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Structured Entrepreneurship Education Assessment in Vocational Colleges: A HyperSoft Set Model with an MCDM-Based Framework

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Abstract: We develop a multi-criteria decision making (MCDM) approach for Innovation and Entrepreneurship Education Evaluation in Vocational Colleges. Two MCDM methods are used in this study such as MEREC methodology to compute the criteria weights and the VIKOR methodology to rank the alternatives. We use the HyperSoft set to deal with criteria and sub criteria. This study uses eight criteria and eight alternatives. Then we use the best sub criteria to evaluate and rank the alternatives. We conduct sensitivity and comparative in this study. The results show the proposed approach is effective compared to MCDM methods and the sensitivity analysis shows the rank of alternatives are stable under different cases.

Keywords: HyperSoft Set Model; MCDM Approach; Innovation and Entrepreneurship; Education; Vocational Colleges.

1. Introduction

In the modern knowledge-based economy, innovation and entrepreneurship education (IEE) plays a pivotal role in enhancing students' employability and fostering economic development. Vocational colleges, which are designed to equip students with practical skills and industry-oriented knowledge, have increasingly integrated entrepreneurial education into their curricula to meet the demands of an evolving job market. The objective of IEE in vocational education is not only to instill business acumen but also to develop students' creativity, problem-solving skills, and adaptability in competitive industries[1], [2]. However, evaluating the effectiveness of these programs requires a structured approach that considers curriculum relevance, institutional support, industry collaboration, and student engagement. The integration of innovation and entrepreneurship education in vocational colleges faces various challenges, such as limited financial resources, inadequate faculty training, and weak industry partnerships. Effective evaluation frameworks must assess how well the curriculum aligns with real-world business challenges, the extent to which practical training opportunities are provided, and the level of institutional backing available for student startups. Moreover, factors such as digital transformation, technological integration, and mentorship availability significantly impact the success of entrepreneurship education[3], [4]. Without a comprehensive evaluation framework, vocational colleges may struggle to identify areas for improvement and optimize their programs for better student outcomes. To systematically evaluate innovation and entrepreneurship education, Multi-Criteria Decision-Making (MCDM) methods provide a structured approach to ranking and assessing different educational models. Methods can be employed to measure the effectiveness of various vocational colleges in terms of curriculum design, faculty expertise, student engagement, and startup success rates. These methodologies enable policymakers and educators to make data-driven decisions that enhance the quality of entrepreneurial training, ensuring that students receive the necessary skills to thrive in dynamic job markets[5], [6]. Furthermore, the use of big data analytics and artificial intelligence in evaluating IEE programs can offer deeper insights into student performance and institutional effectiveness.

The evaluation of innovation and entrepreneurship education in vocational colleges is crucial for enhancing program efficiency, fostering industry collaboration, and ensuring student success. A well-structured evaluation framework helps identify the best practices, refine teaching methodologies, and bridge the gap between education and industry needs. By adopting advanced MCDM techniques and digital evaluation tools, vocational colleges can continually improve their entrepreneurship education models, ultimately contributing to a more innovative and competitive workforce[7], [8]. Moving forward, it is essential to integrate technology, research-based evaluation methods, and industry-driven insights to shape a robust and future-ready entrepreneurial education system in vocational training institutions.

Innovation and entrepreneurship education in vocational colleges is a MCDM problem, which is a problem in which decision alternatives are evaluated according to their performance values in each evaluation criteria, which are weighted according to their importance to the decision makers (DMs). Many MCDM methods have been developed to solve decision problems, and they can be divided into compensatory and non-compensatory techniques[9]. Compensatory techniques are those in which a lower performance value of an alternative in one criterion can be offset by a higher performance value in another criterion.

Innovations in sustainable engineering and technology are essential for cutting carbon emissions. The active involvement of businesses in tackling carbon reduction as a systemic strategy is a crucial component of this. Chinese businesses have created carbon reduction systems in response to government incentives in the People's Republic of China, which help them match their organizational objectives with long-term national policies. Six firms' carbon reduction plans are assessed by Esangbedo and Tang [10] as MCDM dilemma. To do this, they suggested the grey-MEREC-MAIRCA approach, a novel hybrid MCDM technique. Their approach combined the multi-attribute ideal-real comparative analysis (MAIRCA) based on the grey system theory with the recently established method based on the removal effects of criteria (MEREC) for weighting.

The added advantage of their hybrid approach is that it takes decision-making uncertainty into consideration. According to the decision-maker scores, their study's noteworthy conclusions include the importance of energy-saving efficiency and the reduction of direct carbon emissions. On the other hand, making a commitment to corporate social responsibility through information transparency and carbon public welfare is regarded as a lower priority. Furthermore, the ranking results generated using this method are contrasted with those from the conventional weighted sum model and the methodology for order preference by similarity to ideal solution (TOPSIS), verifying the pick of the top organization. Even if their suggested approach has drawbacks and requires extra steps for evaluation, it created the possibility for future studies to create more straightforward MCDM techniques in the face of ambiguity.

1.1 Why HyperSoft Set Was Used in This Study

The HyperSoft Set is a powerful mathematical tool for solving complex decision-making problems. Unlike traditional soft sets, which assign only one value to each parameter, the HyperSoft Set allows each parameter to have multiple values, making it more suitable for real-world applications where criteria often overlap.

It helps in managing uncertain and vague data, making it highly effective in fields like education, industry, healthcare, and artificial intelligence. By providing a structured way to group and classify information, it ensures that decision-making processes are more accurate and adaptive.

The HyperSoft Set also enhances multi-criteria decision-making (MCDM) by offering a more detailed and flexible evaluation model. It improves the ranking and selection of alternatives by considering all possible influences and dependencies between different factors.

Because of these advantages, the HyperSoft Set is widely used in educational assessment, industrial decision-making, medical diagnostics, and intelligent systems. Its ability to handle complex and uncertain data makes it an essential tool for modern decision-making challenges.

1.2 Importance of HyperSoft Set in the Proposed Work

In this study, the HyperSoft Set is essential for handling the complex decision-making process involved in evaluating entrepreneurship education in vocational colleges. Traditional methods often struggle with multi-level criteria and overlapping factors, making decision-making less precise. The HyperSoft Set offers a structured way to deal with multiple criteria and sub-criteria, improving accuracy and clarity in ranking alternatives.

By using the HyperSoft Set, this research ensures a more flexible and systematic evaluation framework. It helps in categorizing different educational factors effectively, considering the relationships between various criteria. The integration of HyperSoft Set with the MEREC method allows for precise calculation of criteria weights, while its combination with the VIKOR method enhances the ranking process, ensuring a data-driven and reliable decision-making approach.

This approach is particularly useful in entrepreneurship education, where multiple elements such as curriculum relevance, faculty expertise, student engagement, and industry collaboration must be evaluated together. The HyperSoft Set makes it easier to handle these interconnected factors, leading to more accurate and insightful results.

2. HyperSoft Set-MEREC-VIKOR

This section shows the steps of the proposed approach. We use the MEREC method to compute the criteria weights and the VIKOR method to rank the alternatives. HyperSoft set is used in this study to deal with the criteria and sub criteria[11].

HyperSoft Set [12], [13]

We can define the soft set as:

Let's have $n \geq 2$ Soft set

$$\begin{pmatrix} F_1: A_1 \to P(H), \\ F_2: A_2 \to P(H), \\ F_3: A_3 \to P(H) \\ F_4: A_4 \to P(H) \\ F_5: A_5 \to P(H) \\ F_6: A_6 \to P(H) \\ F_7: A_7 \to P(H) \\ \vdots \\ F_n: A_n \to P(H) \end{pmatrix} \quad (1)$$

Where $a_1, a_2, \dots .. a_n$ are the attributes and the $A_1, A_2, \dots ., A_n$ are the corresponding sets of attributes' values such that

$$A_i \cap A_j = \emptyset \; f o \; i \neq j \; and \; i, j \; \in \{1,2, \dots, n\} \quad (2)$$

The Soft set product computed such as:

$$F_1 \times F_2 \dots \times F_n: A_1 \times A_2 \times \dots A_n \to P(H) \times P(H) \times \dots \times P(H) \quad (3)$$

Let we have $F = \; F_1 \times F_2 \dots \times F_n$

Then we can define the HyperSoft Set as:

$F: A_1 \times A_2 \times \dots \times A_n \to P(H)$ such that for each $(e_1, e_2, \dots e_n) = F_1(e_1) \cap F_2(e_2) \cap \dots \cap F_n(e_n)$ (4)

MEREC Model

This method is used to compute the criteria weights[10].

Construct the decision matrix

The decision matrix is built in the first step to show the opinions of the experts and decision makers for each criterion and alternatives.

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{mn} \end{pmatrix}$$
(5)

Combine the decision matrix

We combine the decision matrix into a single matrix.

Normalize the decision matrix

The decision matrix is normalized for the positive and negative criteria such as:

$$n_{ij} = \frac{\min_i x_{ij}}{x_{ij}} \quad (6)$$

$$n_{ij} = \frac{x_{ij}}{\max_i x_{ij}} \quad (7)$$

Compute the overall performance of the alternatives

$$T_i = \ln\left(1 + \left(\frac{1}{m}\sum_i \left|\ln\left(n_{ij}\right)\right|\right)\right) \quad (8)$$

Compute the overall performance by deleting each criterion

$$T_{ij}^{/} = \ln\left(1 + \left(\frac{1}{m}\sum_{k,k\neq j} \left|\ln\left(n_{ij}\right)\right|\right)\right) \quad (9)$$

Compute the removal effect of the criterion

$$U_i = \sum_i \left|T_{ij}^{/} - T_i\right| \quad (10)$$

Compute the criteria weights

$$w_j = \frac{U_i}{\sum_i U_i} \quad (11)$$

VIKOR Model

This method is used to rank the alternatives based on a set of criteria and sub criteria[14], [15]. The steps of the VIKOR method are shown as follows:

Compute the min and max values in the decision matrix.

$$z_i^* = \max_i x_{ij} \quad (12)$$

$$z_i^- = \min_i x_{ij} \quad (13)$$

For the non-beneficial criteria

$$z_i^* = \min_i x_{ij} \quad (14)$$

$$z_i^- = \max_i x_{ij} \quad (15)$$

Normalize the decision matrix

$$y_{ij} = \frac{(z_i^* - x_{ij})}{(z_i^* - z_i^-)} \quad (16)$$

Compute the weighted decision matrix

$$q_{ij} = w_j y_{ij} \quad (17)$$

Compute the S and R indexes

$$S_i = \sum_{j=1}^{n} q_{ij} \quad (18)$$

$$R_i = \max_j q_{ij} \quad (19)$$

Compute the VIKOR index

$$V_i = \varphi \times \left(\frac{(S_i - S^+)}{(S^- - S^+)}\right) + (1 - \varphi) \times \left(\frac{(R_i - R^+)}{(R^- - R^+)}\right) \quad (20)$$

$$S^+ = \min_i S_i \quad (21)$$

$$S^- = \max_i S_i \quad (22)$$

$$R^+ = \min_i R_i \quad (23)$$

$$R^- = \max_i R_i \quad (24)$$

Rank the alternatives

3. Results and Discussion

To analyze the effectiveness of the proposed model, we conducted a case study that evaluates the criteria weights and ranks the available alternatives. The MEREC method was used to determine the importance of each criterion, while the VIKOR method was applied to rank the alternatives based on their performance. These methods provided a structured approach to decision-making, ensuring a clear and objective evaluation process.

For this study, three experts and decision-makers were invited to assess the criteria and alternatives. The evaluation was based on eight key criteria, each representing a significant aspect of entrepreneurship education in vocational colleges. Each criterion was assigned three levels to allow for a more detailed assessment. The criteria used in this study were:

1. Student Engagement in Innovation (High, Medium, Low)
2. Technological Integration (Advanced, Moderate, Basic)
3. Employment and Startup Success Rate (High, Medium, Low)
4. Industry Collaboration (Strong, Moderate, Weak)

5. Institutional Support (Strong, Moderate, Weak)
6. Faculty Competency (Highly Skilled, Moderately Skilled, Basic Skills)
7. Curriculum Relevance (High, Medium, Low)
8. Practical Training Opportunities (Extensive, Moderate, Limited)

Each of these criteria plays a vital role in assessing the quality of entrepreneurship education programs and their impact on student success. The study aimed to identify strengths and weaknesses within these programs, helping educational institutions make informed improvements.

To begin the evaluation process, we constructed the decision matrix using Equation (5). The decision matrix included values ranging from 0.1 to 0.7, representing the relative performance of each alternative against the selected criteria. These values were then combined into a single matrix for further analysis.

To ensure consistency and comparability, the decision matrix was normalized using Equation (6), as illustrated in Figure 1. Normalization ensures that all values are scaled appropriately, allowing for a fair comparison between different criteria.

Once the normalization was completed, we calculated the overall performance of the alternatives using Equation (8). This step helped determine which alternatives performed better relative to the set criteria. To further refine the results, we computed the overall performance after removing each criterion individually using Equation (9), as shown in Figure 2. This approach helped us understand the impact of each criterion on the final ranking.

Additionally, we calculated the removal effect of each criterion using Equation (10). This allowed us to measure how much influence each criterion had on the overall decision-making process. Finally, we determined the criteria weights using Equation (11), as presented in Figure 3. These weights provided valuable insights into which criteria were the most influential in ranking the alternatives.

By following this structured evaluation process, we ensured that the ranking method was objective, data-driven, and reliable. The results obtained from this case study demonstrate the effectiveness of integrating HyperSoft Set, MEREC, and VIKOR in decision-making. This approach not only improves the accuracy of evaluations but also provides a solid framework for enhancing entrepreneurship education programs in vocational colleges.

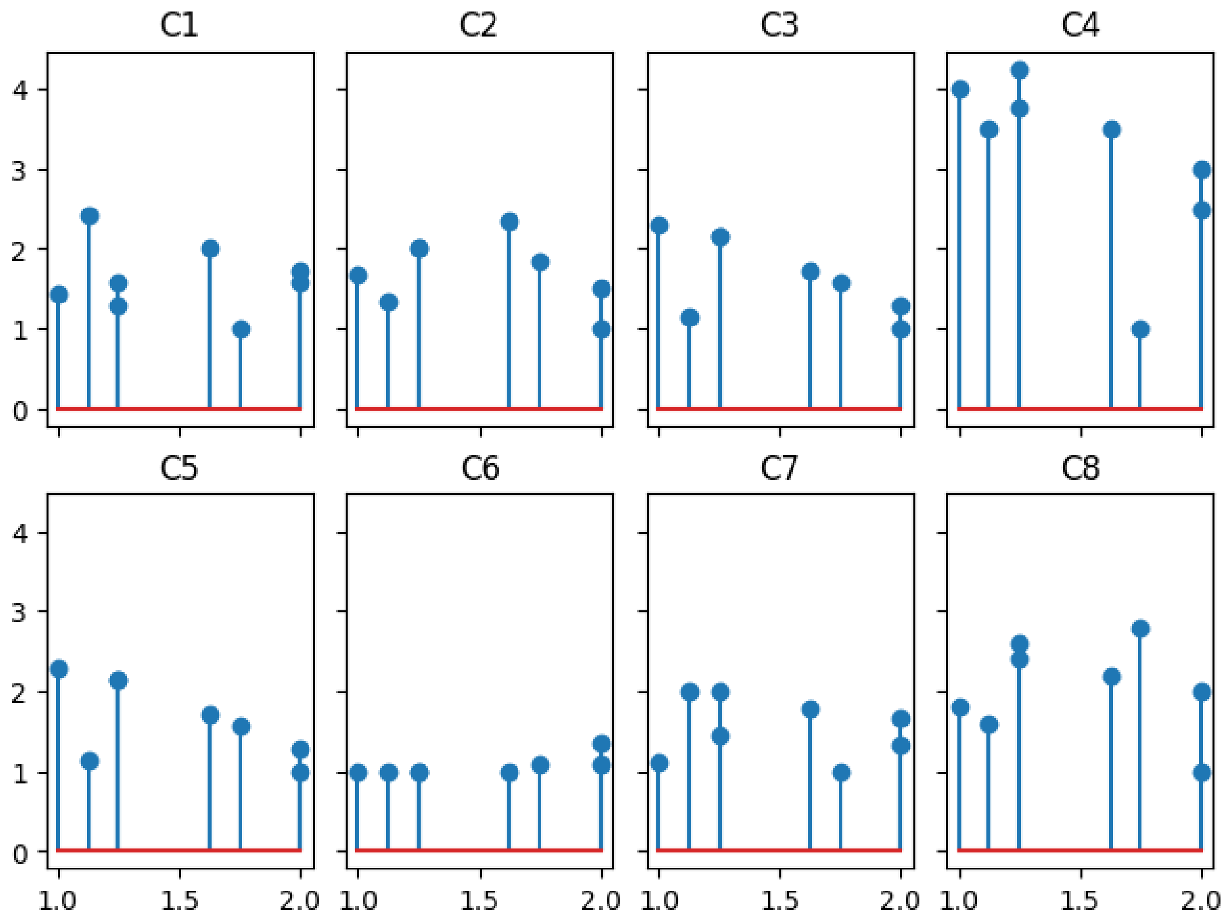

Fig 1. The normalization matrix.

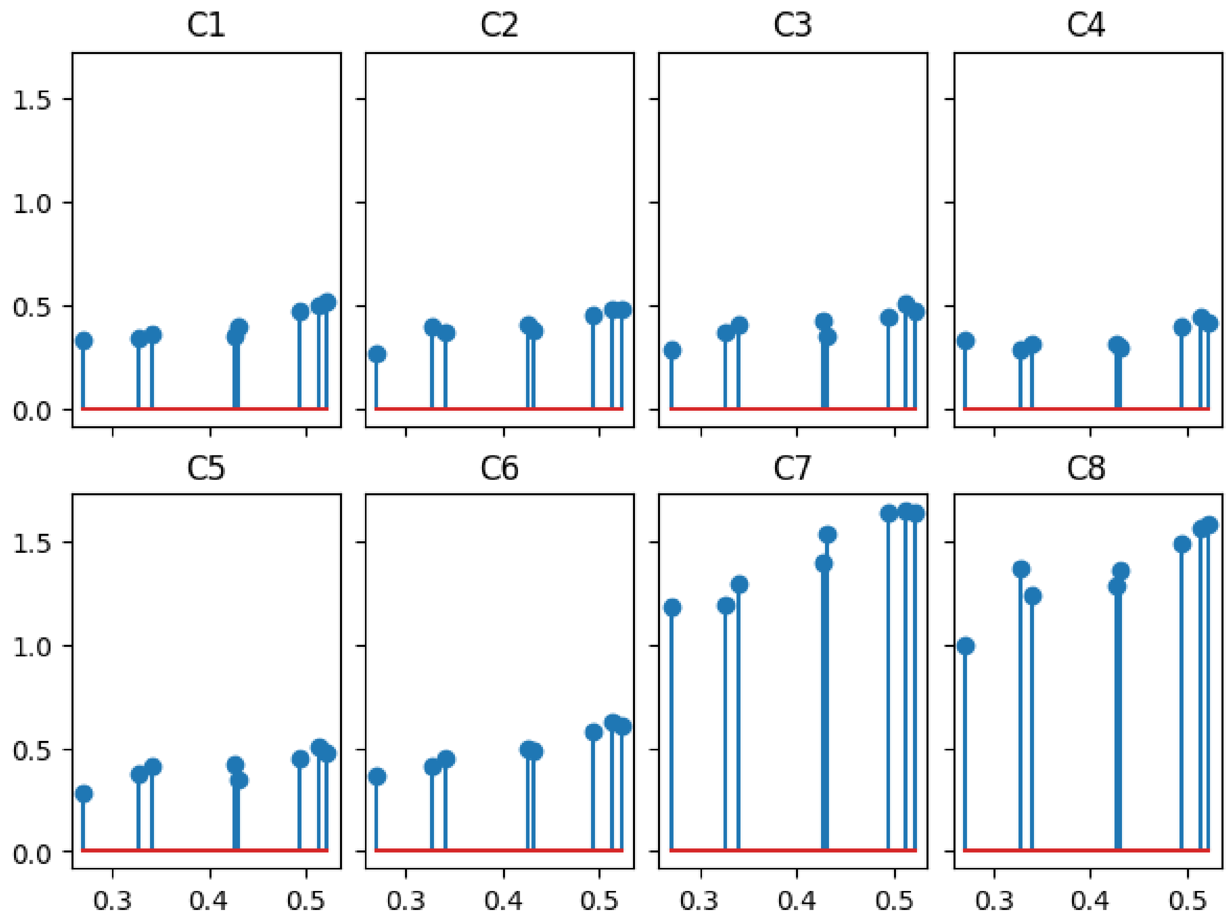

Fig 2. The overall performance by deleting each criterion.

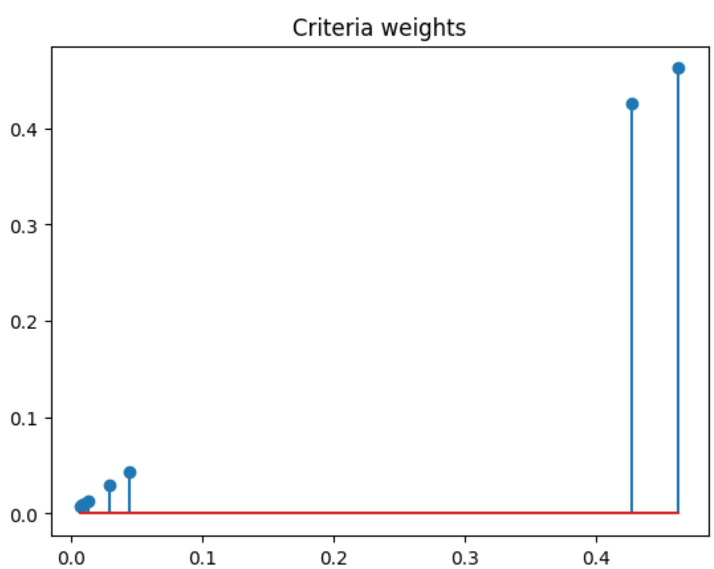

Fig 3. The criteria weights.

4. Results of the VIKOR Model

To rank the alternatives, we used the HyperSoft Set method to handle the criteria and sub-criteria. The sub-criteria considered in this study were:
{High, Advanced, Medium, Moderate, Strong, Highly Skilled, High, Moderate}. After defining these sub-criteria, we applied the VIKOR method to evaluate the alternatives.

Calculation Steps:

1. Finding the Minimum and Maximum Values:

   We used Equations (12) and (13) to determine the lowest and highest values in the decision matrix.

2. Normalizing the Decision Matrix:

   Equation (16) was applied to standardize the values in the matrix, making it easier to compare different alternatives. The normalized matrix is shown in Figure 4.

3. Calculating the Weighted Decision Matrix:

   Using Equation (17), we assigned weights to the decision matrix based on the importance of each criterion. The result is shown in Figure 5.

4. Computing S and R Indexes:

   We calculated these indexes using Equations (18) and (19). These values represent the performance of each alternative, as shown in Figure 6.

5. Computing the VIKOR Index:

   After obtaining the previous values, we used Equation (20) to calculate the VIKOR index, which determines the final ranking of the alternatives. This is illustrated in Figure 7.

   In this study, we used $\varphi = 0.5$ as a balancing factor.

6. Ranking the Alternatives:

   Finally, based on the calculated values, we ranked the alternatives using the VIKOR method. The rankings are shown in Figure 8.

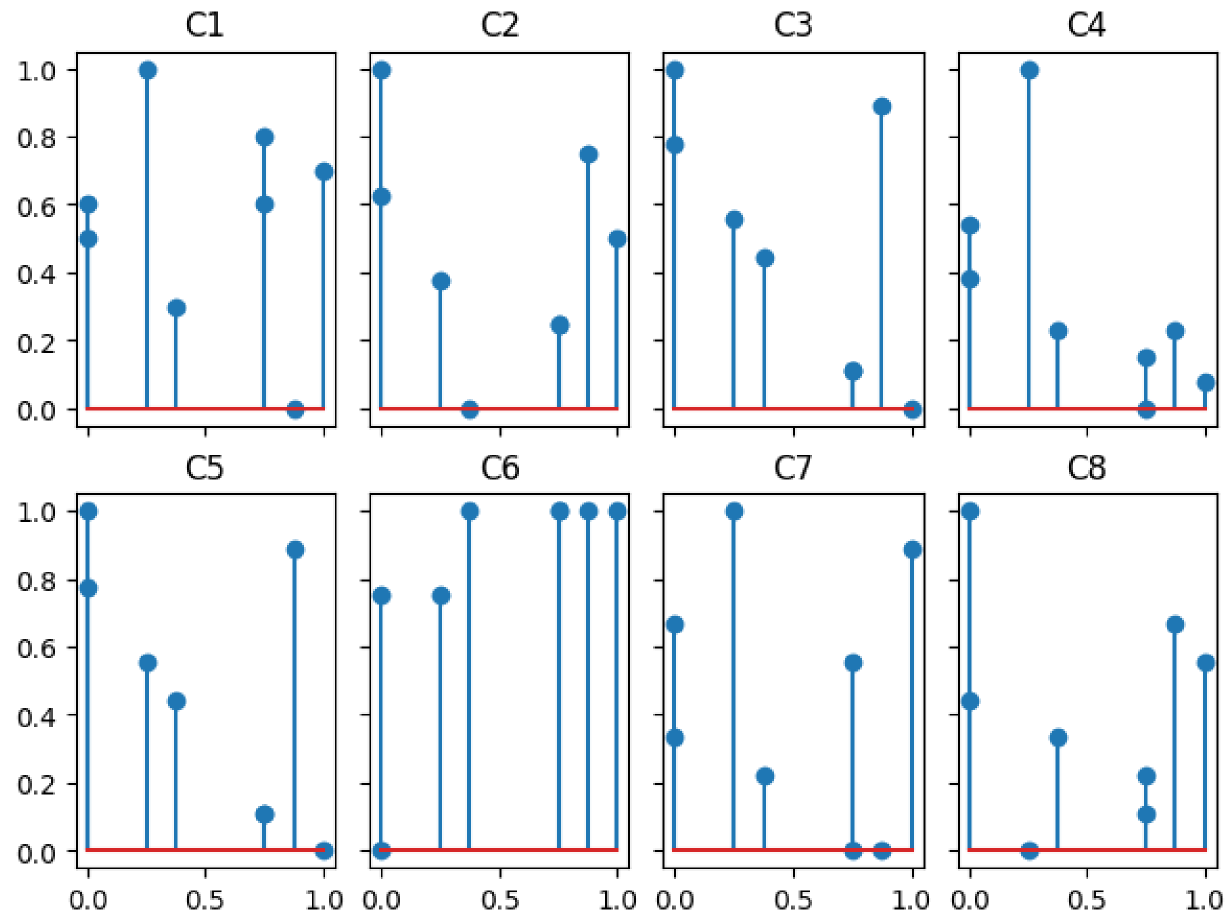

Fig 4. The normalization values by the VIKOR method.

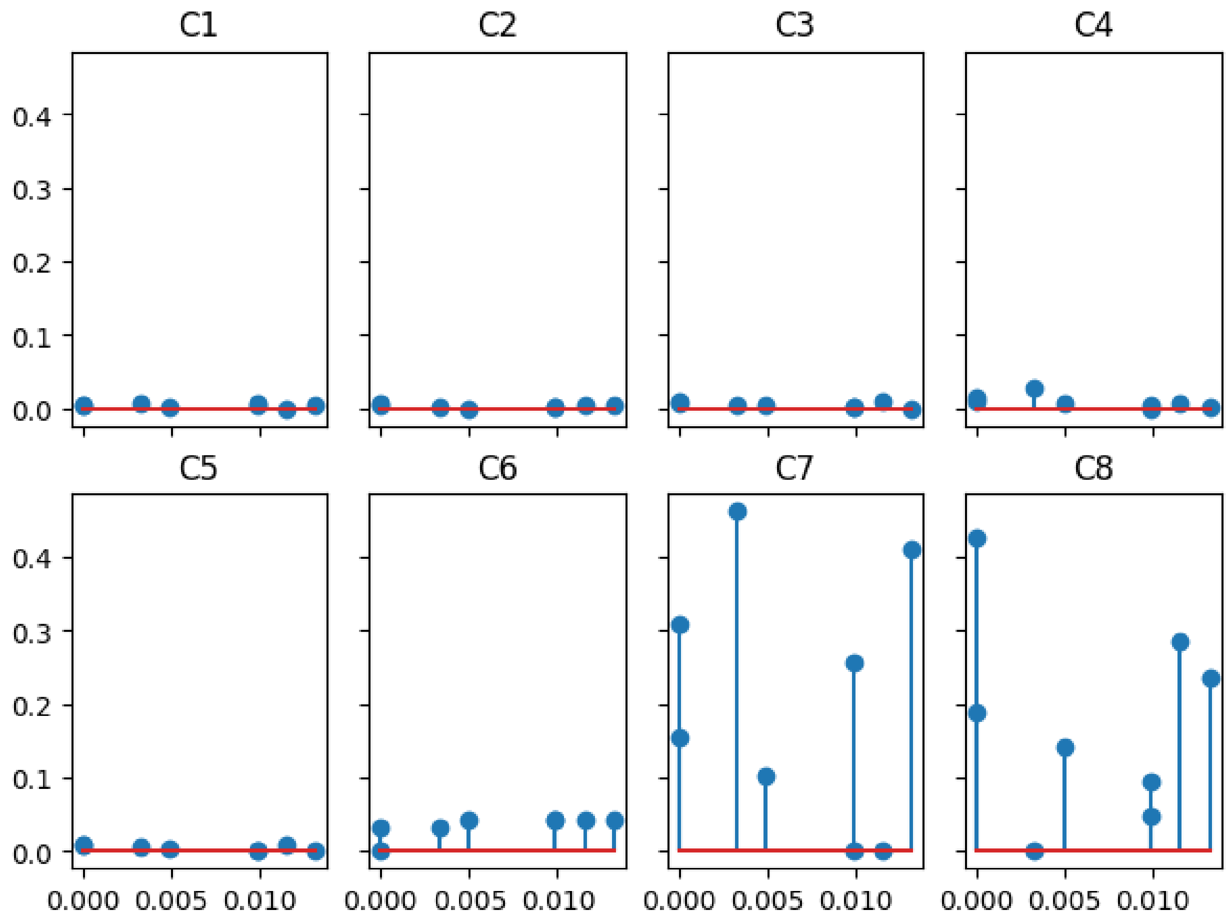

Fig 5. The weighted decision matrix.

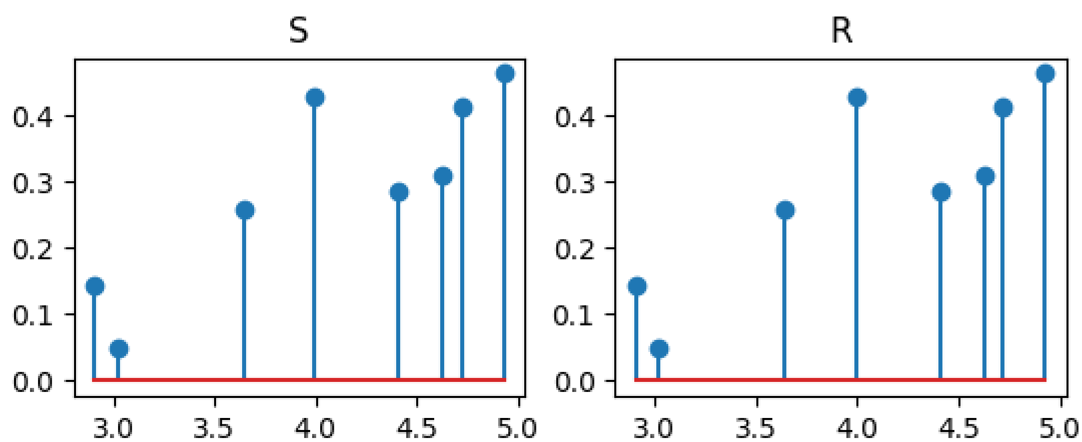

Fig 6. The values of S and R indexes.

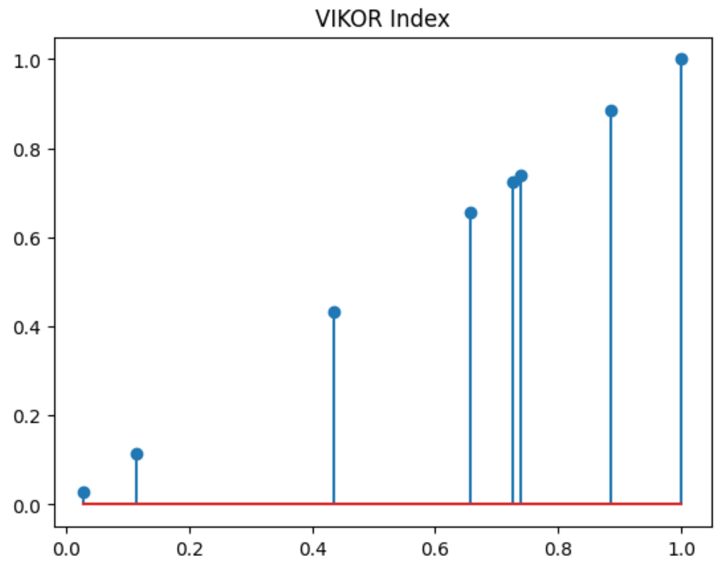

Fig 7. The VIKOR index.

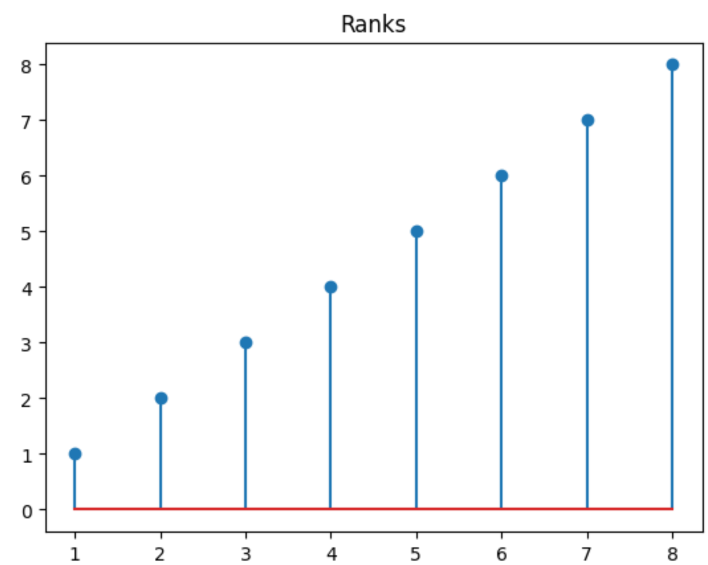

Fig 8. The rank of alternatives.

4. Investigation

This section shows the comparative and sensitivity analysis of the proposed approach. In the comparative analysis, we compered the proposed approach with different MCDM methods to show the validation and effectiveness of the proposed approach. We compared it by four different methods. The results show alternative 1 is the best and alternative 4 is the worst. The results show the proposed approach is effective compared to other MCDM methods. The results of comparative analysis are shown in Fig 9. The proposed approach can deal with the positive and negative criteria in the decision-making process and ranking the alternatives.

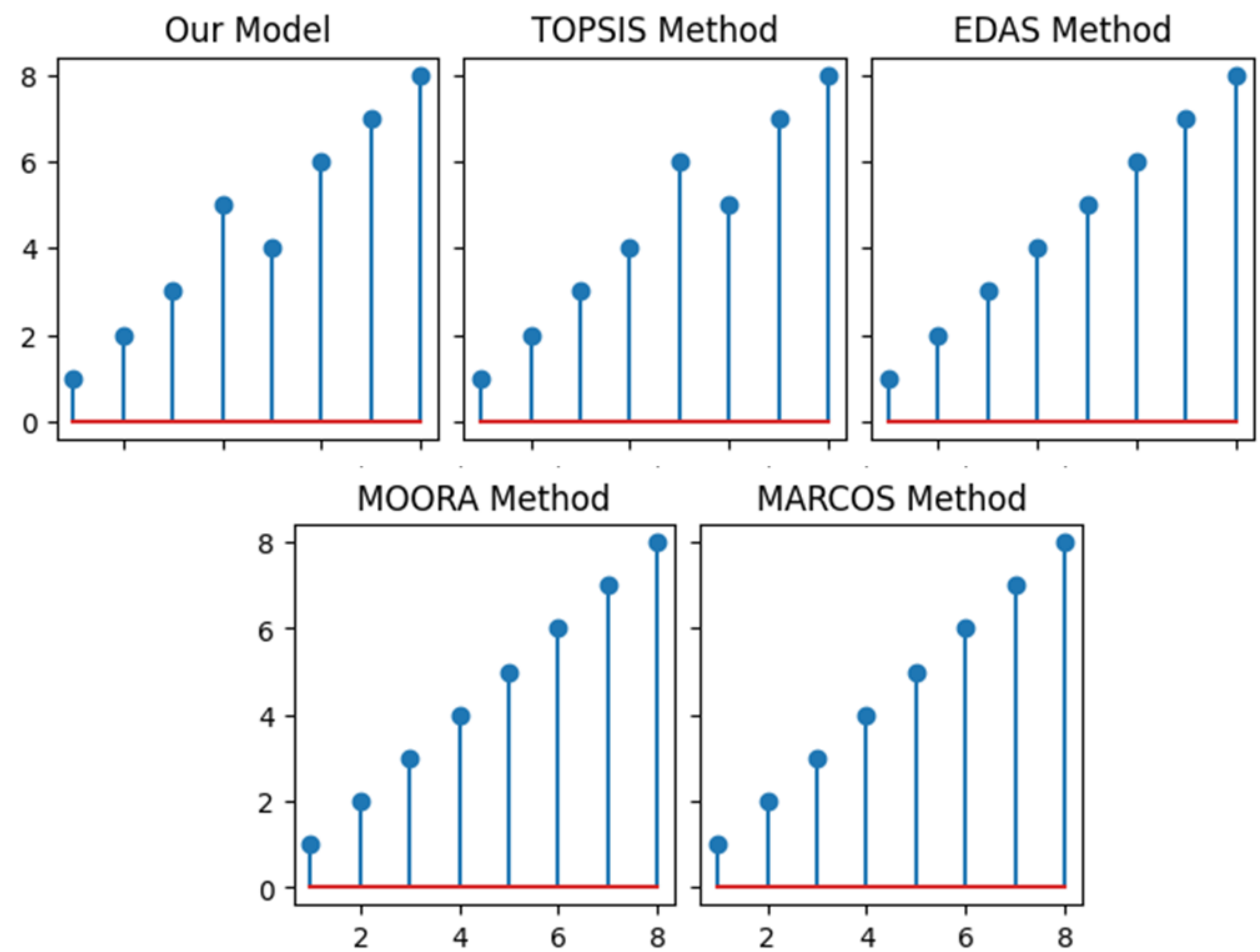

Fig 9. Comparative analysis.

Sensitivity Analysis

In this section, we examine how the ranking of alternatives changes under different conditions. To do this, we adjust the φ value, varying it between 0 and 1, and then observe how the rankings are affected.

Findings*:*

1) After testing different values of φ, the results show that Alternative 1 consistently ranks as the best option, while Alternative 4 remains the worst.
2) The stability of rankings across different scenarios indicates that the proposed model is robust and reliable in decision-making.
3) Figure 10 presents the results of the sensitivity analysis, showing that the rankings do not significantly change under different conditions.

This analysis confirms that the VIKOR method produces stable and reliable rankings, ensuring that the decision-making process is consistent and unaffected by minor changes in parameters.

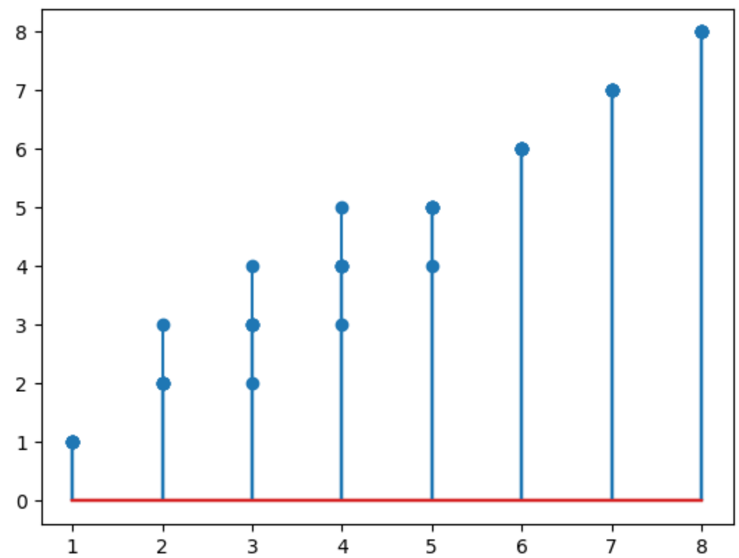

Fig 10. The ranks of alternatives under different cases.

5. Conclusion and Future Work

5.1 Conclusion

This study developed a decision-making model to evaluate Innovation and Entrepreneurship Education in vocational colleges. We used the MEREC method to calculate the importance of each criterion and the VIKOR method to rank the alternatives. Three experts evaluated the options using a scale from 0 to 0.7.

The results showed that Alternative 1 was the best, while Alternative 4 ranked the lowest. A sensitivity analysis was done with ten different cases, and the rankings remained stable, proving the reliability of the model. The comparative analysis with four other MCDM methods confirmed that this approach is effective and can be used to improve decision-making in vocational education.

5.2 Future Work

— Test the model on more vocational colleges and different types of alternatives
— Use artificial intelligence and machine learning to improve accuracy and provide better recommendations
— Compare the results with other MCDM methods like TOPSIS and AHP to check if there are better alternatives
— Study the effect of industry partnerships and hands-on training on the success of innovation and entrepreneurship education
— Conduct long-term research to see how the rankings change over time and how policies impact education
— Develop a digital tool based on this model to help educators and policymakers make better decisions

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