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Performance Evaluation of Human Resource Management in Power Enterprises using Multi-Criteria Decision-Making Methodology and TreeSoft Set

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Abstract: Human Resource Management (HRM) plays a crucial role in the operational success and sustainability of power enterprises. So, this study proposes a multi-criteria decision-making approach (MCDM) for Performance Evaluation of Human Resource Management in Power Enterprises. Two MCDM methods are used in this study such as CIMAS to compute the criteria weights and COPRAS method to rank the alternatives. We used the TreeSoft set with the MCDM approach to deal with various criteria and sub criteria. We divide the problem into three levels such as first level present root node, second level presents the criteria, and third level presents the sub criteria. Then we propose a case study to show the validation of the proposed approach. We applied comparative analysis to show the effectiveness of the proposed approach.

Keywords: TreeSoft Set; MCDM Method; Human Resource Management; Power Enterprises; COPRAS.

1. Introduction

Human Resource Management (HRM) plays a crucial role in the operational success and sustainability of power enterprises. As the energy sector continues to evolve with technological advancements, regulatory changes, and workforce transformations, the ability of HRM to effectively manage talent, optimize productivity, and foster employee engagement has become a key determinant of organizational performance. Unlike other industries, power enterprises require highly skilled professionals to handle complex systems, ensure safety compliance, and drive innovation in energy generation, distribution, and maintenance[1], [2]. Therefore, evaluating the performance of HRM in this sector is essential for ensuring long-term competitiveness and efficiency. The performance evaluation of HRM in power enterprises involves multiple key criteria, including employee productivity and efficiency, talent development and training, employee satisfaction and retention, and HR technology digitalization. These factors influence the overall effectiveness of workforce management, determining how well employees adapt to industry changes, acquire new skills, and remain committed to organizational goals. High employee satisfaction and retention rates lead to a stable and motivated workforce, while advanced HR digitalization streamlines recruitment, training, and performance assessment. By assessing these criteria, power enterprises can identify HRM strengths and areas needing improvement, ultimately enhancing their ability to attract and retain top talent. To ensure comprehensive HRM evaluation, multi-criteria decision-making (MCDM) methodologies can be utilized. These analytical tools provide a structured approach to ranking and comparing HRM strategies across different power enterprises. By integrating qualitative and quantitative assessments, decision-makers can make data-driven improvements to HR policies, training programs, and employee engagement strategies. Additionally, the incorporation of artificial intelligence and HR analytics enables enterprises to track workforce performance in real time, predict future HR trends, and optimize resource allocation for better decision-making[3], [4]. As power enterprises continue to expand and integrate renewable energy sources, HRM strategies must adapt to evolving industry needs. The demand for specialized skills in smart grid technology, sustainable energy management, and automation requires continuous learning and workforce development initiatives. By systematically evaluating HRM performance, power enterprises can enhance employee capabilities, drive operational efficiency, and ensure long-term sustainability in an increasingly competitive energy market. A well-structured HRM evaluation framework serves as a strategic tool for achieving organizational excellence, ensuring that human capital remains a key driver of success in the power sector[5], [6].

1.1 TreeSoft Set

Decision-making in real-world applications often involves complex, uncertain, and hierarchical data structures, requiring advanced mathematical models for effective analysis. The TreeSoft Set is designed to handle hierarchical and multi-level relationships between parameters and objects. Unlike conventional soft sets, where parameters are considered independent, TreeSoft sets organize parameters in a tree-like structure, allowing for a more structured and granular representation of decision-making problems[7], [8]. This hierarchical approach is particularly useful in domains such as MCDM, hierarchical classification, medical diagnosis, and engineering assessments. The fundamental concept of the TreeSoft Set provides a flexible framework for handling vagueness and uncertainty in data. In a TreeSoft set, parameters are arranged in a parent-child relationship, forming a structured tree where each node represents a specific attribute, and its sub-nodes refine the attribute further. This structure enables decision-makers to evaluate both general and detailed aspects of a problem simultaneously[9], [10]. For example, in an employee performance evaluation, the top-level parameter could be "Work Efficiency," with sub-parameters like "Task Completion Time" and "Error Rate" branching out to provide more detailed insights. One of the main advantages of the TreeSoft Set is its ability to model hierarchical decision systems while maintaining computational efficiency. It allows for better organization of criteria dependencies, reducing redundancy and improving interpretability in complex decision-making scenarios. This structured approach is particularly beneficial in engineering, medical diagnostics, environmental assessment, and intelligent systems, where multiple interdependent factors must be considered[11], [12]. Additionally, the TreeSoft set framework can be integrated with other decision-making methods, to enhance decision accuracy and ranking efficiency. As research in soft computing and decision analysis advances, the TreeSoft Set continues to gain attention for its ability to handle uncertainty in structured data environments. By incorporating a hierarchical decision-making perspective, it provides a robust solution for problems where parameters cannot be treated in isolation[13], [14]. Future developments in this field may focus on fuzzy TreeSoft sets, hybrid models with artificial intelligence, and real-world applications in big data analytics, further expanding its potential in solving complex, multi-layered decision problems.

2. Proposed Model

This section shows the steps of the MCDM methodology to compute the criteria weights and ranking the alternatives.

CIMAS Methodology

This methodology is used to compute the criteria weights[15].

Build the decision matrix

Experts build the decision matrix between the criteria and the alternatives. They used scale between 0.9 to 0.1 to evaluate the criteria and alternatives.

Combine the decision matrix

Accomplish the normalization decision matrix

$$r_{ij} = \frac{x_{ij}}{\sigma_j} \tag{1}$$

Where σ_j refers to the standard deviation

Establish the expert-weighted criteria decision matrix.

$$E_{ij} = r_{ij} q_{ij} \tag{2}$$

Where q_{ij} refers to the wight of experts

Compute the maximum and minimum value of positive and cost criteria.

$$y_{ij} = \max_i E_{ij} \tag{3}$$

$$y_{ij} = \min_i E_{ij} \tag{4}$$

Calculate the matrix disparities between the positive and cost criteria.

$$L_j = y_{ij}^{max} - y_{ij}^{min} \tag{5}$$

Compute the criteria weights.

$$W_j = \frac{L_j}{\sum_{j=1}^{n} L_j} \tag{6}$$

COPRAS Method

This methodology is used to rank the alternatives[16], [17].

Normalize the decision matrix

$$s_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{7}$$

Compute the weighted decision matrix.

$$d_{ij} = s_{ij} w_j \tag{8}$$

Compute the max and min indexes for positive and cost criteria

$$K_{+i} = \sum_{j=1}^{g} d_{ij} \tag{9}$$

$$K_{-i} = \sum_{j=g+1}^{n} d_{ij} \tag{10}$$

Where g refers to the number of positive criteria and n-g refers to the number of negative criteria

Compute the relative value

$$H_o = K_{+i} + \frac{\sum_{i=1}^{m} K_{-i}}{K_{-i} \sum_{i=1}^{m} \frac{1}{K_{-i}}} \tag{11}$$

Rank the alternatives.

TreeSoft Set (TSS)

Let U as a universal set and $P(U)$ is a power set of U. Let a set of criteria such as $R_1, R_2, \dots R_n and\ n \geq 1\ for\ the\ first\ level$. Every criterion $R_i, 1 \leq 1 \leq n$, is formed by sub criteria:

$$\begin{gathered} R_1 = \{R_{11}, R_{12}, R_{13}, R_{14}, R_{15}\} \\ R_2 = \{R_{21}, R_{22}, R_{23}, R_{24}, R_{25}\} \\ R_3 = \{R_{31}, R_{32}, R_{33}, R_{34}, R_{35}\} \\ R_4 = \{R_{41}, R_{42}, R_{43}, R_{44}, R_{45}\} \\ R_5 = \{R_{51}, R_{52}, R_{53}, R_{54}, R_{55}\} \\ \vdots \\ R_n = \{R_{n1}, R_{n2}, R_{n3}, R_{n4}, R_{n5}\} \end{gathered} \tag{12}$$

Where R_{ij} are sub criteria and these criteria are formed as level in tree. The first level presents the root nodes, the second level presents the main criteria, and the third level presents the sub criteria values. Fig 1 shows the tree nodes.

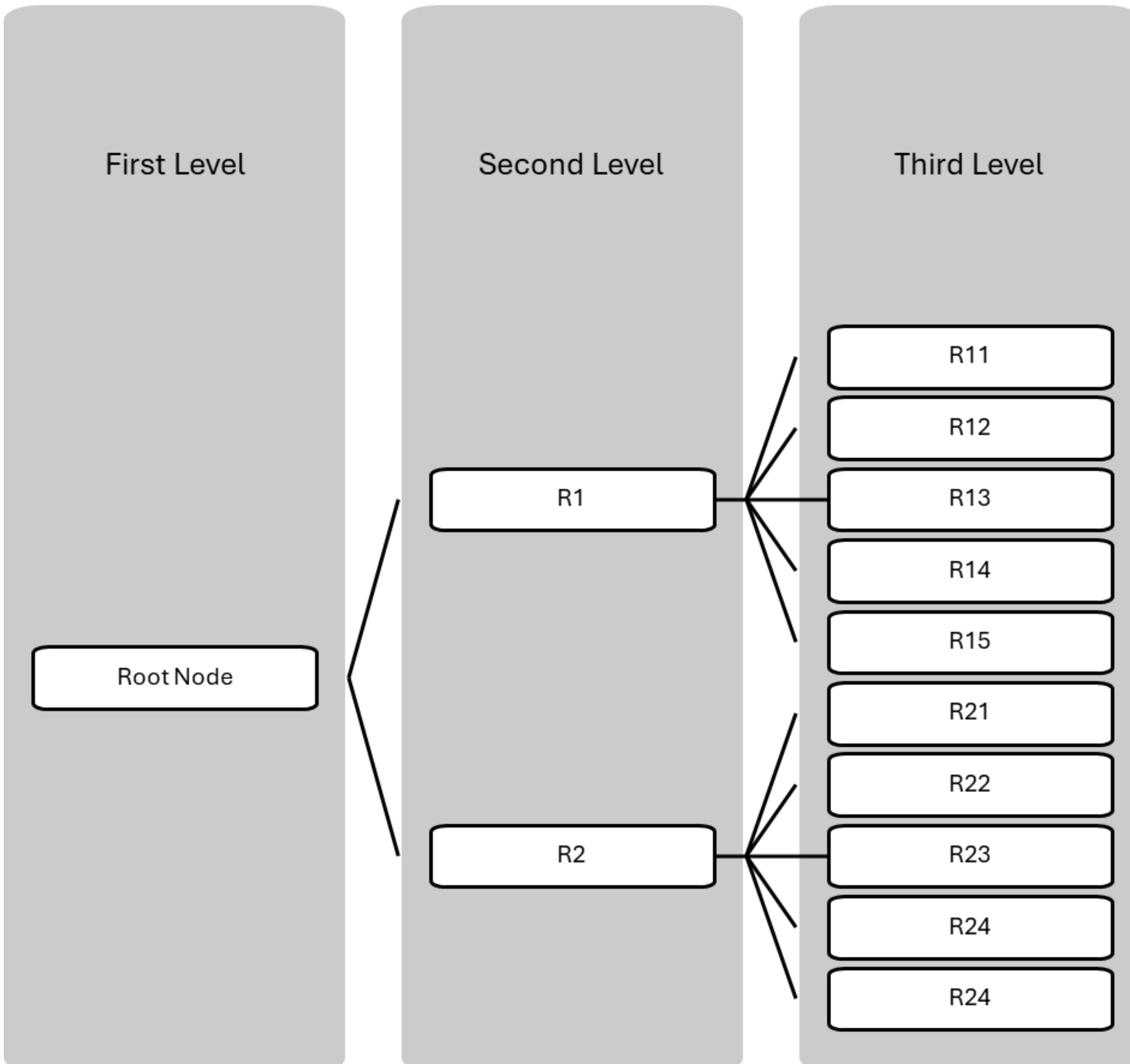

Fig 1. The nodes in TreeSoft set.

The TSS can be formed as:

$$F: P\big(Tree(A)\big) \rightarrow P(H) \quad (13)$$

3. Results and Discussion

We applied the steps of two MCDM methods to compute the criteria weights and ranking the alternatives. Four experts are evaluated the criteria and alternatives. They used scale between 0.1 and 0.9. This study uses four criteria and seven alternatives to be evaluated. We used the TreeSoft set to deal with various criteria. Fig 2 shows the different levels of TreeSoft set.

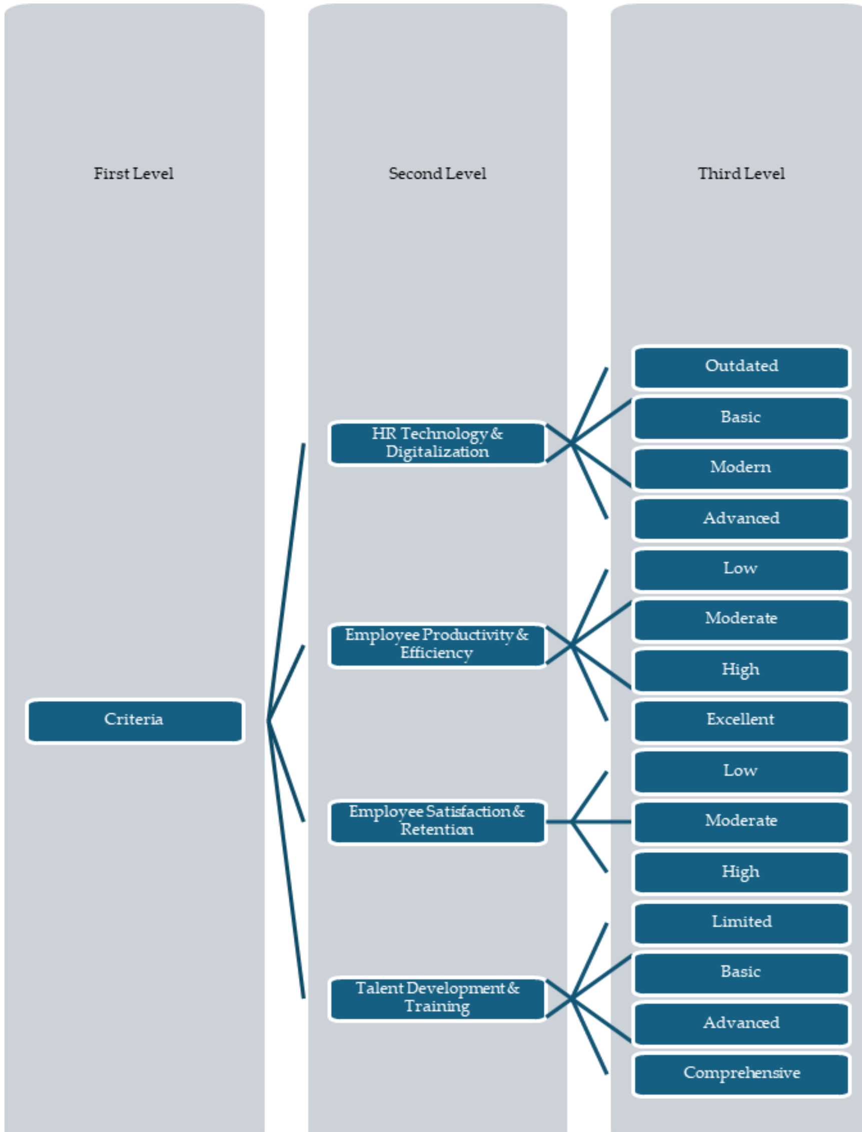

Fig 2. Three different TreeSoft set in this study.

We used the best values in the third level. Then we have four criteria and seven alternatives. Then we applied the CIMAS and COPRAS methods.

CIMAS Methodology Results

We build the decision matrix between the criteria and alternatives using scale between 0.9 to 0.1 as shown in Table 1.

Then we combine the decision matrix

Then we accomplish the normalization decision matrix using eq. (1) as shown in Fig 3.

Then we establish the expert-weighted criteria decision matrix using eq. (2) as shown in Fig 4.

Then we compute the maximum and minimum value of positive and cost criteria.

Then we calculate the matrix disparities between the positive and cost criteria using eq. (5).

Then we compute the criteria weights using eq. (6) as shown in Fig 5.

Table 1. The decision matrix.

	R_1	R_2	R_3	R_4
A_1	0.8	0.7	0.6	0.5
A_2	0.8	0.1	0.2	0.4
A_3	0.7	0.6	0.5	0.4
A_4	0.5	0.6	0.7	0.8
A_5	0.4	0.5	0.6	0.7
A_6	0.4	0.4	0.5	0.4
A_7	0.2	0.2	0.6	0.2
	R_1	R_2	R_3	R_4
A_1	0.5	0.7	0.6	0.5
A_2	0.6	0.1	0.2	0.5
A_3	0.7	0.6	0.5	0.6
A_4	0.8	0.6	0.7	0.7
A_5	0.1	0.5	0.6	0.8
A_6	0.5	0.5	0.5	0.1
A_7	0.6	0.6	0.6	0.2
	R_1	R_2	R_3	R_4
A_1	0.8	0.7	0.6	0.5
A_2	0.1	0.1	0.2	0.4
A_3	0.2	0.8	0.5	0.4
A_4	0.4	0.1	0.8	0.8
A_5	0.5	0.2	0.1	0.8
A_6	0.6	0.4	0.2	0.1
A_7	0.7	0.5	0.4	0.2
	R_1	R_2	R_3	R_4
A_1	0.2	0.1	0.7	0.1
A_2	0.1	0.8	0.8	0.8
A_3	0.1	0.7	0.1	0.7
A_4	0.7	0.7	0.7	0.4
A_5	0.8	0.8	0.8	0.8
A_6	0.1	0.1	0.1	0.7
A_7	0.8	0.6	0.5	0.4

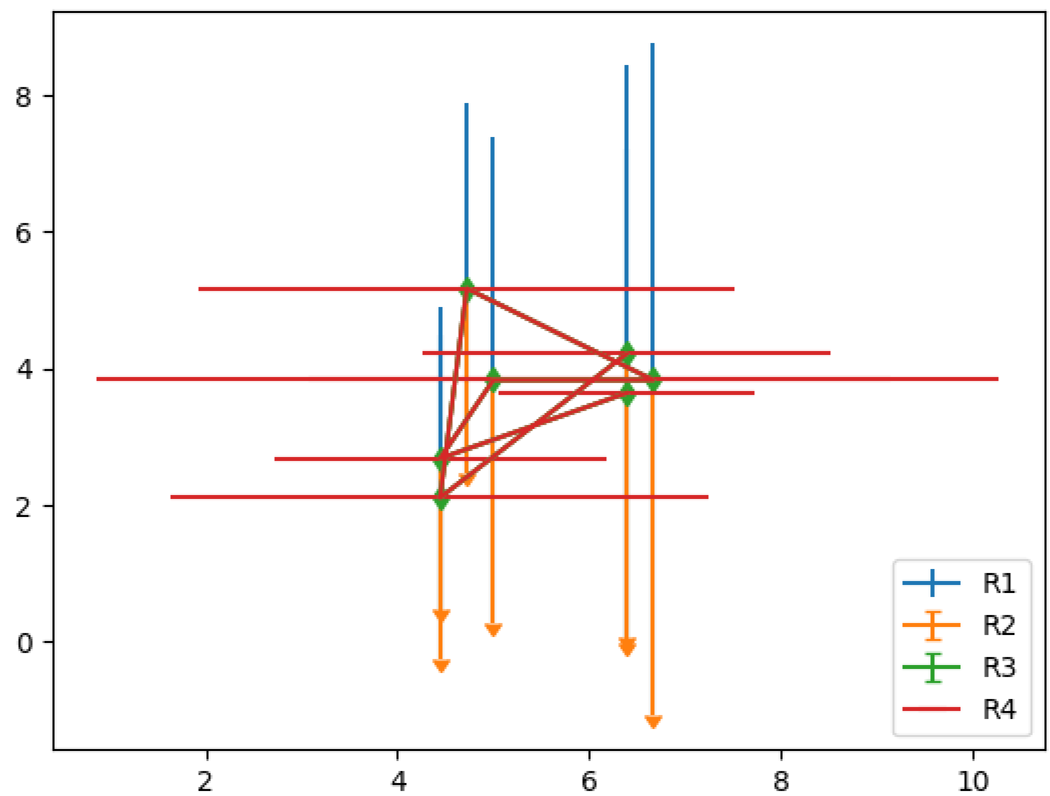

Fig 3. The normalization values.

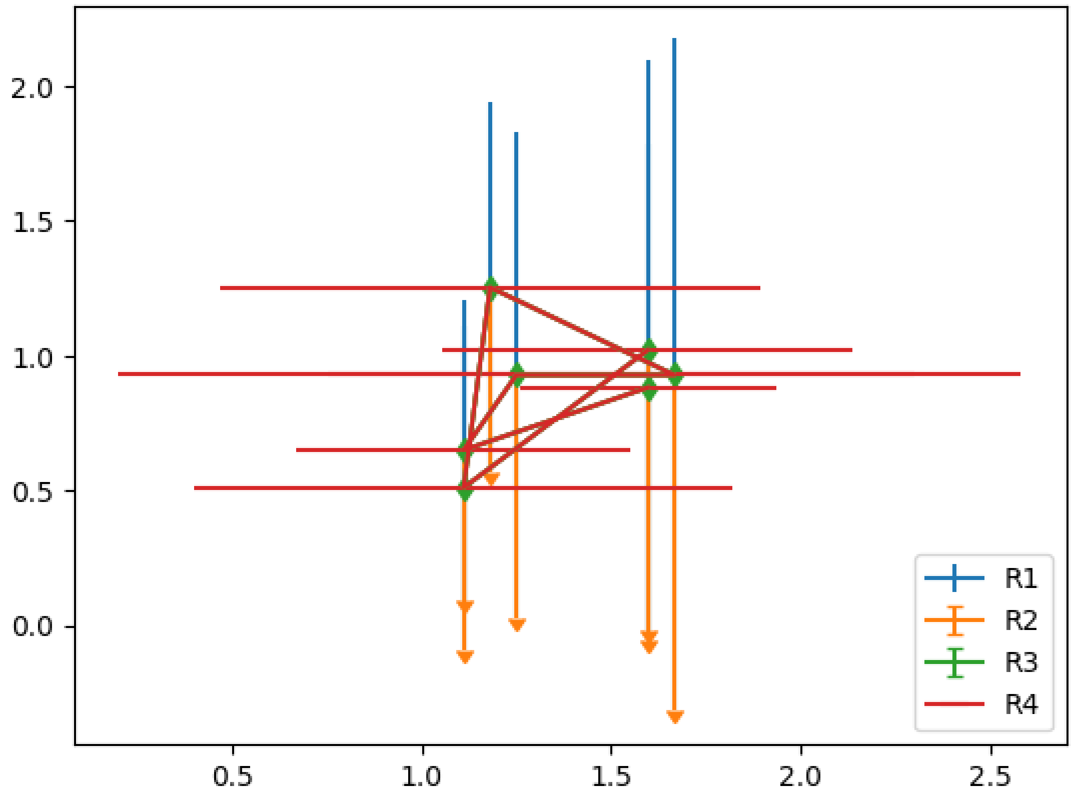

Fig 4. expert-weighted criteria decision matrix.

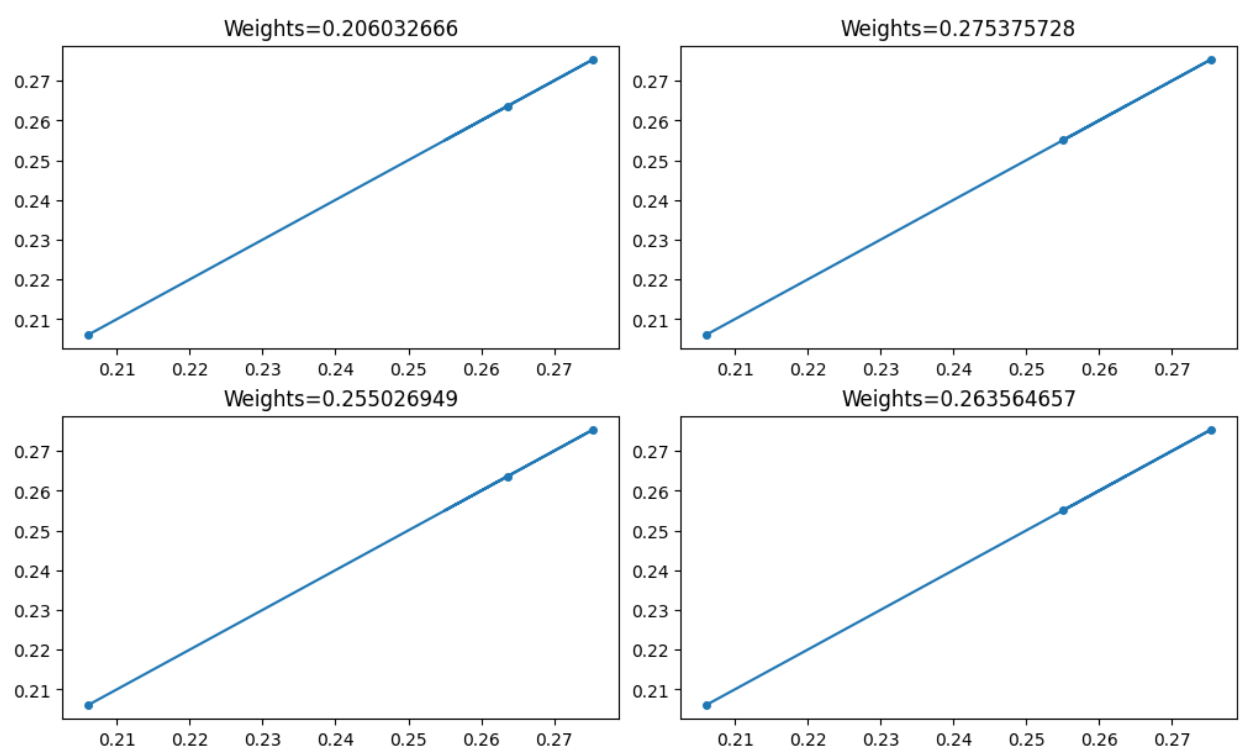

Fig 5. The criteria weights.

COPRAS Method Results

We normalize the decision matrix using Eq. (7) as shown in Fig 6.

We compute the weighted decision matrix using Eq. (8) as shown in Fig 7.

Then we compute the max and min indexes for positive and cost criteria using Eqs. (9 and 10).

Then we compute the relative value using Eq. (11) as shown in Fig 8. Then we rank the alternatives as shown in Fig 9.

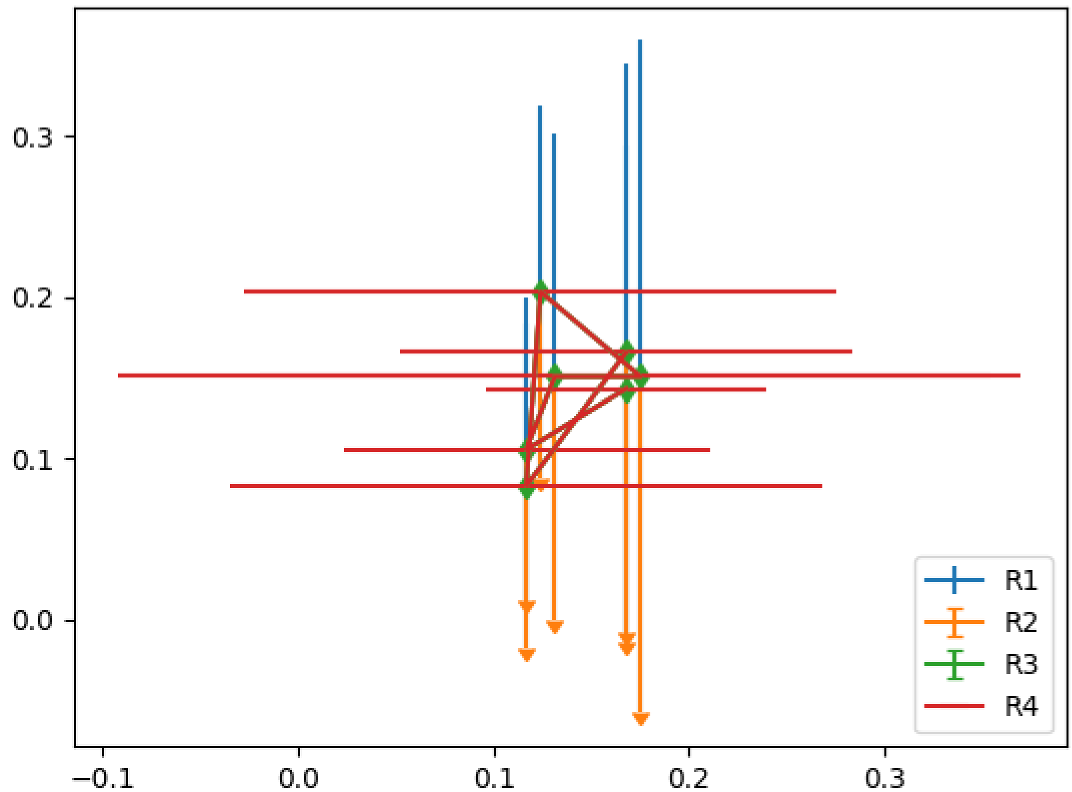

Fig 6. The normalization values by the COPRAS method.

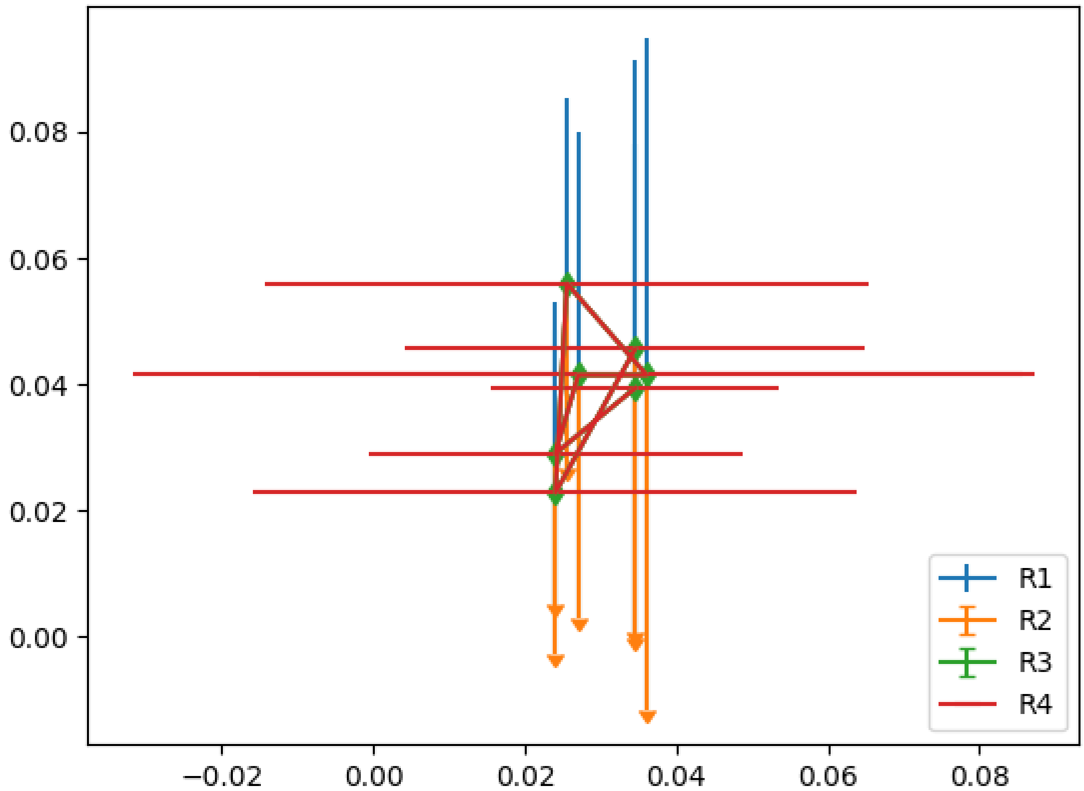

Fig 7. The weighted decision matrix.

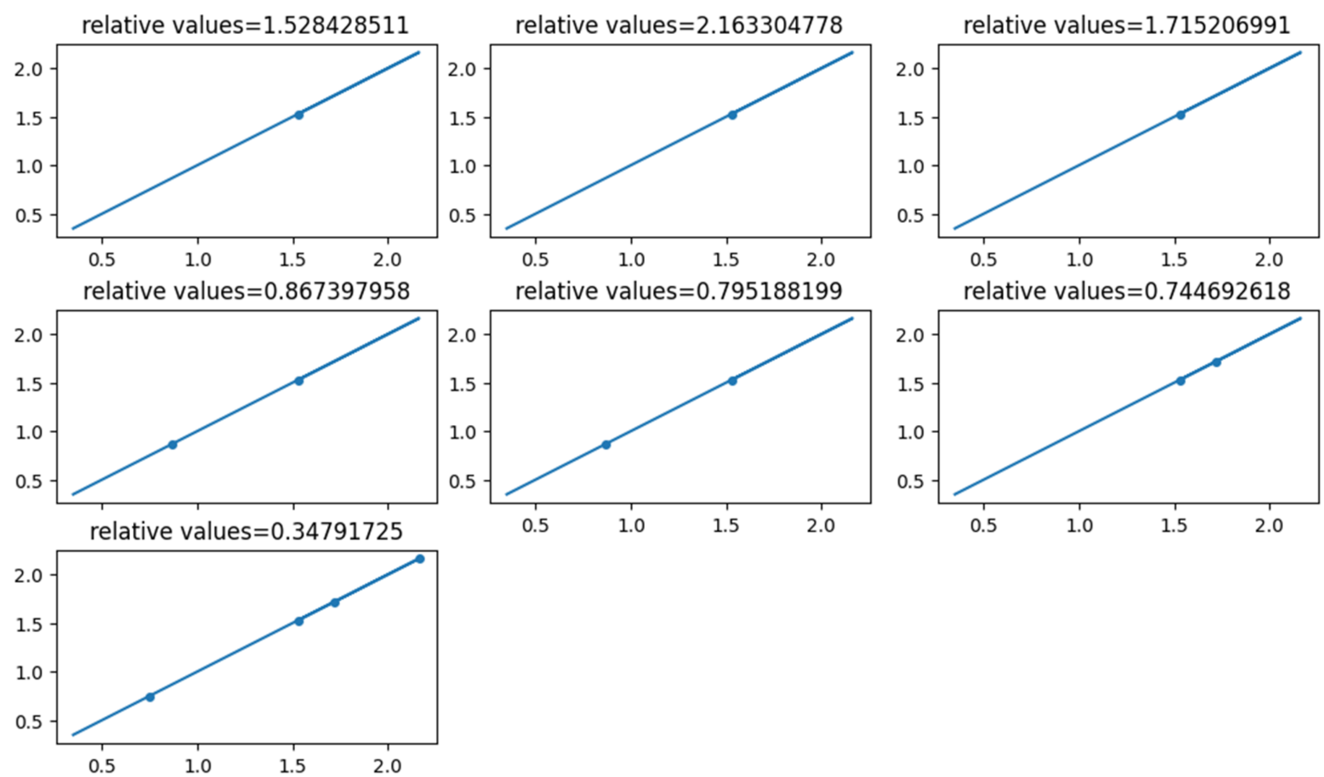

Fig 8. The relative values.

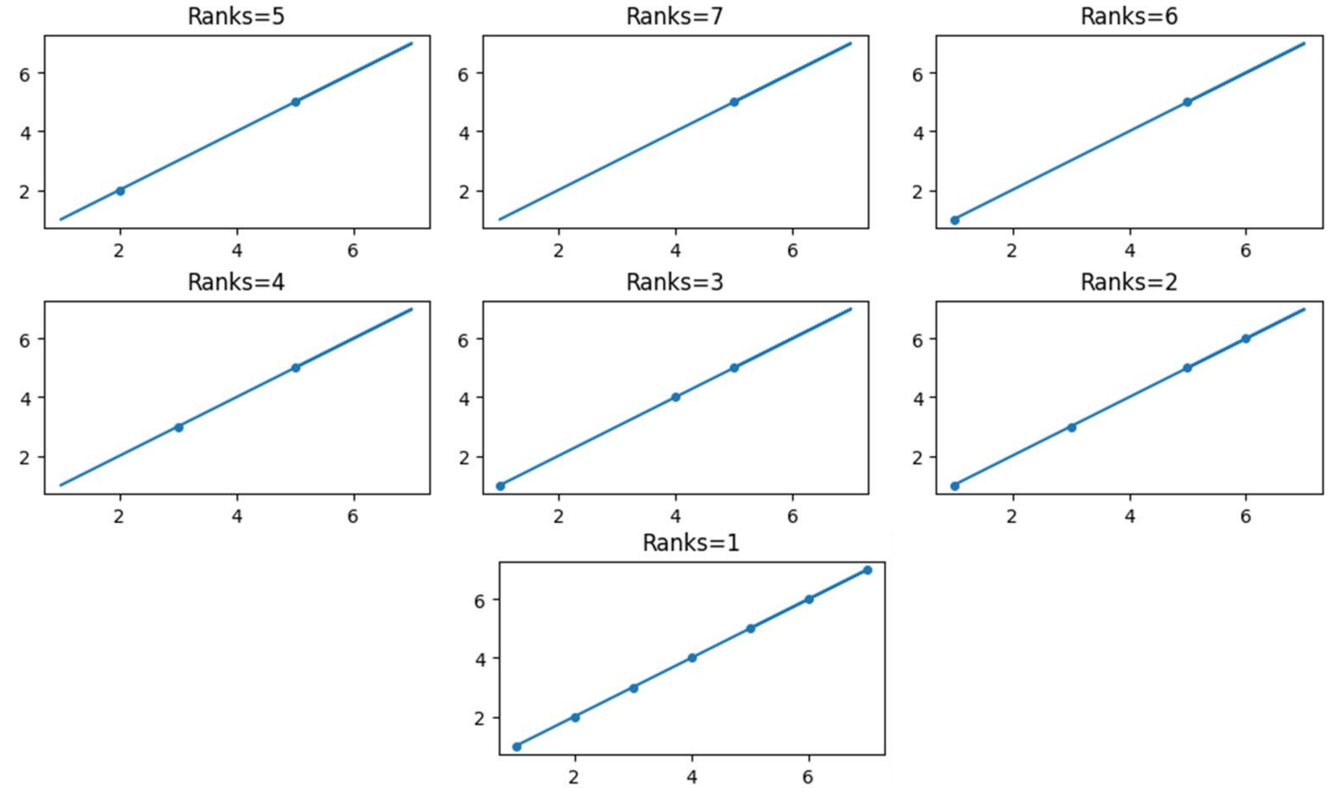

Fig 9. The rank of alternatives.

4. Comparative Analysis

This section shows the comparative analysis between the proposed approach and other MCDM methods to show the validation and effectiveness of the proposed approach. We compared the proposed approach with four different methods. The results show alternative 2 is the best and alternative 7 is the worst. The results show the proposed approach is effective compared to other MCDM methods. Fig 10 shows the comparative ranks.

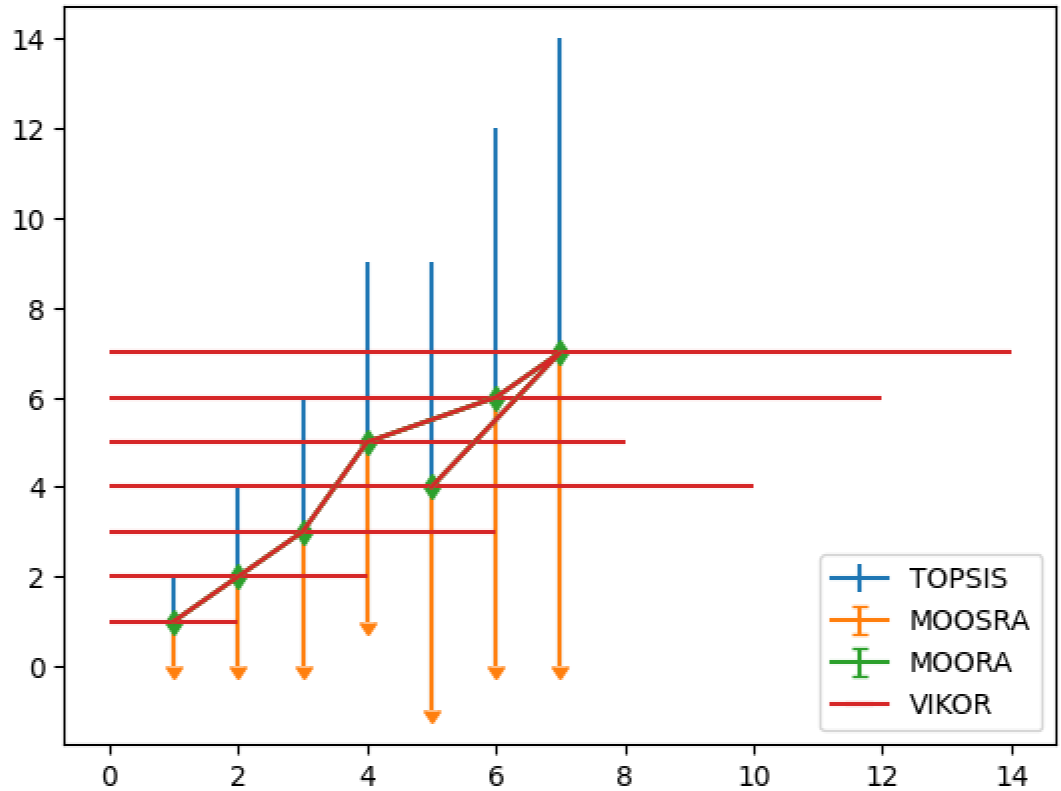

Fig 10. The comparative ranks.

5. Conclusions and Future Study

This study proposed a MCDM approach for Performance Evaluation of Human Resource Management in Power Enterprises. We proposed two MCDM methods such as CIMAS method to compute the criteria weights and the COPRAS method to rank the alternatives. These methods are used with the TreeSoft Set to dela with different criteria and sub criteria. Four criteria and different sub criteria are printed as tree with three levels, then we applied the MCDM methods. The results show alternative 2 is the best and alternative 7 is the worst. TreeSoft set can be used in the future study with other uncertainty models such as fuzzy sets, neutrosophic sets. Different MCDM methods can be used to compute the criteria weights and rank the alternatives.

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