteria weighting is one of the important steps in MCDM because it serves to represent the relative importance of each criterion in the process of evaluating alternatives[6], [7]. The resulting weights will affect each criterion's contribution to the final score and can ultimately determine the ranking of alternatives. However, various conventional MCDM methods still have limitations in producing consistent and stable rankings, especially when there are changes in the performance values of alternatives, criteria weights, or decision-making conditions. Even small changes in these parameters under certain conditions can cause significant shifts in alternative positions, reducing confidence in the decision results. Therefore, robust alternative ranking becomes an important aspect in developing decision support systems, because it doesn't just focus on determining the best alternative, but also ensures that the ranking results remain relatively stable when facing variations or uncertainties in data and weights[8]–[10]. In this way, evaluating robustness can give an idea of how reliable the method is in producing consistent and accountable decisions under different decision-making conditions.

Even though various MCDM methods have been developed, there are still a number of methodological gaps that can affect the stability and reliability of alternative ranking results[11]–[13]. One of the main

Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

issues is the sensitivity of rankings to changes in criterion values, where a small change in an alternative's performance value can lead to a significant shift in its ranking position. In addition, some MCDM methods still heavily rely on certain normalization mechanisms, so the way values are transformed during normalization can directly impact the final result. Another problem is the less-than-optimal balance in handling benefit and cost criteria, especially when both types of criteria have different ranges and contribution patterns[14], [15]. At the aggregation stage, using a value merging mechanism that doesn't really consider the contribution structure of each criterion can also lead to distortions, because the influence of one criterion on the final score can become too dominant or too reduced. On the other hand, root-based assessment approaches haven't really been explored much as a way to map out the contribution of criteria and produce more stable rankings. This situation shows that there's a need to develop new approaches that can reduce ranking sensitivity, treat benefit and cost criteria more fairly, and use root-based assessment mechanisms more optimally to generate robust alternative rankings in a multi-criteria decision-making environment.

The Root Assessment Method (RAM) is an approach in MCDM that uses root-based transformations to evaluate the relative contributions of alternatives to each criterion before producing the final scores and ranking[16]–[18]. Using root functions can offer some advantages, especially in reducing the impact of extreme values, controlling the dominance of alternatives or criteria with overly large values, and generating more moderate contributions during the aggregation stage. RAM can also be designed to accommodate both benefit and cost criteria through different formulations, ensuring that the preference direction of each criterion is maintained. That said, RAM still has some limitations, such as dependence on the form and order of the root function, possible influence of the normalization mechanism on the final results, and potential loss of some information differences due to the value compression process[15], [19], [20]. Besides that, using root-based transformations doesn't automatically guarantee a robust ranking, because the stability of the results can still be influenced by changes in criterion values and weights. So, there's still room to develop RAM with a more balanced mechanism in handling benefit and cost criteria, controlling the contribution of each criterion during aggregation, and optimizing root-based assessment to produce alternative rankings that are more stable and robust to changes in data and weights.

1.1. Motivation for Conducting Research

The motivation behind developing the Enhanced Root Assessment Method (ERAM) comes from the need to strengthen the root-based approach's ability to represent the relationship between alternative performance and criteria contributions more proportionally. This development isn't just about changing the mathematical formulas; it's about creating an assessment mechanism that can retain important information throughout the evaluation process until the final alternative scores are obtained.

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

The ERAM structure is designed so that each stage has a clear role in forming the alternative scores, making the assessment process less dependent on just one calculation component. This approach is expected to provide a more controlled assessment, especially when there are significant differences in contributions across criteria.

The next ERAM is motivated by the need to build a more structured relationship between performance values, criteria weights, and the final contribution of alternatives. By using a normalized decision matrix and a weighted normalized matrix, performance information and the importance of criteria are placed in a consistent representation before entering the root-based assessment process. Meanwhile, separating the contributions of benefits and costs allows information from both groups of criteria to be retained according to their preference direction before being combined in the final stage. This mechanism provides a basis for applying root-based final assessment as the core of the evaluation, so the final value is not just the sum of contributions, but also reflects the structure of the relationships between the assessment components built into the method.

Another motivation is to make ranking stability an integral part of method development, not just an additional analysis after the ranking is obtained. ERAM is designed to allow evaluation results to be checked through changes in input conditions so that ranking characteristics can be understood more objectively. This approach is important for distinguishing between methods that only produce a certain ranking and methods that can maintain priority patterns when evaluation parameters vary. In this way, the development of ERAM is aimed at creating a root-based assessment mechanism that not only functions as a ranking procedure but also provides a basis for evaluating consistency, sensitivity, and the robustness of decision outcomes.

1.2. Research Objectives

This research aims to develop the ERAM as an MCDM method that can provide a more structured and adaptive evaluation mechanism for alternatives according to the characteristics of decision problems. Specifically, the study is aimed at producing final alternative scores by proportionally considering the contributions of benefit and cost criteria, so that differences in preference directions between criteria are accurately reflected in the assessment process. In addition, this research aims to obtain a more stable ranking of alternatives, so that the resulting priority order doesn’t easily change due to variations in evaluation conditions. Achieving these goals is expected to give ERAM characteristics that are different from existing MCDM approaches, especially in producing consistent assessments under conditions with diverse criteria characteristics.

To find out how effective the developed method is, this study also aims to carry out a comparative evaluation between ERAM and several other MCDM methods under equivalent testing conditions. The comparison is done to identify differences in score values, the order of alternatives, and the level of ranking agreement produced by each approach. Furthermore,

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

sensitivity analysis is used to test how the rankings respond to changes in parameters, especially variations in criteria values and weights. The test results serve as a basis to assess the robustness of ERAM and to see how well the method can maintain the priority pattern of alternatives under various change scenarios. So, the research evaluation doesn't just focus on the final ranking results, but also on the consistency and resilience of the method when applied in different decision-making conditions.

1.3. Research Contribution

The main contributions of this study lie in the formulation and empirical validation of the ERAM as a new framework for multi-criteria evaluation. The proposed approach introduces a more structured computational mechanism in which the information generated at each evaluation stage is carried forward to construct the final preference measure, allowing the resulting scores to reflect the relative contribution of the considered criteria. A distinct treatment of benefit and cost criteria is incorporated to maintain the directionality of preference throughout the assessment process, while the root-based formulation provides the mathematical foundation for deriving a unified score for each alternative. Beyond the formulation of the method itself, this study contributes an extensive evaluation framework that examines the behavior of ERAM under different decision conditions, including comparisons with established MCDM approaches and variations in relevant parameters. The resulting analyses provide evidence regarding the consistency of alternative priorities, the degree of ranking variation, and the robustness of the proposed method, thereby providing a more comprehensive basis for assessing its applicability to multi-criteria decision problems.

II. Methodology

2.1. Framework ERAM

The ERAM is proposed as an improved framework for multi-criteria decision-making that focuses on evaluating the relative performance of alternatives through a root-based assessment mechanism. The framework is designed to transform the original decision matrix into a comparable assessment structure while considering the different characteristics of benefit and cost criteria. By establishing a consistent reference for each criterion, ERAM enables the performance of alternatives to be evaluated on a common scale and reduces the influence of differences in measurement units and criterion magnitudes. The resulting assessments are subsequently aggregated according to the importance of each criterion to produce an overall performance score for every alternative.

The main advantage of ERAM lies in its ability to provide a structured and robust evaluation of alternatives while maintaining a relatively simple computational framework. The method emphasizes the

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

relationship between alternative performance and criterion-specific reference values, allowing stronger-performing alternatives to obtain more favorable assessment values. The framework can accommodate heterogeneous criteria and can be integrated with objective or subjective weighting approaches depending on the decision context. Through the resulting overall assessment, alternatives can be ordered from the most to the least preferable, providing a clear basis for decision-making. Thus, ERAM is intended to offer an interpretable and flexible MCDM framework that can be applied to various selection, prioritization, and ranking problems. The overall mathematical framework of ERAM is presented in Figure 1.

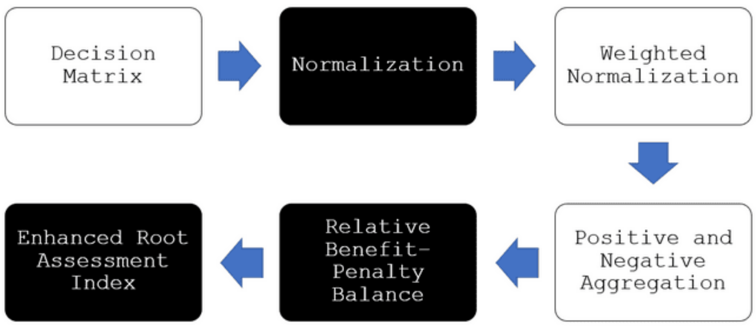

Figure 1. Framework ERAM

The ERAM framework consists of six main stages designed to create a more systematic and adaptive multi-criteria decision-making process. The process starts with a Decision Matrix to lay out the initial values of each alternative based on all the criteria used. Next, Normalization (Modification) is done to standardize the data scale while considering the characteristics of benefit and cost criteria. The normalized results are then combined with the criteria weights through the Weighted Normalization stage to get the relative contribution of each criterion to each alternative. These values are then separated and aggregated through Positive and Negative Aggregation to show the contribution of benefits and penalties for each alternative. The Relative Benefit-Penalty Balance (Modification) is used to balance the influence of positive and negative values so that a more representative performance measure for alternatives is obtained. The final stage is the Enhanced Root Assessment Index (Modification), which produces a final assessment index as the basis for ranking the alternatives, with higher index values indicating better alternatives.

2.2. ERAM Method

The ERAM method is an MCDM method developed to evaluate and rank alternatives based on the positive and negative contributions of various criteria in an integrated way. This method processes the decision matrix through a normalization process that takes into account benefit and cost characteristics, then combines the normalized results with the criteria weights to get a weighted contribution. Next, ERAM separates and

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

aggregates positive and negative aspects, calculates the relative balance between benefits and penalties, and produces the Enhanced Root Assessment Index as the final measure of an alternative's performance. With this approach, ERAM can provide a ranking mechanism that considers not just the level of benefits gained, but also the penalties or losses inherent in each alternative, resulting in a more comprehensive evaluation in multi-criteria decision-making.

The ERAM stages consist of six main processes. The first stage is the Decision Matrix, which is used to represent the performance value of each alternative against each criterion using (1). The second stage is Normalization, which aims to equalize the value scale between criteria by considering the characteristics of benefits and costs using (2). Next, Weighted Normalization is carried out by integrating the normalized values with the weight of each criterion using (3). The fourth stage is Positive and Negative Aggregation, which is used to accumulate the positive and negative contributions of each alternative based on (4) and (5). The next stage, Relative Benefit–Penalty Balance, is used to obtain the relative balance between the benefits and penalties of each alternative using (6). The next stage is the Enhanced Root Assessment Index, which is calculated using Equation (7) to obtain an assessment index for each alternative. Finally, the Final Index Alternative is calculated using Equation (8) to obtain the final performance value of each alternative, which serves as the basis for determining the final ranking. In this assessment, a lower Final Index Alternative value indicates better overall performance, meaning that the alternative with the lowest index value is ranked as the most preferred alternative.

$$X = [x_{ij}]_{mxn} \tag{1}$$

$$n_{ij} = \begin{cases} \frac{x_{ij}}{\max_j x_{ij}}; benefit \\ \frac{\min_j x_{ij}}{x_{ij}}; cost \end{cases} \tag{2}$$

$$k_{ij} = w_j * n_{ij} \tag{3}$$

$$S_{+i} = \sum_{j=1}^{n} k_{+ij} \tag{4}$$

$$S_{-i} = \sum_{j=1}^{n} k_{-ij} \tag{5}$$

$$D_i = \frac{S_{+i}}{S_{+i} - S_{-i}} \tag{6}$$

$$ERI_i = \sqrt[\frac{2+S_{-i}}{D_i}]{2 + S_{+i}} \tag{7}$$

$$R_i = \frac{ERI_i}{\max_i ERI_i} \tag{8}$$

In the ERAM method, $X = [x_{ij}]_{mxn}$ denotes the decision matrix, where x_{ij} is the performance value of alternative i with respect to criterion j, m is the number of alternatives, and n is the number of criteria. The normalized value n_{ij} represents the normalized performance of alternative i under criterion j, while w_j denotes the weight of criterion j. The

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

weighted normalized value k_{ij} represents the weighted contribution of criterion j to alternative i. The terms k_{+ij} and k_{-ij} denote the positive and negative contributions, respectively, which are aggregated into S_{+i} and S_{-i} to represent the total positive and negative performance of alternative i. The term D_i denotes the Relative Benefit-Penalty Balance, which reflects the relationship between the positive and negative contributions of alternative i. The ERI_i represents the Enhanced Root Assessment Index, which integrates the positive and negative assessment components into a root-based preference measure. Finally, R_i denotes the final normalized preference score of alternative i, obtained by dividing its ERI_i by the maximum ERI_i value among all alternatives. Higher values of R_i indicate more preferred alternatives in the final ERAM ranking.

The strength of ERAM lies in its ability to provide a more comprehensive evaluation of alternatives by considering both the benefits and penalties of each criterion at the same time. Modifications in the normalization stage, Relative Benefit-Penalty Balance, and Enhanced Root Assessment Index allow this method to produce assessments that are more adaptive to data characteristics and reduce the dominance of a single aspect in the ranking process. In addition, ERAM has a systematic and relatively simple calculation structure, so it can be applied to various Multi-Criteria Decision Making (MCDM) problems that involve criteria with both benefit and cost characteristics.

2.3. Research Stage

The research stages are a series of systematic processes used to guide the implementation of research, starting from problem identification to obtaining results and conclusions[21], [22]. Each stage is arranged sequentially and interconnected to ensure that data collection, data processing, method application, result analysis, and evaluation can be done in a structured way. In research on the development of the ERAM method, the research stages serve as a framework for designing the method formulation, applying it to MCDM problems, comparing results with other methods, and testing the stability and robustness of rankings through sensitivity analysis. The research stages are shown in Figure 2.

Figure 2. Research Stage

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

The research stages start with Dataset Preparation, which involves preparing and organizing alternative data and criteria used as the basis for evaluation, including making sure the characteristics of each criterion and the quality of the data before processing it using the proposed method. Next, Ranking Using the ERAM Method is carried out by applying all the calculation steps of the Enhanced Root Assessment Method (ERAM) to obtain the final values and priority order of each alternative. After the ranking is obtained, Sensitivity Analysis is conducted by giving variations to certain parameters, such as criterion values or weights, to observe changes in alternative positions and to understand the stability level of the results produced by ERAM. The final stage is Comparative Analysis, which compares the ERAM results with several other MCDM methods based on scores, ranking order, and the measure of ranking match or correlation to understand the characteristics and relative performance of the proposed method.

III. Result and Discussion

The research results were obtained through a series of data processing and analysis steps according to the established research stages. The prepared data was then used to get evaluation results using the proposed method, and then analyzed to identify patterns, differences, and characteristics emerging from those results. Each finding was interpreted based on the research objectives and compared with results from other relevant approaches to gain a more comprehensive understanding. Additionally, the analysis was done to check the consistency and reliability of the results under different testing conditions, giving a clearer picture of how well the developed method supports decision-making.

3.1. Dataset

A dataset is a collection of structured data used as a basis in the process of analysis, testing, and evaluation of a research method. In the context of MCDM, a dataset usually consists of several alternatives evaluated based on multiple criteria, where each value represents the performance level of an alternative against a specific criterion. The dataset serves as the main input to form a decision matrix, apply processing and calculation methods, and produce evaluation values and alternative rankings. The quality, completeness, and characteristics of the dataset are important factors because they can affect the evaluation results as well as the method's ability to make consistent and reliable decisions.

The dataset used in the study consists of evaluation data obtained from [23], which contains several alternatives assessed based on multiple criteria. Each alternative is evaluated according to the performance values associated with the criteria, forming the decision matrix used in the decision-making process. The criteria represent different aspects of the assessment and may have either benefit or cost characteristics

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

depending on their influence on the overall evaluation. This dataset is used as the main input for the proposed ERAM method, including the normalization, weighting, aggregation, and ranking processes, as presented in Table 1.

Table 1.New Store Location Assessment Dataset[23]

Alternatives	RC	BA	A	CT	PA	I
SLOC-1	45	120	8	550	10	9
SLOC-2	40	100	7	500	8	8
SLOC-3	55	150	9	600	12	9
SLOC-4	38	90	6	480	6	7
SLOC-5	60	160	8	620	15	10
SLOC-6	42	130	9	570	11	8
SLOC-7	36	110	7	510	9	7
SLOC-8	48	140	8	590	13	9

Dataset pada Table 1 consists of eight new store location alternatives (SLOC-1 to SLOC-8) evaluated based on six criteria, namely Rental Cost (RC), Building Area (BA), Accessibility (A), Consumer Traffic (CT), Parking Availability (PA), and Infrastructure (I). Each alternative is represented by a set of performance values that describe the characteristics of the respective store location. The criteria have different measurement characteristics, where Building Area, Accessibility, Consumer Traffic, Parking Availability, and Infrastructure are considered benefit criteria, while Rental Cost is treated as a cost criterion. The dataset forms the decision matrix used as the primary input for the proposed ERAM method to perform normalization, weighted assessment, positive and negative aggregation, benefit-penalty balancing, and final ranking of the store location alternatives.

The calculation results and rankings of those eight alternatives are presented in Table 2. These results are used as a reference to compare with the ranking results obtained using the ERAM method in this study.

Table 2.Rank Alternatives

Alternatives	Rank
SLOC-5	1
SLOC-3	2
SLOC-8	3
SLOC-6	4
SLOC-1	5
SLOC-7	6
SLOC-2	7
SLOC-4	8

The ranking results obtained through the ERAM method were then compared with the ranking results in the original paper to see how well they match and where the positions of each alternative differ. This comparison serves as a basis for evaluating ERAM's ability to produce an alternative order that's consistent with the reference ranking, while also showing the impact of modifications applied in the normalization

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

stage, Relative Benefit-Penalty Balance, and Enhanced Root Assessment Index. So, the results in Table 2 don't just show the best alternatives, but also provide a foundation to assess how well the ERAM method performs compared to previous research.

The dataset in Table 1 was selected because it provides a suitable decision environment for evaluating the proposed ERAM method, particularly in handling heterogeneous criteria with different measurement scales and both benefit and cost orientations. The store location selection problem involves eight alternatives evaluated using six criteria that represent diverse aspects of location performance, including financial considerations, physical capacity, accessibility, customer potential, parking availability, and infrastructure. The presence of one cost criterion (Rental Cost) alongside five benefit criteria creates an appropriate setting for examining ERAM's ability to balance positive and negative contributions during the assessment process. In addition, the dataset has an established reference ranking, allowing the results produced by ERAM to be directly compared with a previous study and providing a consistent basis for evaluating ranking agreement, stability, and robustness.

3.2. Ranking Alternative using ERAM Method

The ranking alternative using the ERAM method is conducted to determine the priority order of alternatives based on their overall performance across multiple evaluation criteria. The method provides a comparative assessment by considering the performance characteristics of each alternative and producing a final index that reflects its relative preference. This ranking provides a clear basis for identifying the best-performing alternative and supports objective decision-making in selecting the most suitable store location.

The ERAM method consists of six main stages. The first stage is the Decision Matrix, which represents the performance values of each alternative with respect to each criterion. The decision matrix provides the initial representation of the alternatives and their corresponding criterion values and is formulated using (1). The resulting decision matrix is presented below.

$$X = \begin{matrix} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \\ A_7 \\ A_8 \end{matrix} \begin{bmatrix} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \\ 45 & 120 & 8 & 500 & 10 & 9 \\ 50 & 100 & 7 & 550 & 8 & 8 \\ 55 & 150 & 9 & 600 & 12 & 9 \\ 38 & 90 & 6 & 480 & 6 & 7 \\ 60 & 160 & 8 & 620 & 15 & 10 \\ 42 & 130 & 9 & 570 & 11 & 8 \\ 36 & 110 & 7 & 510 & 9 & 7 \\ 48 & 140 & 8 & 590 & 13 & 9 \end{bmatrix}$$

The second stage is Normalization, which aims to transform the original criterion values into comparable scales while considering the characteristics of benefit and cost criteria. This process ensures that differences in measurement units and value ranges do not directly affect the subsequent evaluation process. The normalization process is

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

performed using (2), and the resulting normalized values are presented in Table 3.

Table 3. Normalization Results of the ERAM Method

Alternatives	RC	BA	A	CT	PA	I
SLOC-1	0.8000	0.7500	0.8889	0.8871	0.6667	0.9000
SLOC-2	0.9000	0.6250	0.7778	0.8065	0.5333	0.8000
SLOC-3	0.6545	0.9375	1.0000	0.9677	0.8000	0.9000
SLOC-4	0.9474	0.5625	0.6667	0.7742	0.4000	0.7000
SLOC-5	0.6000	1.0000	0.8889	1.0000	1.0000	1.0000
SLOC-6	0.8571	0.8125	1.0000	0.9194	0.7333	0.8000
SLOC-7	1.0000	0.6875	0.7778	0.8226	0.6000	0.7000
SLOC-8	0.7500	0.8750	0.8889	0.9516	0.8667	0.9000

The third stage is Weighted Normalization, which incorporates the importance of each criterion into the normalized performance values. The normalized values are multiplied by the corresponding criterion weights to obtain weighted performance values that represent the contribution of each criterion to the overall assessment. This calculation is performed using (3), with the resulting weighted normalized values presented in Table 4.

Table 4. Weighted Normalization Results of the ERAM Method

Alternatives	RC	BA	A	CT	PA	I
SLOC-1	0.1370	0.1349	0.1521	0.1167	0.1331	0.1319
SLOC-2	0.1542	0.1124	0.1331	0.1061	0.1065	0.1173
SLOC-3	0.1121	0.1686	0.1711	0.1274	0.1597	0.1319
SLOC-4	0.1623	0.1011	0.1141	0.1019	0.0798	0.1026
SLOC-5	0.1028	0.1798	0.1521	0.1316	0.1996	0.1466
SLOC-6	0.1468	0.1461	0.1711	0.1210	0.1464	0.1173
SLOC-7	0.1713	0.1236	0.1331	0.1083	0.1198	0.1026
SLOC-8	0.1285	0.1573	0.1521	0.1252	0.1730	0.1319

The fourth stage is Positive and Negative Aggregation, which evaluates the positive and negative contributions of each alternative based on the weighted normalized values. The positive aggregation represents the accumulated beneficial contribution, whereas the negative aggregation represents the accumulated penalty associated with the evaluated criteria. These calculations are performed using (4) and (5), and the resulting positive and negative aggregation values are presented in Table 5.

Table 5. Positive and Negative Aggregation Results of the ERAM Method

Alternatives	Positive	Negative
SLOC-1	0.5367	0.1370
SLOC-2	0.4580	0.1542
SLOC-3	0.6267	0.1121
SLOC-4	0.3969	0.1623
SLOC-5	0.6631	0.1028
SLOC-6	0.5845	0.1468
SLOC-7	0.4847	0.1713
SLOC-8	0.6076	0.1285

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

The fifth stage is Relative Benefit-Penalty Balance, which determines the relative balance between the beneficial and penalty contributions obtained from the previous stage. This measure provides an overall representation of the relative performance of each alternative by considering both positive and negative effects. The calculation is performed using (6), and the resulting Relative Benefit-Penalty Balance values are presented in Table 6.

Table 6. Relative Benefit-Penalty Balance Results of the ERAM Method

Alternatives	Relative
SLOC-1	0.7966
SLOC-2	0.7482
SLOC-3	0.8482
SLOC-4	0.7098
SLOC-5	0.8658
SLOC-6	0.7992
SLOC-7	0.7389
SLOC-8	0.8255

The next stage is the Enhanced Root Assessment Index, which is calculated using (7) to obtain an assessment index for each alternative. This index represents the relative performance of the alternatives based on the previously obtained benefit-penalty balance and serves as an intermediate measure in the overall evaluation process rather than the final ranking value. The resulting Enhanced Root Assessment Index values are presented in Table 7.

Table 7. Enhanced Root Assessment Index Results of the ERAM Method

Alternatives	Root Assessment Index
SLOC-1	12.1489
SLOC-2	13.3229
SLOC-3	11.0748
SLOC-4	14.3402
SLOC-5	10.7930
SLOC-6	12.8143
SLOC-7	14.5070
SLOC-8	11.8385

Finally, the Final Index Alternative is calculated using (8) to obtain the final performance value of each alternative, which serves as the basis for determining the final ranking. In this assessment, a lower Final Index Alternative value indicates better overall performance, meaning that the alternative with the lowest index value is ranked as the most preferred alternative. The resulting Final Index Alternative values and ranking are presented in Table 8.

Table 8. Final Index Alternative of the ERAM Method

Alternatives	Final Index
SLOC-1	0.8375
SLOC-2	0.9184
SLOC-3	0.7634
SLOC-4	0.9885

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

SLOC-5	0.7440
SLOC-6	0.8833
SLOC-7	1.0000
SLOC-8	0.8160

Based on the Final Index Alternative values, the alternatives are subsequently ranked according to their respective index values. Since a lower Final Index Alternative value indicates better performance, the alternative with the lowest value is assigned the first rank, followed by alternatives with progressively higher values. The resulting ranking of the alternatives is presented visually in Table 9.

Table 9. Rank Alternative of the ERAM Method

Alternatives	Final Index	Rank
SLOC-5	0.7440	1
SLOC-3	0.7634	2
SLOC-8	0.8160	3
SLOC-1	0.8375	4
SLOC-6	0.8833	5
SLOC-2	0.9184	6
SLOC-4	0.9885	7
SLOC-7	1.0000	8

The ranking results obtained using the ERAM Method show that SLOC-5 is the best-performing alternative, achieving the lowest Final Index value of 0.7440 and ranking first. It is followed by SLOC-3 with a value of 0.7634 in second place and SLOC-8 with 0.8160 in third place. Meanwhile, SLOC-1, SLOC-6, and SLOC-2 occupy the fourth, fifth, and sixth positions with Final Index values of 0.8375, 0.8833, and 0.9184, respectively. The lowest-ranked alternatives are SLOC-4 with a value of 0.9885 in seventh place and SLOC-7 with 1.0000 in eighth place. These results indicate that SLOC-5 is the most preferred store location alternative, while SLOC-7 is the least preferred alternative, based on the ERAM evaluation.

3.3. Sensitivity Analysis

Sensitivity analysis is a step in evaluation used to find out how strong and consistent a decision-making result is when there are changes in the parameters used in the method, especially the criteria weights[24], [25]. Sensitivity testing is done by creating several scenarios of weight changes, then recalculating the ranking process for each scenario and comparing it with the initial condition. Through this approach, you can see whether relatively small changes in weights cause significant changes in ranking or actually result in a consistently stable decision. Sensitivity analysis also serves to identify the stability level of a method, to know which criteria or parameters have a greater impact on decision outcomes, and to measure the model's resistance to changes in evaluation conditions[26], [27]. The more stable the ranking results are under various change scenarios, the stronger the indication that the method used can produce robust decisions and is not too dependent on certain weight configurations. Therefore, sensitivity

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

analysis is not just used as an additional test, but also as a tool to assess the reliability and trustworthiness of ranking results before the method is applied to real decision-making problems.

A sensitivity analysis on changes in weights was done by applying variations of +0.05 and −0.05 to the criteria weights to create several test scenarios[28]–[30]. These changes were used to see how much the rankings of alternatives were affected by increases or decreases in the criteria weights from their initial values. Each scenario was then recalculated to get the alternative rankings, so any changes in positions could be compared with the original rankings. This approach aims to find out how stable the decision results are when there are changes in the importance of the criteria. The changes in alternative rankings for each sensitivity analysis scenario are shown in Figure 3.

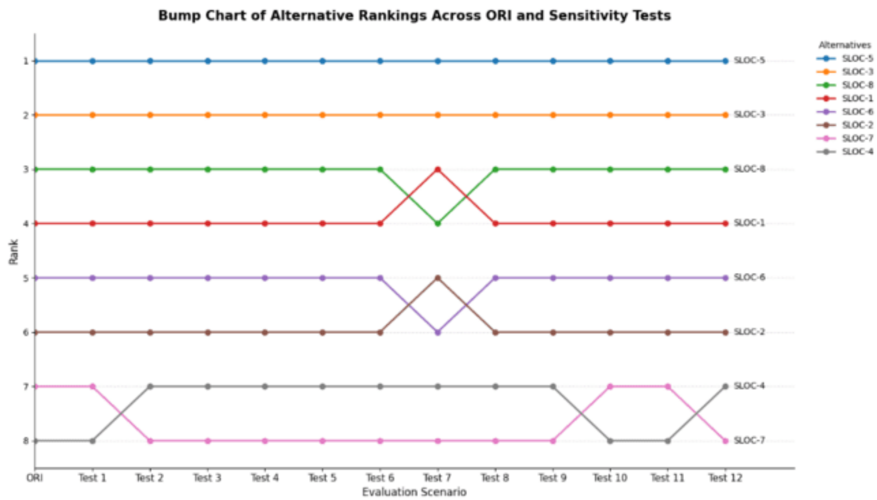

Figure 3. Alternative Rankings for each Sensitivity Analysis

The sensitivity analysis results show that the ranking of alternatives generally has a high level of stability against changes in weights of ±0.05 across various test scenarios. SLOC-5 stays in first place and SLOC-3 remains in second place in all scenarios, indicating that both alternatives are not affected by the given weight changes. SLOC-8 and SLOC-1 also show high stability, staying in third and fourth place respectively, except in Test 7 when their positions swapped to fourth and third. A similar pattern occurs with SLOC-6 and SLOC-2, which keep fifth and sixth place respectively, but switch positions in Test 7. Meanwhile, the biggest changes were seen in SLOC-7 and SLOC-4, which swapped positions a few times between seventh and eighth place from Test 2 to Test 9 and then changed again from Test 10 to Test 12. Even though there were some shifts in a few options, the overall ranking structure stayed pretty consistent and didn't show any extreme changes. This suggests that the ranking results are quite robust against a ±0.05 change in criteria weights.

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

3.4. Comparative Analysis

Comparative Analysis is an analysis used to compare the results of one method with another based on certain aspects, such as ranking values, result consistency, level of suitability, stability, or the method's ability to produce different or similar decisions[31]–[33]. In the context of MCDM, comparative analysis is generally done by applying several methods to the same dataset and criteria, then comparing the ranking results of the alternatives obtained. This approach aims to understand the characteristics and performance differences of each method and provide a more objective basis for assessing the reliability of the proposed method. Besides that, comparative analysis can be used to identify the level of match in results through correlation measures or certain evaluation metrics, so it can be seen whether the developed method produces decision patterns that are consistent with the comparison method. Therefore, comparative analysis serves as one approach to strengthen the validation of research results and show the position and advantages of the method used compared to alternative approaches.

The comparative evaluation in this study focuses on the extent to which the proposed method produces ranking patterns that are aligned with or different from those of established MCDM methods. Particular attention is given to the relative position of each alternative and the overall agreement among the resulting rankings. This evaluation is important because a method may produce a different ranking not necessarily due to lower performance, but because of differences in normalization, weighting, aggregation, and preference formulation. Therefore, examining the ranking patterns across methods provides a basis for determining whether the behavior of ERAM is consistent with established decision approaches while also identifying distinctive ranking characteristics resulting from its proposed assessment mechanism.

The comparison was done by applying ERAM, SAW, WASPAS, GRA, and MOORA to the same dataset and criteria to get an idea of how consistent the ranking results are. ERAM was used as the main method, and its results were compared with several widely used MCDM methods, namely SAW, WASPAS, GRA, and MOORA. This comparison looked at the ranking positions produced by each method for every alternative, so we can see how similar or different the decision results are. Using several comparison methods with different calculation characteristics allows for a more comprehensive evaluation of ERAM's results. If ERAM's ranking results show a relatively consistent pattern with the comparison methods, it can be an indication that the decisions have a good level of reliability. On the other hand, ranking differences can be used to identify the influence of each method's characteristics on the final results and serve as a basis for analyzing the strengths and sensitivity of ERAM in solving multi-criteria decision-making problems. The ranking comparison results between the ERAM, SAW, WASPAS, GRA, and MOORA methods are shown in Figure 1. This comparison is used to see how well the position of each alternative generated by ERAM aligns with the other comparison methods.

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

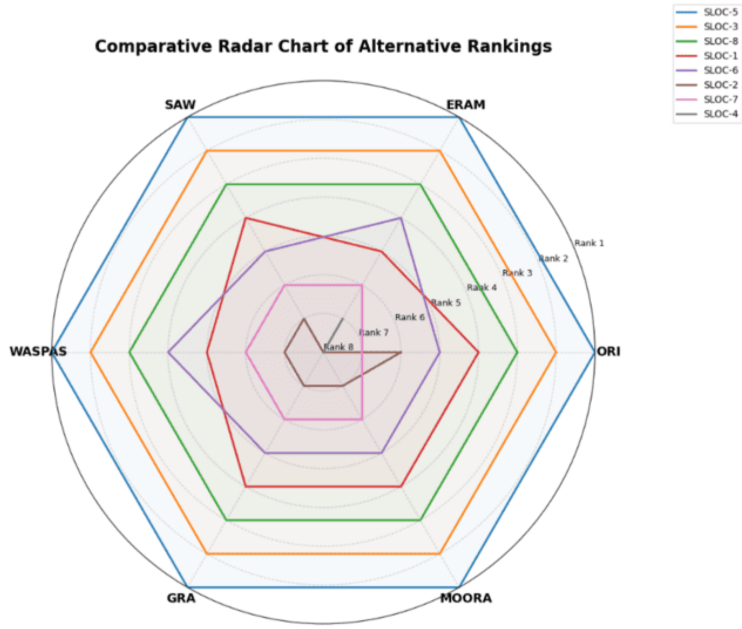

Figure 4. Ranking Comparison with the MCDM Method

The radar chart shows a comparison of the rankings of eight alternatives, from SLOC-1 to SLOC-8, based on six MCDM methods: ORI, ERAM, SAW, WASPAS, GRA, and MOORA. The results show that SLOC-5 consistently ranks first across all methods, followed by SLOC-3 in second place and SLOC-8 in third, indicating a strong level of consistency and dominance. SLOC-1 and SLOC-6 show minor shifts in position, especially in the ERAM and WASPAS methods, while SLOC-2, SLOC-7, and SLOC-4 experience relatively greater ranking variations. Overall, the radar pattern shows that most methods produce a similar ranking structure, indicating consistency in the rankings across methods and reinforcing SLOC-5's reliability as the best-performing alternative.

The comparison of rankings obtained from the ORI, ERAM, SAW, WASPAS, GRA, and MOORA methods is then analyzed using Spearman's correlation coefficient to measure how well and consistently the ranking results relate to each other. The Spearman correlation value is used to determine how much the changes in alternative positions in one method follow a similar pattern to the others, with values closer to 1 indicating a stronger ranking relationship[34]–[36]. The results of the correlation calculations between methods are then presented in the form of a correlation matrix in Figure 5, so the consistency and similarity of ranking patterns between methods can be analyzed more clearly.

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

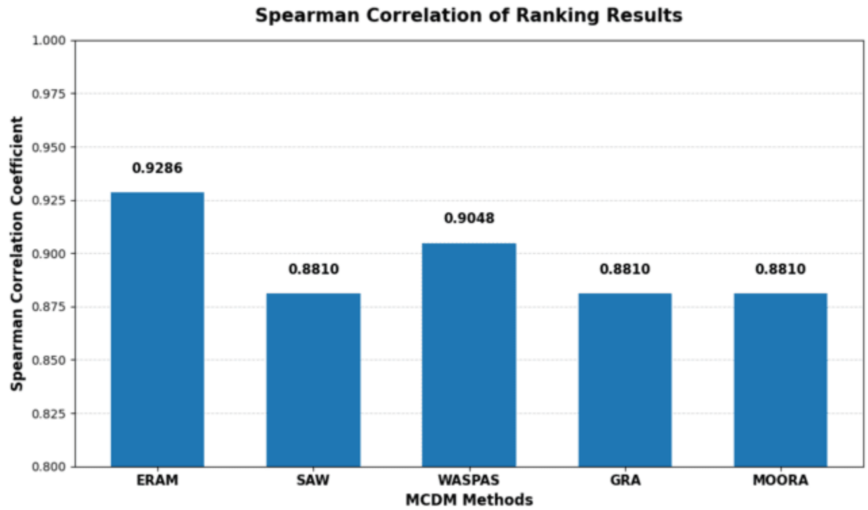

Figure 5. Comparison of Correlation Values

The comparison results show the Spearman correlation values between the rankings produced by the ORI method and the ERAM, SAW, WASPAS, GRA, and MOORA methods. The results indicate that ERAM has the highest correlation value at 0.9286, followed by WASPAS at 0.9048, while SAW, GRA, and MOORA each scored 0.8810. All correlation values are above 0.88, showing a very strong and consistent ranking relationship between ORI and the other methods. This finding suggests that changes in the alternative positions in ORI generally follow a similar pattern to the other methods, with ERAM showing the-highest ranking agreement.

3.5. Discussion

The comparative results reveal a pronounced and structurally consistent preference pattern among the evaluated store location alternatives. SLOC-5 emerges as the most preferred alternative, followed by SLOC-3 and SLOC-8, and this ordering is consistently reproduced across the evaluated MCDM approaches. This consistency is particularly noteworthy because the alternatives are assessed across criteria with heterogeneous measurement characteristics and opposing preference directions, where Rental Cost is treated as a cost criterion while the remaining criteria represent benefits. The persistent superiority of SLOC-5 can be attributed to its relatively strong performance across several benefit-oriented dimensions, particularly Building Area, Consumer Traffic, Parking Availability, and Infrastructure. More importantly, its favorable aggregate performance remains sufficient to compensate for its relatively less advantageous rental cost. This finding indicates that the ranking is not driven by a single criterion but rather reflects the cumulative interaction of multiple performance dimensions. From a decision-making perspective, the stable dominance of SLOC-5 suggests that its selection is structurally supported by the dataset and is therefore less likely to be an artifact of a particular ranking mechanism.

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

Despite the strong agreement among the leading alternatives, moderate ranking variations are observed for alternatives occupying the middle and lower positions. In particular, SLOC-1 and SLOC-6 exhibit changes in their relative positions, while SLOC-2, SLOC-7, and SLOC-4 also demonstrate differences depending on the applied MCDM approach. These variations are methodologically meaningful because they reflect how alternative decision-making procedures respond to differences in criterion values and relative performance. Methods such as SAW, WASPAS, GRA, MOORA, and ERAM employ distinct normalization and aggregation mechanisms, which can alter the relative contribution of criteria when alternatives have comparable performance profiles. Consequently, small differences in criterion performance may become sufficient to change the ordering of closely competing alternatives. Conversely, the absence of substantial changes among the top-ranked alternatives suggests that their performance separation is sufficiently pronounced to withstand methodological differences. This distinction between stable and sensitive alternatives provides an important insight: methodological disagreement is concentrated primarily in marginal cases, whereas the identification of the most competitive alternatives remains comparatively robust.

The Spearman correlation analysis provides quantitative evidence supporting the observed consistency of the ranking structure. The correlation between ORI and ERAM reaches 0.9286, while WASPAS produces a correlation of 0.9048 and SAW, GRA, and MOORA each achieve 0.8810. Rather than interpreting these coefficients merely as numerical indicators of similarity, their magnitude demonstrates that the relative ordering of alternatives is largely preserved across fundamentally different MCDM procedures. The particularly high association between ORI and ERAM indicates that ERAM reproduces the reference preference structure with the greatest degree of concordance among the evaluated approaches. This result is important because rank correlation evaluates the ordering relationship rather than absolute score similarity; consequently, a high coefficient indicates that alternatives tend to move in a consistent directional pattern across methods. The relatively small differences between the correlation coefficients further suggest that the dataset contains an underlying preference structure that is sufficiently strong to be captured by multiple MCDM formulations. Nevertheless, the correlation results should be interpreted as evidence of ranking agreement rather than evidence that one method is intrinsically more accurate than another.

The findings from the sensitivity analysis provide an additional dimension of validation by examining whether the ranking structure persists under perturbations of the criterion weights. The results demonstrate that moderate weight variations of ±0.05 do not substantially disrupt the overall ordering, particularly for the leading alternatives. SLOC-5 and SLOC-3 remain consistently positioned at the top, while only limited positional exchanges occur among alternatives with relatively close performance. The most pronounced changes are observed between SLOC-4 and SLOC-7, which alternate between the final ranking positions under

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

several scenarios. This behavior is theoretically consistent with the principle that alternatives with similar aggregate performance are more susceptible to changes in preference weights than alternatives with clearly superior or inferior profiles. More broadly, the coexistence of high inter-method correlation and ranking stability under weight perturbations provides convergent evidence of methodological robustness. The results therefore suggest that ERAM is not excessively dependent on a narrowly defined weight configuration and can maintain a relatively stable preference structure under moderate uncertainty in criterion importance. Such robustness is particularly relevant in practical MCDM environments, where criterion weights are often subject to expert judgment and may inherently contain a degree of uncertainty.

The results have direct implications for strategic store location selection because they provide not only a prioritized alternative but also an indication of the confidence associated with that prioritization. The persistent identification of SLOC-5 as the leading alternative across different MCDM approaches and sensitivity scenarios strengthens its position as the most defensible candidate within the examined decision environment. This consistency is practically important because location selection involves substantial long-term commitments, and decisions based on rankings that are highly sensitive to methodological assumptions may expose decision makers to additional uncertainty. SLOC-3 and SLOC-8 can consequently be regarded as viable secondary options because their favorable positions are also maintained across alternative evaluation procedures. Conversely, the lower-ranked alternatives should not necessarily be interpreted as inherently unsuitable; rather, their positions indicate comparatively weaker aggregate performance under the current criterion structure and weighting configuration. Decision makers may therefore use the ranking results as a screening mechanism, followed by more detailed feasibility assessments involving financial, operational, geographic, and strategic considerations that may not be fully represented in the current dataset.

The principal contribution of this study is the provision of a multidimensional evaluation of ERAM that extends beyond conventional ranking-based validation. By integrating comparative analysis with Spearman rank correlation and sensitivity analysis, the study evaluates ERAM from complementary perspectives of inter-method agreement and parameter robustness. The high correlation with established MCDM approaches, together with the stability observed under moderate weight perturbations, provides empirical support for the consistency of the proposed method in the examined store location problem. Nevertheless, several limitations should be acknowledged. First, the empirical evaluation is based on a single dataset comprising eight alternatives and six criteria, which limits the extent to which the findings can be generalized to other decision environments. Second, the use of a fixed criterion structure and weighting configuration may not fully capture the uncertainty and subjectivity inherent in real-world location selection. Third, strong rank correlation should not be equated with methodological superiority, as correlation measures agreement in

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

ordering rather than predictive accuracy or decision quality. Future research should therefore test ERAM across larger and heterogeneous datasets, different domains, alternative weighting strategies, and additional robustness and statistical validation procedures. Such extensions would provide stronger evidence regarding the generalizability, discriminatory capability, and practical effectiveness of ERAM in complex MCDM applications.

IV. Conclusion

This study proposed the Enhanced Root Assessment Method (ERAM) as an alternative MCDM framework for addressing decision problems involving heterogeneous benefit and cost criteria. The proposed framework integrates normalization, weighted assessment, benefit-penalty balancing, and root-based assessment to provide a more structured mechanism for evaluating alternative performance. The main contribution of this study is the development of an enhanced root-based assessment framework that explicitly balances positive and negative criterion contributions and incorporates an Enhanced Root Assessment Index to improve the consistency and interpretability of multi-criteria rankings. The findings indicate that ERAM can maintain a consistent preference structure under moderate changes in criterion weights and demonstrates strong agreement with established MCDM approaches.

The study confirms that combining root-based assessment with explicit consideration of positive and negative contributions can provide a balanced and interpretable approach to multi-criteria evaluation. The integration of comparative and sensitivity analyses also strengthens the evaluation of ERAM by examining both ranking consistency and robustness rather than relying solely on the final ranking. However, the validation is limited to a single dataset and decision context. Future research should therefore investigate ERAM using larger datasets, different domains, alternative weighting techniques, and additional robustness measures to further establish its generalizability and practical effectiveness.

CRediT Authorship Contribution Statement

Aditya Lapu Kalua: Conceptualization, Methodology, Writing – Original Draft Preparation, Writing – Review & Editing. **Angreine Kewo:** Formal analysis, Writing – Original Draft Preparation, Writing – Review & Editing. **Susi Hendartie:** Investigation, Validation, Writing – Original Draft Preparation. **Yampi R Kaesmetan:** Investigation, Software, Writing – Original Draft Preparation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

Funding Statements

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Declaration of Generative AI and AI-assisted Technologies in The Writing Process

The authors used Generative AI to improve the writing clarity of this paper. They reviewed and edited the AI-assisted content and take full responsibility for the final publication.

References

[1] D. A. Megawaty *et al.*, "DAM Weighting: A New Approach to Determining Criteria Weighting in Multi-Criteria Decision Making," *Evergreen*, vol. 13, no. 2, pp. 788–800, 2026, doi: 10.5109/7432655.

[2] Z. Liu *et al.*, "An integrated cubic Pythagorean fuzzy MAIRCA model with novel variation coefficient similarity measure for food safety risk assessment," *Sci. Rep.*, vol. 16, no. 1, p. 11323, 2026, doi: 10.1038/s41598-026-39302-z.

[3] Y. Djeddi, "Hybrid Solution (HYBSO) based on Hybrids Normalization and Aggregation for the Multi-criteria Decision-Making Problems," *Yugosl. J. Oper. Res.*, vol. 36, no. 1, pp. 1–24, 2026, doi: 10.2298/YJOR241020020D.

[4] S. Bošković, L. Švadlenka, M. Dobrodolac, S. Jovčić, and M. Zanne, "An Extended AROMAN Method for Cargo Bike Delivery Concept Selection," *Decis. Mak. Adv.*, vol. 1, no. 1, pp. 1–9, Jun. 2023, doi: 10.31181/v120231.

[5] M. S. Saidin, L. S. Lee, S. M. Marjugi, M. Z. Ahmad, and H.-V. Seow, "Fuzzy Method Based on the Removal Effects of Criteria (MEREC) for Determining Objective Weights in Multi-Criteria Decision-Making Problems," *Mathematics*, vol. 11, no. 6, p. 1544, Mar. 2023, doi: 10.3390/math11061544.

[6] T. Oztas and G. Z. Oztas, "Innovation Performance Analysis of G20 Countries: A Novel Integrated LOPCOW-MAIRCA MCDM Approach Including the COVID-19 Period," *Veriml. Derg.*, pp. 1–20, Jan. 2024, doi: 10.51551/verimlilik.1320794.

[7] S. Dhruva, R. Krishankumar, E. K. Zavadskas, K. S. Ravichandran, and A. H. Gandomi, "Selection of Suitable Cloud Vendors for Health Centre: A Personalized Decision Framework with Fermatean Fuzzy Set, LOPCOW, and CoCoSo," *Informatica*, vol. 35, no. 1, pp. 65–98, Nov. 2024, doi: 10.15388/23-INFOR537.

[8] K. Kara, G. Cihan Yalçın, V. Simic, A. Tuğrul Yıldırım, D. Pamucar, and P. Siarry, "A spherical fuzzy-based DIBR II-AROMAN model for sustainability performance benchmarking of wind energy power plants," *Expert Syst. Appl.*, vol. 253, p. 124300, 2024, doi: 10.1016/j.eswa.2024.124300.

[9] M. Arshad, H. Sulistiani, S. Maryana, P. Palupiningsih, Y. Rahmanto, and S. Setiawansyah, "Modification of the Grey Relational Analysis Method in Determining the Best Mechanic," *Build. Informatics, Technol. Sci.*, vol. 6, no. 3 SE-Articles, Dec. 2024, doi: 10.47065/bits.v6i3.5678.

Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

[10] B. Yagmahan and H. Yılmaz, "An integrated ranking approach based on group multi-criteria decision making and sensitivity analysis to evaluate charging stations under sustainability," *Environ. Dev. Sustain.*, vol. 25, no. 1, pp. 96–121, 2023, doi: 10.1007/s10668-021-02044-1.
[11] K. Subramani, D. Nithyanandham, F. Augustin, S. Ramasamy, A. P. Paulose, and P. V, "An integrated picture fuzzy entropy-MAIRCA-TOPSIS framework for sustainable soil suitability evaluation," *Int. J. Appl. Earth Obs. Geoinf.*, vol. 152, p. 105474, 2026, doi: 10.1016/j.jag.2026.105474.
[12] G. Demir, P. Chatterjee, and D. Pamucar, "Sensitivity analysis in multi-criteria decision making: A state-of-the-art research perspective using bibliometric analysis," *Expert Syst. Appl.*, vol. 237, p. 121660, 2024, doi: 10.1016/j.eswa.2023.121660.
[13] A. Jusufbašić, "MCDM Methods for Selection of Handling Equipment in Logistics: A Brief Review," *Spectr. Eng. Manag. Sci.*, vol. 1, no. 1 SE-Articles, pp. 13–24, Aug. 2023, doi: 10.31181/sems1120232j.
[14] G. N. Yücenur and A. Maden, "Sequential MCDM methods for site selection of hydroponic geothermal greenhouse: ENTROPY and ARAS," *Renew. Energy*, vol. 226, p. 120361, 2024, doi: 10.1016/j.renene.2024.120361.
[15] T. Van Dua, D. Van Duc, N. C. Bao, and D. D. Trung, "Integration of objective weighting methods for criteria and MCDM methods: application in material selection," *EUREKA Phys. Eng.*, no. 2, pp. 131–148, Mar. 2024, doi: 10.21303/2461-4262.2024.003171.
[16] S. Biswas, B. Biswas, and K. Mitra, "A Novel Group Decision Making Model to Compare Online Shopping Platforms," *Spectr. Decis. Mak. Appl.*, vol. 2, no. 1, pp. 1–27, Aug. 2024, doi: 10.31181/sdmap2120259.
[17] M. Ramesh, D. J. D. James, S. Mohan, and K. Panneerselvam, "Evaluation and study of PBI reinforced with HDPE on abrasive wear using ANOVA and CODAS approach for protective shell applications," *J. Pipeline Sci. Eng.*, p. 100279, 2025, doi: 10.1016/j.jpse.2025.100279.
[18] D. T. Do, "Assessing the Impact of Criterion Weights on the Ranking of the Top Ten Universities in Vietnam," *Eng. Technol. Appl. Sci. Res.*, vol. 14, no. 4, pp. 14899–14903, Aug. 2024, doi: 10.48084/etasr.7607.
[19] A. Sotoudeh-Anvari, "Root Assessment Method (RAM): A novel multi-criteria decision making method and its applications in sustainability challenges," *J. Clean. Prod.*, vol. 423, p. 138695, Oct. 2023, doi: 10.1016/j.jclepro.2023.138695.
[20] D. Trung, D. Duc, N. Bao, and D. Thuy, "Using the root assessment method to choose the optimal solution for mushroom cultivation," *Yugosl. J. Oper. Res.*, no. 00, pp. 7–7, 2024, doi: 10.2298/YJOR240115007T.
[21] A. Yudhistira, S. Setiawansyah, T. Ardiansah, S. Maryana, Y. Yadin, and R. Oktaviani, "Development of Multi-Attribute Utility Theory Methods in Dynamic Decision Models Using Change-Data Driven," *Evergreen*, vol. 11, no. 4, pp. 3279–3289, Dec. 2024, doi: 10.5109/7326962.
[22] D. A. Megaraty, H. Sulistiani, Setiawansyah, A. Qurania, Y. Yadin, and R. Oktaviani, "Integration Method Based on the Removal Effects of Criteria Weighting and MOORA Method: Wi-Fi Router Selection Case Study," in *2024 International Conference on Informatics, Multimedia, Cyber and Information System (ICIMCIS)*, 2024, pp. 241–246. doi: 10.1109/ICIMCIS63449.2024.10956545.
[23] R. D. Gunawan, M. W. Arshad, A. D. Wahyudi, R. R. Suryono, T. Widodo, and F. Ulum, "Modification of Additive Ratio Assessment Method through Distance-Based Weighting Approach for Optimizing Assessment Accuracy," *Paradig. - J. Komput. dan Inform.*, vol. 27, no. 2, pp. 55–64, 2025, doi: 10.31294/p.v27i2.8810.

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6

Volume 1 Number 2 March 2027, Available online: March 20, 2027.
Journal of Decision Support Systems and Multi-Criteria Decision Making
ISSN: 3164-7022
Page 140-163
Journal Homepage: https://research.pilar.or.id/index.php/jodesma

[24] M. Wu, J. Song, and J. Fan, "Three-way decision based on ITARA and public weights DEA under picture fuzzy environment and its application in new energy vehicles selection," *Complex Intell. Syst.*, vol. 10, no. 1, pp. 927–947, 2024, doi: 10.1007/s40747-023-01188-z.
[25] J. Hallak, "Optimizing construction supplier selection in conflict-affected regions: a hybrid multi-criteria framework," *Oper. Manag. Res.*, vol. 17, no. 4, pp. 1270–1294, 2024, doi: 10.1007/s12063-024-00505-0.
[26] A. L. Olteanu (Burcă) *et al.*, "Prioritizing the European Investment Sectors Based on Different Economic, Social, and Governance Factors Using a Fuzzy-MEREC-AROMAN Decision-Making Model," *Sustainability*, vol. 16, no. 17. 2024. doi: 10.3390/su16177790.
[27] A. Shekhovtsov, B. Kizielewicz, and W. Sałabun, "The universal library for solving multi-criteria decision-making problems," *SoftwareX*, vol. 24, p. 101519, 2023, doi: 10.1016/j.softx.2023.101519.
[28] D. Desyanti, I. Ahmad, and S. Sanusi, "Assessing Microcredit Eligibility Using LOGSTA Weighting and Comprehensive Distance-Based Ranking: A Multi-Criteria Decision-Making Approach," *J. Comput. Data Sci.*, vol. 1, no. 1, pp. 1–31, doi: 10.67449/jcoda.v1i1.1.
[29] A. Puška, D. Božanić, Z. Mastilo, and D. Pamučar, "Extension of MEREC-CRADIS methods with double normalization-case study selection of electric cars," *Soft Comput.*, vol. 27, no. 11, pp. 7097–7113, 2023, doi: 10.1007/s00500-023-08054-7.
[30] A. Katrancı, N. Kundakcı, and D. Pamucar, "Financial performance evaluation of firms in BIST 100 index with ITARA and COBRA methods," *Financ. Innov.*, vol. 11, no. 1, p. 34, 2025, doi: 10.1186/s40854-024-00704-5.
[31] S. Maniyan, R. Ghousi, and A. Haeri, "Data mining-based decision support system for educational decision makers: Extracting rules to enhance academic efficiency," *Comput. Educ. Artif. Intell.*, vol. 6, p. 100242, 2024, doi: 10.1016/j.caeai.2024.100242.
[32] S. H. Gurmani, S. Zhang, F. A. Awwad, and E. A. A. Ismail, "Combinative distance-based assessment method using linguistic T-spherical fuzzy aggregation operators and its application to multi-attribute group decision-making," *Eng. Appl. Artif. Intell.*, vol. 133, p. 108165, 2024, doi: 10.1016/j.engappai.2024.108165.
[33] J. Więckowski and W. Sałabun, "Supporting multi-criteria decision-making processes with unknown criteria weights," *Eng. Appl. Artif. Intell.*, vol. 140, p. 109699, 2025, doi: 10.1016/j.engappai.2024.109699.
[34] D. Tiwari and V. Soni, "Multi-response optimization in the ORC-VCR system using the EDAS Method," *Energy Build.*, vol. 313, p. 114281, 2024, doi: 10.1016/j.enbuild.2024.114281.
[35] M. I. Takaendengan, "Performance Comparison of Multi-Criteria Decision-Making Methods in Decision Support Systems," *J. Comput. Data Sci.*, vol. 1, no. 1, pp. 88–108, 2026, doi: 10.67449/jcoda.v1i1.5.
[36] G. Patel, S. Das, and R. Das, "Evaluation of optimal normalization techniques in multi-criteria decision-making to rank CMIP6 climate models," *Theor. Appl. Climatol.*, vol. 156, no. 7, p. 385, 2025, doi: 10.1007/s00704-025-05617-6.

DOI: https://doi.org/10.67449/jodesma.v1i2.6

Article Link: https://research.pilar.or.id/index.php/jodesma/article/view/6