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An Application on Enterprise Resource Planning (ERP) Selection with Multi-Criteria Decision-Making Methods

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Abstract

Enterprise Resource Planning (ERP) systems play a crucial role in modern company operations, integrating different functions such as supply chain, customer relations, human resources and finance into an adhesive system. The selection of an appropriate ERP system is a critical and complex decision that impacts an organization's efficiency and competitiveness. This study utilizes the Entropy and Multi-MOORA (Multi-Objective Optimization by Ratio Analysis) multi-criteria decision-making methods to evaluate ERP systems based on six criteria: cost, functionality, user-friendliness, reliability, technical support, and integration capability. Three ERP alternatives are assessed to define the most suitable system for a manufacturing company aiming to optimize its production and inventory management. The Entropy method objectively determines the weights of the criteria, while the Multi-MOORA method ranks the ERP alternatives. This comprehensive and unbiased selection process underscores the importance of a systematic approach in ERP system evaluation. By leveraging advanced decision-making techniques, organizations can make informed choices that enhance operational efficiency, drive innovation, and maintain a competitive edge. The study highlights the critical role of ERP systems and the necessity of using robust evaluation methods to ensure the selected system aligns with the organization's strategic goals and operational needs.

Keywords: Enterprise Resource Planning, Entropy Method, Multi-Criteria Decision-Making, Multi-MOORA Method

1. Introduction

In today's fast-changing business environment, choosing an Enterprise Resource Planning (ERP) system has become a crucial decision for companies aiming to stay competitive. The complexity of this decision is compounded by the myriad of criteria that must be considered, ranging from cost and reliability to compatibility and usability. As businesses expand and diversify, the integration of comprehensive ERP systems is crucial to streamline operations and enhance overall efficiency [1].

The process of selecting an ERP system is fraught with challenges, particularly in ensuring that the chosen system aligns with the strategic goals and operational needs of the organization. Various decision-making methods have been developed to aid in this process, including the use of fuzzy logic and Multicriteria Decision-making (MCDM) approaches. The application of these methods helps in systematically evaluating and comparing different ERP solutions based on a set of predefined criteria [2].

In the context of this study, the focus is on the application of the Entropy-based MOORA method for ERP selection. This method provides a robust framework for handling the inherent uncertainties and subjectivities in the decision-making process. By incorporating both quantitative and qualitative criteria, the Multi-MOORA method offers a comprehensive evaluation of potential ERP systems, ensuring that the selected system meets the specific needs of the organization [3].

The case study presented in this research involves a bearing company seeking to select the most suitable ERP system from a set of alternatives. The decision-making process involves several steps, starting with the identification of relevant criteria and the evaluation of alternatives. The final selection is made based on the weighted scores of each alternative, derived from the MOORA method. This approach not only facilitates a more objective comparison of ERP systems but also enhances decision-making efficiency by reducing the complexity associated with traditional selection methods [4] We chose the Entropy method for its ability to objectively determine criteria weights based on the data, reducing subjectivity in the decision-making process. Multi MOORA was selected for its simplicity and effectiveness in ranking alternatives across multiple criteria. Together, these methods provide a robust and transparent framework for ERP selection.

2. Literature Review

In this section, studies conducted using the Entropy and Multi-MOORA methods are mentioned.

Entropy-based methods are widely utilized in MCDM due to their ability to handle uncertainty and provide objective weightings for criteria. Boroushaki [5] integrates Entropy-based weights with a modified TOPSIS algorithm within a GIS-based MCDM to address spatial decision-making problems where exact numerical judgments are difficult. Kasim and Jemain (2020) highlight the use of probability density functions in computing the Entropy of criteria, leading to more valid outcomes in resolving MCDM problems. Yang et al. [6] suggested the exponential probabilistic hesitant fuzzy entropy as a new fuzzy entropy for probabilistic hesitant fuzzy sets, aiding in MCDM using the TODIM method, demonstrated in a green building application.

Zhiyuan [7] discusses the Entropy method in evaluation systems based on multiple attributive decision theory, highlighting its superiority in solving index weighting problems compared to other methods. Rao et al. [8] present a hybrid MCDM method based on relative Entropy weight and projection algorithm, integrating interval numbers, linguistic fuzzy numbers, and incomplete information on attribute weights. Wang and Chen [9] introduce an Entropy metric for computing the diversity of Mult objective optimization algorithms, serving as an efficient diversity criterion. Xiao and Fu [10] utilize a three-parameter interval grey number approach based on information Entropy in a TOPSIS-based uncertainty decision-making framework to determine optimal solutions for problems with indeterminate attribute weight. Garg et al. [11] use Entropy functions to find attribute weight vectors for MCDM under uncertain conditions. Suri et al. [12] propose a novel Entropy measure for q-row orthopair fuzzy sets, aiding in MCDM problems.

Hua [13] applies the weighted moving average Entropy method to rank stocks, demonstrating its effectiveness in the decision-making process of value investment. Rani and Jain [14] use the Entropy method in the Intuitionistic Fuzzy PROMETHEE Technique for MCDM problems. The Entropy technique for fuzzy information decision-making is covered by LiYi et al. [15]. It involves utilizing Entropy, triangular fuzzy numbers, and closeness degree to determine the best way to evaluate various proposals. Abbas [16] discusses methods based on the maximum Entropy principle to obtain joint probability distributions in decision analysis.

Grendár [17] presents the Empirical Maximum Entropy method, a special nonparametric case of the Maximum Entropy Empirical Likelihood method. Sogawa et al. [18] evolved the multivariate maximum Entropy distribution for hydrologic frequency analysis, comparing it to Pearson's system of frequency curves.

The Multi-MOORA method has been extensively utilized in various fields of multicriteria decision-making. The method is applied for water resources planning, providing optimal solutions based on different indicators and criteria from multiple stakeholders Brauers [19]. Kundakçı [20] combines the MACBETH method for determining criteria weights with the MULTIMOORA method for final alternative ranking in decision-making scenarios. Anantama and Hidayat [21] compare the performance of deep learning and MOORA methods in selecting the best public health center, with MOORA achieving 95.75% accuracy.

Sarkar and Biswas [22] introduce a Pythagorean fuzzy multicriteria decision-making method, PFMULTIMOORA, to address deficiencies in existing methods by incorporating unknown criteria weights using an Entropy weight model. Lestari et al. [23] use the MOORA method to determine the best employees in a company, aiding in effective employee motivation. Ulfah and Hasugian [24] utilize MOORA in a decision support system for selecting healthy toddlers, based on various health criteria. Liang et al. [25] present an enhanced MULTIMOORA method using interval-valued Pythagorean fuzzy sets for robust decision-making. Perbawa [26] employs MOORA in a decision support system to rank alternatives for selecting recipients of the Smart Indonesia Program.

Trung [27] uses multiple MCDM methods including MOORA for determining optimal cutting parameters in the milling process. Krishna et al. [28] integrate MOORA with COPRAS and Entropy methods to select the best experiment in turning Nimonic C263 alloy. Ekmis et al. [29] compare Multi-MOORA with traditional univariate approaches for selecting products in an e-commerce marketplace. Uma and Geetha [30] propose an integrated MCDM model using MOORA for ranking cloud service providers based on criteria weights obtained through the Full Consistency Method. Osintsev [31] applies various MCDM methods, including MOORA, for ranking management decisions in transport and logistics.

Başaran and Tarhan [32] use MOORA to select suitable locations for offshore wind turbines in Turkey. Mathew and Sahu [33] compare new MCDM methods, including MOORA, for material handling equipment selection. Özekenci [34] evaluates the export performance of metropolitan cities in Turkey using integrated MCDM methods, including MOORA. Prajapati and Patel [35] optimize process parameters of abrasive water jet machining using MCDM methods, highlighting MOORA's applicability. The effectiveness of MOORA in various decision-making contexts underscores its versatility and robustness.

3. Entropy and Multi-MOORA Methods

In this section, the methods used in the study are explained in detail.

3.1 Entropy Methodology

The Entropy method is a powerful tool in MCDM used to determine the weight of criteria based on the amount of information each criterion provides. It quantifies the uncertainty or diversity inherent in a set of data. In MCDM, the Entropy method helps to objectively assign weights to criteria, avoiding the biases that can come from subjective judgment Chodha et al. [36].

Steps of the Entropy Method

Step 1: The first step in applying the Entropy method is to normalize the decision matrix. This is done to ensure that all criteria are comparable, typically using the following formula for normalization:

Normalized Value

$(R_{ij}) = X_{ij}$ / sum (X_{ij}) **(1)**

for benefit criteria

(R_{ij}) = min $(X_{ij}) / X_{ij}$ **(2)**

for cost criteria

where X_{ij} is the original value of the j_{th} criterion for the i_{th} alternative.

Step 2: The Entropy value for each criterion is calculated to measure the disorder or uncertainty associated with it. The formula to calculate the Entropy (E_j) for each criterion is:

E_j = k*sum $(R_{ij}$*ln $(R_{ij}))$ **(3)**

where k is a constant equal to $1/ln_m$ (m is the number of alternatives), and R_{ij} is the normalized value of the i_{th} alternative for the j_{th} criterion.

Step 3: The degree of divergence (d_j) for each criterion is calculated next. It represents the level of useful information provided by each criterion and is computed as:

$d_j = 1\text{-}E_j$ **(4)**

where E_j is the Entropy of the j_{th} criterion.

Step 4: Finally, the weights (w_j) for each criterion are determined using the degree of divergence. The weight for each criterion is calculated as:

$w_j = d_j$ / sum(d_j) **(5)**

3.2 Multi-MOORA Methodology

A useful tool in mixed-criteria decision-making is the Multi-MOORA method, which combines numerous techniques to assess and prioritize options according to a variety of factors. To improve decision-making precision, it combines the reference point approach and the MOORA method. According to Karande and Chakraborty [37], the Multi-MOORA technique is well-known for its adaptability, robustness, and simplicity in handling both qualitative and quantitative data.

Steps of the Multi-MOORA Method

Step 1: The first step involves constructing the decision matrix, which includes the alternatives and criteria. Each element of the matrix represents the performance value of an alternative concerning a specific criterion.

Step 2: Normalization is performed to make criteria comparable. This is done using the following formula:

Normalized Value $(R_{ij}) = X_{ij}$ / sqrt (sum (X_{ij}^2)) **(6)**

where X_{ij} is the original value of the j_{th} criterion for the i_{th} alternative.

Step 3: In the ratio system approach, the normalized values are used to calculate the overall performance of each alternative. The performance score (P_i) for each alternative is calculated as:

P_i = sum $(w_j$*$R_{ij})$ for benefit criteria - sum $(w_j$*$R_{ij})$ for cost criteria **(7)**

where w_j is the weight of the j_{th} criterion, and R_{ij} is the normalized value.

Step 4: In the reference point approach, the normalized values are compared to a reference point to determine the distance of each alternative from the ideal solution. The reference point (R_j) for each criterion is often the best value among all alternatives. The distance (D_i) is calculated as:

$$D_i = \text{sqrt}(\text{sum}((R_{ij} - R_j)^2)) \quad \textbf{(8)}$$

where R_{ij} is the normalized value and R_j is the reference point for the j_{th} criterion.

Step 5: The full multiplicative form combines the ratio system and reference point approaches. It calculates a composite score for each alternative by multiplying the normalized values for benefit criteria and dividing by the normalized values for cost criteria. The composite score (C_i) is:

$$C_i = (\text{Product of normalized values for benefit criteria}) / (\text{Product of normalized values for cost criteria}) \quad \textbf{(9)}$$

Step 6: Finally, the results from the ratio system, reference point approach, and full multiplicative form are aggregated to determine the final ranking of alternatives. The alternative with the best aggregate score is considered the optimal choice.

The Entropy method is advantageous for its objectivity in determining criteria weights from data, but it can be sensitive to variations in data quality. Multi MOORA offers simplicity and efficiency in handling multi-criteria decision-making, though it may not fully capture complex interactions between criteria. Together, they provide a balance between objectivity and ease of use. However, their combined use may require careful interpretation to ensure accurate decision-making.

4. ERP Selection using Entropy-based Multi-MOORA Method

In this section, the problem addressed in the study is mentioned. First, general information about the problem is given. Afterwards, the steps of the Entropy method are given. Finally, the steps of the Multi-MOORA method are given.

4.1 Problem Definition

A manufacturing business plans to choose an ERP system to optimize production planning and inventory management. This business aims to ensure the integration of the ERP system into production processes, its effectiveness in supply chain management, and the timely fulfillment of customer orders. At the same time, the cost of the ERP system must not exceed their budget and must be compatible with the existing information technology infrastructure. At this point, business management is considering using MCDM methods in the evaluation and selection of ERP systems. These methods will help determine the most suitable ERP system, considering various criteria such as cost, functionality, user-friendliness, reliability, technical support, and integration capability. In the study, a purchasing expert and two IT experts took part as decision-makers. These three decision-makers decided on the criteria in line with the needs. The flowchart of the problem is given in Figure 1. In this study, a solution to this problem faced by the business was sought by considering Entropy and Multi-MOORA methods. Explanations of these criteria used in the study are as follows.

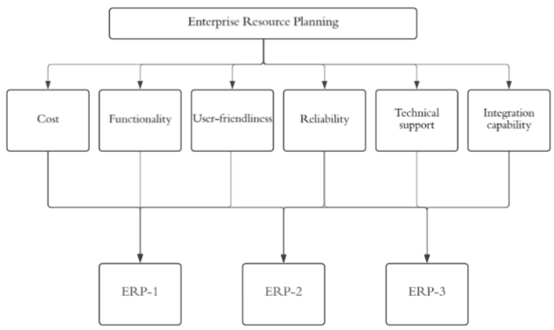

Figure 1: The flowchart of the problem

Cost (K_1): The cost of an ERP system is a critical factor in the selection process. This includes not only the initial purchase price but also implementation ongoing maintenance expenses, costs, and licensing fees. Organizations must consider their budget constraints and evaluate the total cost of ownership over the system's lifecycle. A cost-effective ERP solution should provide significant value without exceeding financial limitations, ensuring a good return on investment.

Functionality (K_2): This criterion refers to the range of features and capabilities an ERP system offers. All essential corporate operations, including customer relationship management, accounting, inventory control, and human resources must be supported by the system of choice. The functionality should align with the organization's specific requirements and goals. Comprehensive functionality ensures that the ERP system can address current needs and scale with future growth and changes in business operations.

User-friendliness(K_3): User-friendliness is a crucial criterion, as it impacts the ease of use and adoption of the ERP system by employees. A user-friendly ERP system should have an intuitive interface, clear navigation, and accessible documentation and training resources. A system that is simple to use minimizes errors, lowers learning curves, and boosts overall productivity. Ensuring that the ERP system is user-friendly can significantly enhance employee satisfaction and efficiency.

Reliability (K_4): This criterion in an ERP system means that it performs consistently and is dependable under various conditions. A reliable system should have minimal downtime, quick recovery from failures, and robust security features to protect sensitive data. The reliability of an ERP system is critical for maintaining continuous business operations and ensuring data integrity. Choosing a reliable ERP system helps prevent operational disruptions and instills confidence in the system's performance.

Technical support (K_5): Technical support encompasses the assistance provided by the ERP vendor in terms of implementation, maintenance, and troubleshooting. Adequate technical support includes comprehensive training, regular updates, and responsive customer service. Reliable technical support ensures that any issues are promptly addressed, minimizing operational disruptions. Organizations should evaluate the quality and availability of technical support services to ensure smooth and effective use of the ERP system.

Integration capability (K_6): Integration capability refers to the ERP system's ability to seamlessly connect with existing software and hardware within the organization. Effective integration allows for the smooth flow of data across different systems, reducing redundancy and improving data accuracy. An ERP system with strong integration capabilities can streamline business processes and enhance overall efficiency. It is essential to choose an ERP system that can integrate well with current and future technologies to support the organization's evolving needs.

4.2 Entropy Application Phase

In this section, the procedural steps for determining criterion weights are detailed. Initially, the decision-maker constructed a decision matrix for the criteria weights, expressing their relative importance levels as shown in Table 1. The criterion weights derived from the Entropy calculation results are presented in Table 2.

Table 1: Decision Values

ERP Alternatives	K_1	K_2	K_3	K_4	K_5	K_6
ERP-1	15	55	50	45	55	50
ERP-2	90	80	75	85	90	100
ERP-3	55	75	70	60	80	70

Table 2: Entropy Weight Values

Criteria	K_1	K_2	K_3	K_4	K_5	K_6
Weight	0,60	0,040	0,04	0,110	0,065	0,12

4.3 Multi-MOORA Application Phase

To apply the Multi-MOORA method, a decision metric is first required that includes the evaluation of each criterion and alternative. This matrix has been completed by the business manager and is provided in Table 3. Each value in the decision matrix was initially squared, followed by summing these squared values and taking their square root. This procedure was iteratively applied to each column, and the outcomes are presented in Table 4.

Table 3: Decision Matrix for Multi-MOORA Method

Criteria	Weights	ERP-1	ERP-2	ERP-3
K_1	0,6088	15	90	55
K_2	0,0404	55	80	75
K_3	0,0470	50	75	70
K_4	0,1100	45	85	60
K_5	0,0657	55	90	80
K_6	0,1281	50	100	70

Table 4: Normalization Process Results

Criteria	ERP 1	ERP 2	ERP 3	Sum	Square
K_1	2,25	8,10	3,02	11,35	106,5
K_2	3,02	6,40	5,62	15,05	122,6
K_3	2,50	5,62	4,90	13,02	114,1
K_4	2,02	7,22	3,60	12,85	113,3
K_5	3,02	8,10	6,40	17,52	132,3
K_6	2,50	10,0	4,90	17,40	131,9

The values obtained in Table 4 represent the initial step of normalizing the decision matrix. To complete the normalization process, each value in Table 3 should be divided by the corresponding value in Table 4. This division process was applied individually to each matrix value, and the outcomes are presented in Table 5. The results of the Ratio, Reference, and Importance of Objectives approaches, along with dominance values used in solving the ERP selection problem using the Multi-MOORA method, are presented in Table 6.

Table 5: Normalized Matrix

Criteria	ERP-1	ERP-2	ERP-3
K_1	0,1408	0,8448	0,5163
K_2	0,4483	0,6521	0,6114
K_3	0,0200	0,0300	0,0280
K_4	0,3970	0,7498	0,5293
K_5	0,4155	0,6799	0,6043
K_6	0,3790	0,7581	0,5307

Table 6: Overall Results

Criteria	ERP-1	ERP-2	ERP-3
Ratio	3	1	2
Reference	1	2	3
Importance of the objectives	1	3	2
Multi-MOORA	**1**	3	2

5. Conclusion

ERP systems, which provide a comprehensive solution for managing a variety of organizational functions, are essential to modern business operations. Finance, HR, supply chain, and customer interactions are just a few of the areas that are combined into a single, seamless system, ERPs enhance operational efficiency and provide real-time insights. The importance of ERP systems lies in their ability to streamline workflows, reduce redundancies, and facilitate data-driven decision-making, driving productivity and competitiveness in today's dynamic business environment.

The selection of an ERP system is a complex and critical decision that significantly impacts an organization's success. Key criteria such as cost, functionality, user-friendliness, reliability, technical support, and integration capability must be meticulously evaluated to ensure the chosen system aligns with the organization's needs and goals. Employing multi-criteria decision-making methods, such as Entropy and Multi-MOORA, can provide a structured and objective approach to this evaluation process. These methods help in determining the relative importance of each criterion and in identifying the ERP system that offers the best overall value.

In this study, six different criteria and three ERP alternatives (ERP-1, ERP-2, and ERP-3) were evaluated using the Entropy and Multi-MOORA methods. The analysis revealed that ERP-1 emerged as the best alternative, effectively balancing cost, functionality, user-friendliness, reliability, technical support, and integration capability. By leveraging Entropy to ascertain objective weights and Multi-MOORA to rank the alternatives, the study ensured a comprehensive and unbiased selection process. The findings underscore the importance of a systematic approach in ERP selection, demonstrating how advanced decision-making techniques can aid organizations in making informed and confident ERP choices. The number of criteria and alternatives can be increased in the study. However, the lack of many decision-makers can also be mentioned as a limitation of the study. New studies can be planned in the future by increasing the number of criteria and alternatives in the study and prioritizing fuzzy logic-based methods.

Author's Contributions

Huriye Akpınar: Drafted and wrote the manuscript, performed the experiment and result analysis

Ethics

There are no ethical issues after the publication of this manuscript.

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