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Quality Assessment in Higher Education Management using the Modified MARCOS Method with Double-Valued Neutrosophic Numbers: A Case Study

Haihua Ding[1], **Haifeng Chen**[2*]

[1]Wenzhou University of Technology, 325000, Zhejiang, China (E-mail: 00195015@wzu.edu.cn)

[2]College of Chemistry and Materials Science, Zhejiang Normal University, 321000, Zhejiang, China
*Corresponding author, E-mail: shchf2023@163.com; shchf@zjnu.cn
https://orcid.org/0009-0004-2590-1240

Abstract

Quality is the core and soul of educational management, and educational management is the carrier of quality. Only by improving the efficiency and quality of educational management can we promote the healthy and long-term development of higher education. In the new era, universities should actively introduce education quality assurance theory and advanced management concepts, reform the education management quality assurance system, and thus play multiple educational functions such as enrollment management, student training, degree awarding, and quality evaluation. Based on the theoretical and event exploration of the quality assurance path of higher education management, China's higher education will inevitably embark on a unique path of innovative development. The quality assessment of higher education management is considered a multiple-attribute decision-making (MADM) problem. Recently, the MARCOS approach has been utilized to advance MADM approaches. Double-valued neutrosophic sets (DVNSs) serve as optimal decision-making approaches to represent uncertainty in data during the evaluation of higher education management in academic institutions. In this research, the MARCOS approach is developed for MADM using DVNSs. Subsequently, the double-valued neutrosophic number MARCOS (DVNN-MARCOS) approach is proposed for MADM. Finally, a numerical example is provided to validate the DVNN-MARCOS model in the context of quality evaluation for higher education management.

Keywords: MADM; DVNSs; MARCOS model; higher education management

1. Introduction

Education management is a guaranteed service rooted in the education industry of universities, laying a solid foundation for improving the quality of education and achieving stable development of school teaching [1]. With the development and progress of society, the management mode of higher education has also undergone profound changes. The quality assurance system is a comprehensive evaluation instituted by the goals, forms, and contents of educational management, and ensures the smooth implementation of educational management work through reasonable means, thereby playing the necessary educational auxiliary role[2]. With the rapid popularization of the concept of education popularization, it is imperative to improve the quality of higher education management and reform the higher education management system[3]. Based on this, the author has analyzed in detail the basic connotation and characteristics of quality assurance in higher education management and proposed a path concept for quality assurance in higher education management, to assist in the construction of a new ecosystem of higher education management[4]. At present, there is no unified definition for the concept of quality assurance in education management, which can only be analyzed from the perspective of basic definition and theoretical connotation. Quality of education management refers to the judgment or measurement of the achievement of established goals by the subject, while the guarantee is to protect it from infringement or destruction and maintain the stability of its supporting structure[5]. Based on studying a large amount of literature on education management quality assurance in the past, the author believes that although there are still significant differences in the subjects and measurement standards of education management quality assurance, research and measures for education management quality assurance should ultimately be implemented on the fundamental aspects of education management quality assurance, such as setting evaluation procedures and methods, establishing quality standards, and establishing quality evaluation institutions, to guide government departments Social organizations, parents, and other educational stakeholders provide "high-quality evidence" to enhance public trust in higher education, enabling universities to gain more development space, opportunities, and resources, and truly achieve high-quality development of educational management[6]. The quality assurance of educational management usually has two significant characteristics[7]. One is the characteristic of the times, which reflects that universities must adopt different education security systems at different stages (development stage of universal higher education, development stage of elite higher education, and development stage of mass higher education). The quality assurance mechanism of higher education management has left a distinct imprint of the times on higher education and is a product of universities adapting to the needs of the times[8]. The second is the system characteristics, specifically the need for an integrated operation to improve the quality of education management [9, 10]. At the level of mechanism, it aims to ensure the smooth implementation of various educational reform projects in universities, and integrate the student-centered concept into teaching practice, in order to improve the efficiency of university management, the quality of talent cultivation, and the level of education. At the level of content assurance, it usually includes factors such as assurance activities, assurance systems, assurance measures, and assurance culture. At the level of mechanism construction, there is a development system and evaluation system that includes quality assurance. Finally, at the content level, it usually includes main elements such as government agencies, social organizations, and universities.

In 1965, Zadeh [11] introduced his groundbreaking theory of fuzzy sets (FSs), aimed at addressing various types of uncertainties. This innovative concept has been successfully applied to model uncertainty across numerous real-world domains. More recently, a new theory known as neutrosophic logic and sets has emerged. The term "neutrosophic" refers to the knowledge of neutral thought, which represents a key distinction between fuzzy and intuitionistic fuzzy logic and sets. Neutrosophic logic, introduced by Florentin [12], posits that each proposition is evaluated with three components: a degree of truth (T), a degree of indeterminacy (I), and a degree of falsity (F). In the neutrosophic sets (NSs), each element of the universe is characterized by these three degrees, all of which fall within the non-standard unit interval [0, 1]. NSs have been successfully applied in various fields, including decision-making [13-15], and have broad applications in natural sciences, operations research, economics, management science, military strategy, and urban planning. They are particularly useful in decision-making scenarios where the ambiguity and complexity of attributes make it difficult to express or evaluate problems using real numbers. However, because NSs are challenging to apply directly in real-life situations, Wang, Smarandache, Zhang, and Sunderraman [16] proposed the concept of SVNSs in 2005. In this framework, the degrees of truth, indeterminacy, and falsity for any element of an NS are restricted to the standard unit interval [0, 1]. The SVNSs generalize several concepts, including classical sets, fuzzy sets, intuitionistic fuzzy sets, and paraconsistent sets, offering a broad range of possibilities for solving real-world problems.

The quality evaluation of higher education management in academic institutions is considered a MADM problem. Recently, the MARCOS model [17] has been utilized to address MADM challenges. While several techniques have been used to process both qualitative and quantitative information simultaneously, they still face limitations, particularly in dealing with DVNSs [18,19], which are well-suited for representing uncertain data during the quality evaluation of higher education management. The primary goal of this research is to overcome the shortcomings of conventional classroom teaching quality evaluation methods, fully account for objective attribute weight, and manage uncertain data. To achieve this, the DVNSs and MARCOS approach were utilized to address the quality evaluation of higher education management. The DVNN-MARCOS approach. Finally, a comparative analysis was instituted between the DVNN-MARCOS approach and existing techniques to validate the effectiveness of the DVNN-MARCOS approach.

2. Preliminary Concepts and Definitions

The concept of Double-Valued Neutrosophic Sets (DVNSs) has been recognized as a valuable tool in managing uncertainty and indeterminacy within complex systems. This framework extends traditional neutrosophic sets by introducing dual membership functions for truth, indeterminacy, and falsity, enabling a more nuanced representation of ambiguous data. In the study presented by Kandasamy [18], DVNSs were employed to explore their applications in constructing minimum-spanning trees and developing clustering algorithms. This usage highlights the practical relevance and adaptability of DVNSs in addressing challenges across various domains in uncertainty analysis.

Definition 1. DVNS is an extension of the classical neutrosophic set, characterized by a pair of membership functions for each of the truth, indeterminacy, and falsity values. Formally, a DVNS as:

$$ZA=\{(\theta, ZT_A(\theta), ZIT_A(\theta), ZIF_A(\theta), ZF_A(\theta))|\theta \in \Theta\}, \quad (1)$$

with $ZT_A(\theta)$ be truth-membership, $ZIT_A(\theta)$ be indeterminacy leaning towards $ZT_A(\theta)$, $ZIF_A(\theta)$ be indeterminacy leaning towards $ZF_A(\theta)$, $ZF_A(\theta)$ is falsity-membership, $ZT_A(\theta), ZIT_A(\theta), ZIF_A(\theta), ZF_A(\theta) \in [0,1]$, $0 \le ZT_A(\theta)+ZIT_A(\theta)+ZIF_A(\theta)+ZF_A(\theta) \le 4$.

The DVNN is expressed as $ZA=(ZT_A, ZIT_A, ZIF_A, ZF_A)$, where $ZT_A, ZIT_A, ZIF_A, ZF_A \in [0,1]$, $0 \le ZT_A + ZIT_A + ZIF_A + ZF_A \le 4$.

Definition 2. The Score Value Number (SVN) for Double-Valued Neutrosophic Numbers (DVNNs) is defined as:

Let $ZA=(ZT_A, ZIT_A, ZIF_A, ZF_A)$ and $ZB=(ZT_B, ZIT_B, ZIF_B, ZF_B)$

$$SVN(ZA)=\frac{(2+ZT_A+ZIT_A-ZIF_A-ZF_A)}{4},\ SVN(ZA)\in[0,1].$$

$$SVN(ZB)=\frac{(2+ZT_B+ZIT_B-ZIF_B-ZF_B)}{4},\ SVN(ZB)\in[0,1]. \quad (2)$$

Definition 3. Let $ZA=(ZT_A, ZIT_A, ZIF_A, ZF_A)$ and $ZB=(ZT_B, ZIT_B, ZIF_B, ZF_B)$ be DVNNs, The Accuracy Value Number (AVN) for a DVNN is defined as:

$$AVN(ZA)=\frac{(ZT_A+ZIT_A+ZIF_A+ZF_A)}{4},\ AVN(ZA)\in[0,1]\ . \quad (3)$$

$$AVN(ZB)=\frac{(ZT_B+ZIT_B+ZIF_B+ZF_B)}{4},\ AVN(ZB)\in[0,1]\ . \quad (3)$$

The AVN provides an evaluation of the accuracy or reliability of a DVNN by considering the difference between its truth and falsity components. This measure plays a crucial role in comparing and ranking DVNNs, especially in scenarios where indeterminacy is not a primary concern.

Definition 4

Let $ZA=\left(ZT_A,ZIT_A,ZIF_A,ZF_A\right)$ and $ZB=\left(ZT_B,ZIT_B,ZIF_B,ZF_B\right)$, $SVN\left(ZA\right)=\frac{\left(2+ZT_A+ZIT_A-ZIF_A-ZF_A\right)}{4}$, $SVN\left(ZB\right)=\frac{\left(2+ZT_B+ZIT_B-ZIF_B-ZF_B\right)}{4}$, $AVN\left(ZA\right)=\frac{\left(ZT_A+ZIT_A+ZIF_A+ZF_A\right)}{4}$, $AVN\left(ZB\right)=\frac{\left(ZT_B+ZIT_B+ZIF_B+ZF_B\right)}{4}$, if $SVN\left(ZA\right)<SVN\left(ZB\right)$, $ZA<ZB$; if $SVN\left(ZA\right)=SVN\left(ZB\right)$, (1)if $AVN\left(ZA\right)=AVN\left(ZB\right)$, $ZA=ZB$; (2) if $AVN\left(ZA\right)>AVN\left(ZB\right)$, $ZA<ZB$.

Definition 5 Let $ZA=\left(ZT_A,ZIT_A,ZIF_A,ZF_A\right)$ and $ZB=\left(ZT_B,ZIT_B,ZIF_B,ZF_B\right)$ be two DVNNs, the operations are defined as:

$$\begin{aligned}
&(1)\ ZA\oplus ZB=\left(ZT_A+ZT_B-ZT_AZT_B,ZIT_A+ZIT_B-ZIT_AZIT_B,ZIF_AZIF_B,ZF_AZF_B\right);\\
&(2)\ ZA\otimes ZB=\left(ZT_AZT_B,ZIT_AZIT_B,ZIF_A+ZIF_B-ZIF_AZIF_B,ZF_A+ZF_B-ZF_AZF_B\right);\\
&(3)\ \lambda ZA=\left(1-\left(1-ZT_A\right)^{\lambda},1-\left(1-ZIT_A\right)^{\lambda},\left(ZIF_A\right)^{\lambda},\left(ZF_A\right)^{\lambda}\right),\lambda>0;\\
&(4)\ \left(ZA\right)^{\lambda}=\left(\left(ZT_A\right)^{\lambda},\left(ZIT_A\right)^{\lambda},1-\left(1-ZIF_A\right)^{\lambda},1-\left(1-ZF_A\right)^{\lambda}\right),\lambda>0.
\end{aligned}$$

Definition 6. Let $ZA=\left(ZT_A,ZIT_A,ZIF_A,ZF_A\right)$ and $ZB=\left(ZT_B,ZIT_B,ZIF_B,ZF_B\right)$, the distance measure between $ZA=\left(ZT_A,ZIT_A,ZIF_A,ZF_A\right)$ and $ZB=\left(ZT_B,ZIT_B,ZIF_B,ZF_B\right)$ is defined as[20]:

$$DVNNDM\left(ZA,ZB\right)=\frac{1}{4}\left(\begin{array}{l}
ZT_A\log\frac{2ZT_A}{ZT_A+ZT_B}+ZT_B\log\frac{2ZT_B}{ZT_A+ZT_B}\\
+ZT_A\log\frac{2ZIT_A}{ZIT_A+ZIT_B}+ZIT_B\log\frac{2ZIT_B}{ZIT_A+ZIT_B}\\
+ZT_A\log\frac{2ZIF_A}{ZIF_A+ZIF_B}+ZIF_B\log\frac{2ZIF_B}{ZIF_A+ZIF_B}\\
+ZF_A\log\frac{2ZF_A}{ZF_A+ZF_B}+ZF_B\log\frac{2ZF_B}{ZF_A+ZF_B}
\end{array}\right) \tag{4}$$

3. DVNN-MARCOS approach for MADM

This section outlines the MARCOS (Measurement Alternatives and Ranking according to the Compromise Solution) method within the framework of Double-Valued Neutrosophic Numbers (DVNN) for Multi-Attribute Decision Making (MADM). The steps of the proposed method are detailed as follows:

Step 1: Create the Initial Decision Matrix

- Construct the decision matrix using DVNN values, where each alternative is evaluated against the criteria using DVNNs.
- Apply the Score Function to convert DVNNs into crisp values, providing a standardized decision matrix.
- Combine individual decision matrices (if applicable) into a single aggregated decision matrix.

Step 2. Creating the extended initial matrix. Expand the initial decision matrix by including the ideal (best) and anti-ideal (worst) solutions based on the criteria. This ensures a comprehensive comparison framework for all alternatives.

$$R = \begin{array}{c} AAI \\ .. \\ AI \end{array} \begin{bmatrix} r_{aa1} & \cdots & r_{aan} \\ \vdots & \ddots & \vdots \\ r_{ai1} & \cdots & r_{ain} \end{bmatrix} \tag{5}$$

Where AAI refers to the cost criteria and AI refers to the positive criteria.

$$AAI = \min r_{ij}\ for\ positive \text{ criteria } and \max r_{ij} for\ cost \text{ criteria} \tag{6}$$

$$AI = \max r_{ij}\ for\ positive \text{ criteria } and \min r_{ij} for\ cost \text{ criteria} \tag{7}$$

Step 3. Normalize the extended matrix.

$$P_{ij} = \frac{r_{ai}}{r_{ij}}\ for\ cost \text{ criteria} \tag{8}$$

$$P_{ij} = \frac{r_{ij}}{r_{ai}}\ for\ positive \text{ criteria} \tag{9}$$

Step 4. Determine the weighted matrix. Multiply the normalized matrix by the weights of the criteria to form the weighted normalized matrix:

$$q_{ij} = w_j * n_{ij} \tag{10}$$

Step 5. Computing the utility degree. Calculate the utility degree for each alternative relative to the ideal and anti-ideal solutions:

$$K_i^- = \frac{S_i}{S_{aai}} \tag{11}$$

$$K_i^+ = \frac{S_i}{S_{ai}} \tag{12}$$

$$S_i = \sum_{i=1}^{n} q_{ij} \tag{13}$$

Step 6. Compute the utility function. Derive the utility function for each alternative using the utility degrees, which represent its relative closeness to the ideal solution.

$$f(K_i) = \frac{K_i^- + K_i^+}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}} \tag{14}$$

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \tag{15}$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \tag{16}$$

Step 7. Order the alternatives.

- Rank the alternatives in descending order based on their utility function values.
- The alternative with the highest utility function value is considered the most optimal solution.

4. A Case study

The rise and fall of higher education are closely related to national development, social order, and individual well-being. Education management usually includes many important links such as enrollment management, student training, degree awarding, quality evaluation, etc. Therefore, universities need to not only do a good job in administrative management but also accelerate the construction of management mechanisms. Firstly, universities must continue to improve the enrollment management system for bachelor's and master's degrees to ensure the quality of students; Secondly, universities must deeply understand the significance of talent cultivation and establish a comprehensive talent cultivation mechanism to ensure the quality and efficiency of talent cultivation, such as implementing professional title evaluation mechanism, pre-employment appointment mechanism, employee assessment mechanism, service system, teaching mechanism, scientific research system, etc. In addition, universities must establish a guarantee system for credit allocation, degree awarding, course learning, and project research to help students complete their studies; Finally, universities must establish a quality assurance system for degree awarding, taking academic constraints, incentives, and management as entry points to effectively improve the academic quality of universities. In addition, universities must establish a quality evaluation mechanism that is compatible with the above system to supervise the implementation of educational policies and the implementation of educational systems, to compensate for the shortcomings and deficiencies of university education management. The key to improving the quality of education is talent cultivation, which requires cooperation from multiple parties such as the government, society, and universities to establish a multi-level internal quality assurance system (such as enrollment quality assurance system, training quality assurance system, degree quality assurance system, etc.), comprehensively promoting the rapid development of higher education from the perspectives of ideology, organization, and activities. Firstly, university managers must clearly guide themselves with internal guarantees and promote the organic integration of administrative management and professional teaching, such as establishing and improving constraint, assessment, and incentive systems, as well as improving quality management, control, and evaluation in areas such as scientific research and development, cultural services, and education, in order to promote the long-term development of universities; Secondly, it is necessary to establish an external evaluation system with the participation and governance of multiple subjects, strictly control the quality of education management, pay attention to the value and effectiveness of subject participation, take internal university evaluation as the core, supplemented by external government evaluation and social evaluation, and form a stable pattern of internal and external coordinated development; Finally, through administrative means, promote the effective integration of internal and external evaluation mechanisms and embed them into educational management work, thereby deepening the management function of internal and external guarantee mechanisms. The quality evaluation of higher education management is MADM. Six provincial comprehensive universities are evaluated with 15 attributes.

In the first step, three experts evaluate the decision matrix, which is presented in Table 1. Their input serves as the foundation for further calculations and analysis.

Next, using Equation (5), an extended version of the decision matrix is constructed. This step ensures that all relevant data is prepared for the subsequent normalization process.

Following this, Equation (8) is applied to normalize the decision matrix. The normalized results are shown in Table 2. After normalization, the criteria weights are calculated, and these weights are illustrated in Figures (1a) and (1b) which illustrate the following points:

The weights for the criteria show significant variability, indicating that different criteria hold varying levels of importance.

Some criteria, such as "Governance and Leadership" (0.0711) and "Strategic Planning and Policy Development" (0.0707), have relatively higher weights, suggesting their strong influence or importance in the context.

The lowest weights are observed for "Use of Technology in Management and Learning" (0.0630) and "Sustainability and Environmental Practices" (0.0622), indicating these criteria are less influential compared to others.

Several criteria, such as "Quality of Academic Programs" (0.0699) and "Financial Management and Resource Allocation" (0.0668), are in the mid-range, reflecting moderate importance.

There are sharp rises and drops in the weights across the criteria:

For instance, after the peak at "Governance and Leadership" (0.0711), the weight for "Use of Technology in Management and Learning" (0.0630) drops sharply.

Similarly, the weight increases again for "Strategic Planning and Policy Development" (0.0707), indicating a strong emphasis on these areas.

Criteria such as "Governance and Leadership", "Strategic Planning and Policy Development", and "Institutional Reputation and Accreditation" have consistently higher weights, emphasizing their critical roles in the evaluation.

Weights for criteria like "Sustainability and Environmental Practices" and "Monitoring and Evaluation Systems" are relatively consistent but low, showing they are not as highly prioritized.

The variability in the weights highlights that some aspects, like leadership, policy development, and academic quality, are deemed more critical, possibly because they directly impact the overall outcomes or goals.

Lower weights for criteria like "Sustainability" or "Technology Usage" could indicate these are either less prioritized in this context or less impactful in achieving the objectives.

The steep changes between certain criteria suggest a strong delineation of priorities.

Subsequently, the weighted decision matrix is created using Equation (9). This process adjusts the normalized values by their respective weights, and the results are displayed in Table 3.

In the fifth step, the utility degree is calculated using Equations (11) through (13). These calculations help in determining how well each alternative aligns with the defined criteria.

The next step involves computing the utility function using Equations (14) through (16). This function provides a comprehensive measure of the effectiveness of each alternative.

Finally, based on the computed values, the alternatives are ranked. The final order of the alternatives is shown in Figure 2, providing a clear comparison of their relative performance.

Table 1. Opinions of the first expert.

	A_1	A_2	A_3	A_4	A_5	A_6
C_1	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.16, 0.47,0.28, 0.59)	(0.79, 0.23, 0.80, 0.34)
C_2	(0.12, 0.65, 0.41, 0.69)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.65, 0.71, 0.20, 0.35)
C_3	(0.65, 0.71, 0.20, 0.35)	(0.79, 0.23, 0.80, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)
C_4	(0.79, 0.23, 0.80, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.32, 0.66,0.91, 0.34)
C_5	(0.16, 0.47,0.28, 0.59)	(0.44, 0.45,0.26, 0.53)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)
C_6	(0.44, 0.45,0.26, 0.53)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.16, 0.47,0.28, 0.59)
C_7	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.32, 0.66,0.91, 0.34)	(0.79, 0.23, 0.80, 0.34)
C_8	(0.12, 0.65, 0.41, 0.69)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.65, 0.71, 0.20, 0.35)
C_9	(0.65, 0.71, 0.20, 0.35)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)
C_{10}	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.79, 0.23, 0.80, 0.34)	(0.32, 0.66,0.91, 0.34)
C_{11}	(0.16, 0.47,0.28, 0.59)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.44, 0.45,0.26, 0.53)
C_{12}	(0.44, 0.45,0.26, 0.53)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)
C_{13}	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.79, 0.23, 0.80, 0.34)
C_{14}	(0.12, 0.65, 0.41, 0.69)	(0.65, 0.71, 0.20, 0.35)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)
C_{15}	(0.12, 0.65, 0.41, 0.69)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)	(0.32, 0.66,0.91, 0.34)	(0.12, 0.65, 0.41, 0.69)

Table 2. The normalized data.

	A_1	A_2	A_3	A_4	A_5	A_6
C_1	1	0.850242	0.830918	0.954911	0.850242	0.908213
C_2	0.594306	0.864769	0.626335	0.6121	0.70344	1
C_3	1	0.669039	0.864769	0.677343	0.615658	0.652432

C_4	0.903846	1	0.879808	0.831731	0.915064	0.831731
C_5	0.868313	0.834019	0.711934	0.783265	1	0.813443
C_6	1	0.75321	0.947218	0.907275	0.736091	0.801712
C_7	0.826087	1	0.850242	0.830918	0.89533	0.908213
C_8	0.594306	0.864769	0.626335	0.6121	0.70344	1
C_9	1	0.644128	0.871886	0.670225	0.622776	0.645314
C_{10}	1	0.84434	0.834906	0.878931	0.886792	0.816038
C_{11}	0.795181	0.990964	0.808735	0.799699	1	0.948795
C_{12}	0.957447	0.788754	1	0.975684	0.775076	0.849544
C_{13}	1	0.832536	1	0.832536	0.832536	0.934609
C_{14}	0.594306	1	0.644128	0.622776	0.696323	0.615658
C_{15}	1	0.744856	0.864198	0.775034	0.716049	0.746228

Table 3. The weighted normalized data.

	A_1	**A_2**	**A_3**	**A_4**	**A_5**	**A_6**
C_1	0.063119	0.053667	0.052447	0.060273	0.053667	0.057326
C_2	0.041543	0.060449	0.043782	0.042787	0.049172	0.069902
C_3	0.071146	0.047599	0.061525	0.04819	0.043802	0.046418
C_4	0.056982	0.063044	0.055467	0.052436	0.057689	0.052436
C_5	0.059765	0.057404	0.049001	0.053911	0.068828	0.055988
C_6	0.067962	0.051189	0.064375	0.06166	0.050026	0.054486
C_7	0.051333	0.06214	0.052834	0.051633	0.055636	0.056436
C_8	0.041543	0.060449	0.043782	0.042787	0.049172	0.069902
C_9	0.07075	0.045572	0.061686	0.047419	0.044062	0.045656
C_{10}	0.063044	0.053231	0.052636	0.055411	0.055907	0.051446
C_{11}	0.053158	0.066246	0.054064	0.05346	0.06685	0.063427
C_{12}	0.063464	0.052282	0.066285	0.064673	0.051376	0.056312
C_{13}	0.064175	0.053428	0.064175	0.053428	0.053428	0.059978
C_{14}	0.039393	0.066285	0.042696	0.041281	0.046156	0.040809
C_{15}	0.066567	0.049583	0.057527	0.051592	0.047666	0.049674

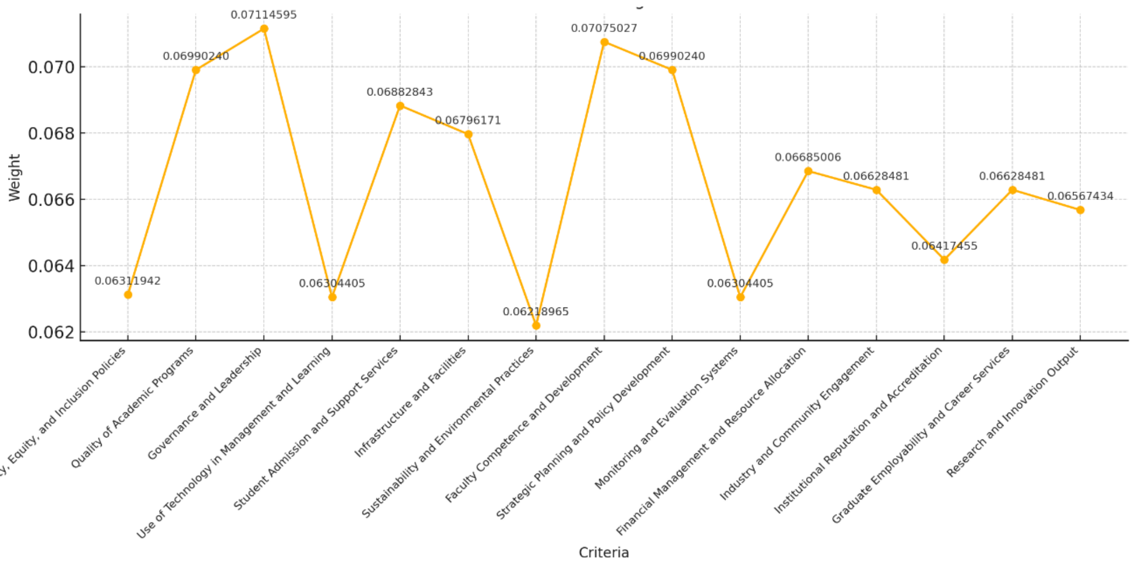

Figure 1a. The criteria weights.

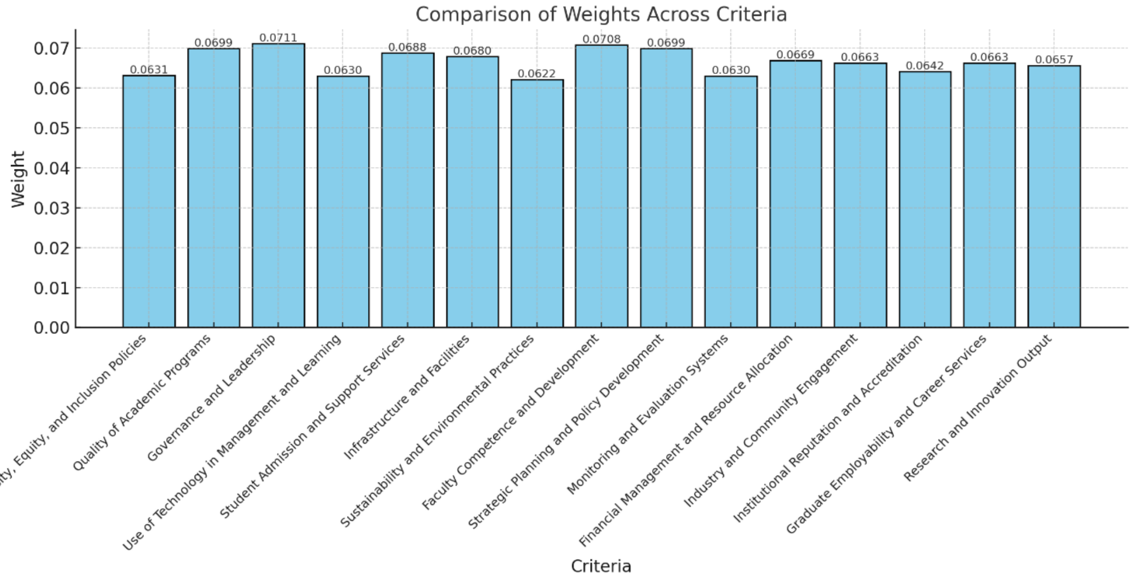

Figure 1b. Comparison of weights across criteria

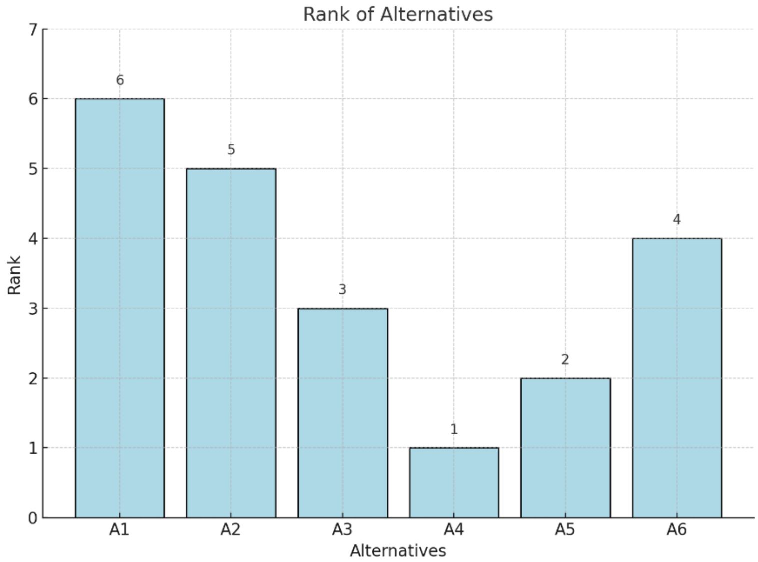

Figure 2. The rank of alternatives.

5. Analysis and Discussion

We conducted a sensitivity analysis by varying the criteria weights across multiple scenarios to examine the ranking of alternatives. Specifically, the criteria weights were adjusted in eight different cases, as illustrated in Figure 3. Using these modified weights, the proposed method was applied to evaluate the alternatives under each case.

The resulting rankings for the alternatives under these scenarios are presented in Figure 4. The analysis demonstrates that the rankings of the alternatives remain consistent and stable, even when the criteria weights are altered across different cases. This stability highlights the robustness of the proposed method.

Figure 3. The different criteria weights.

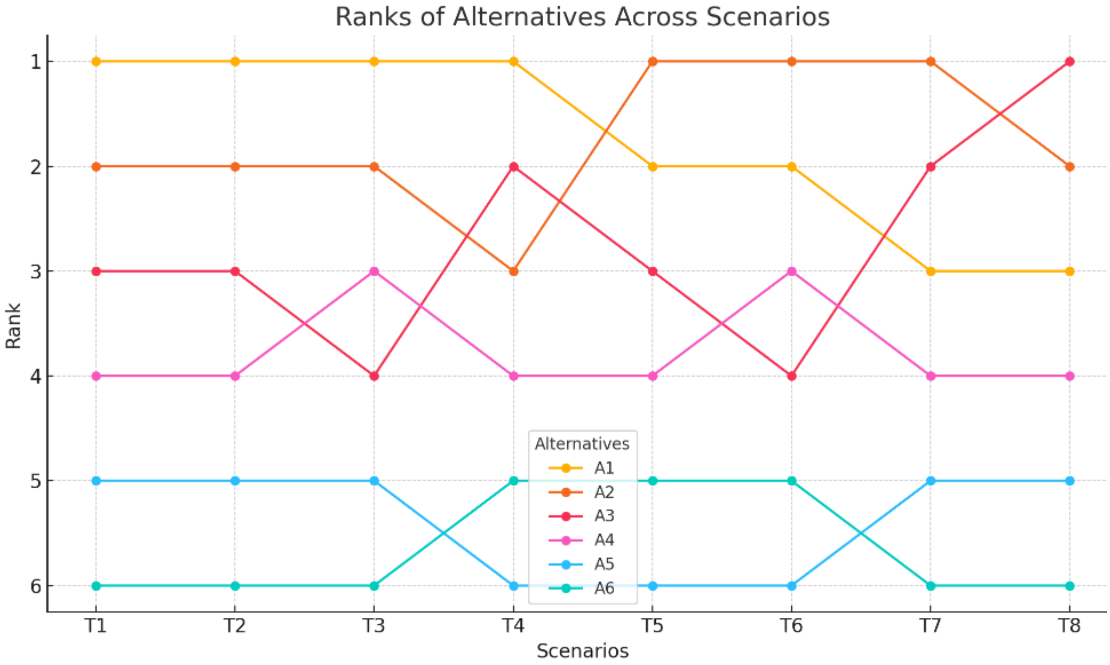

Figure 4. The different ranks of alternatives.

This part shows the comparative analysis between the proposed method and other methods to show the strength of the proposed method. We used the criteria weights of this study and ranked the other methods as shown in Figure 5, this figure compares the ranks of alternatives (A1 to A6) using five different methods: Proposed, CoCoSo method, VIKOR method, Taxonomy method, and EDAS method. Each bar represents the rank assigned to an alternative by a specific method, with the y-axis inverted to display the best rank (1) at the top.

Observations:

For A1, all methods rank it at 6, showing consensus that it is the least favorable alternative.

Similarly, A2 has a consistent rank of 5 across all methods.

For A3, the ranks vary significantly:

Proposed and CoCoSo methods rank it at 4.

VIKOR and EDAS methods rank it at 3.

Best-Performing Alternative:

A4 consistently ranks as 1 across all methods, indicating unanimous agreement that it is the most favorable choice.

A5 is ranked 2 by most methods, except for EDAS, which places it at 4.

A6 has ranks ranging from 3 to 4, showing slight variations in its evaluation.

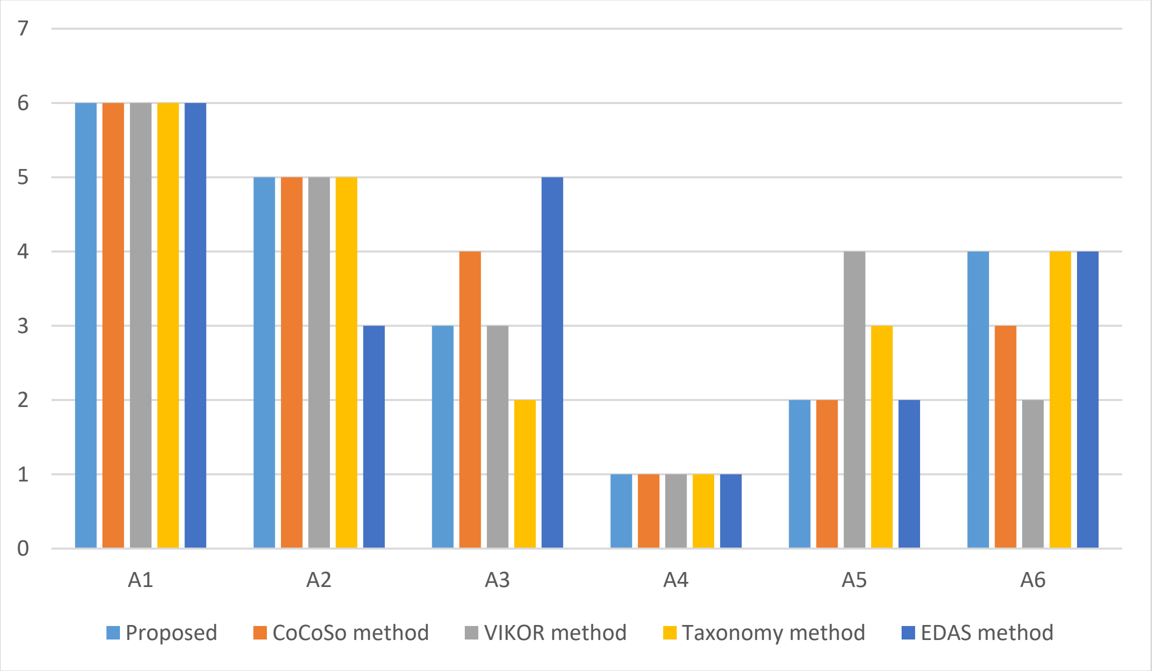

Figure 5. The comparative analysis.

6. Conclusion

The guaranteed environment for educational management must be based on talent cultivation and educational management, integrating individual, government, society, and other aspects to achieve high-quality development of higher education management. Firstly, create a legal environment. The legal system provides strong theoretical guidance and practical constraints for the construction of a quality assurance system for higher education management. Secondly, create an atmosphere of "quality culture". Creating a "quality culture" atmosphere is a prerequisite and main content for improving the quality of education management. It requires highly coordinated and consistent understanding and practice among diverse social entities, in order to form a culture of integration and progress, good quality construction, quality supervision, and quality evaluation. The quality evaluation of higher education management in academic institutions is considered a MADM problem. DVNSs are employed as an effective tool to represent uncertainty during the evaluation process. In this research, the MARCOS method is adapted for MADM for DVNSs. Subsequently, the DVNN- MARCOS approach is developed for MADM. The key contributions of this research are outlined: (1) a novel MADM approach is introduced based on MARCOS approach under DVNSs, and (2) a numerical example for evaluating higher education management in academic institutions, utilizing the DVNN- MARCOS model, is provided.

7. Research Limitations

First, the paper has a limitation in terms of the number of case studies presented. It validates the DVNN- MARCOS model using only one numerical example, which may not be sufficient to demonstrate the model's broad applicability. The lack of diverse case studies, particularly in different types of universities or across various countries, limits the generalizability of the model and its application to a wider range of educational management contexts. Second, the study does not adequately account for dynamic factors that can influence the quality of higher education management. In practice, educational management is affected by constant changes such as policy shifts, technological developments, and variations in faculty quality. The paper’s analysis is based on static data, which overlooks the impact of these dynamic and evolving factors on the quality evaluation process. The paper does not sufficiently address how these subjective factors can be combined with objective methods to create a more balanced and rational decision-making model.

8. Three directions for further research

One potential direction for further research is to expand the scope of case studies. Future work could apply the DVNN- MARCOS model to a wider variety of real-world scenarios, including different types of universities, such as research institutions, application-oriented universities, or vocational colleges. Additionally, testing the model in different countries with varying educational management systems could help verify its robustness and adaptability in diverse contexts. Another direction is to incorporate dynamic decision-making models into the DVNN- MARCOS framework. Higher education management operates in a constantly changing environment, influenced by factors such as policy reforms, advancements in technology, and fluctuations in faculty quality. Future research could explore how dynamic factors can be incorporated into the model, perhaps through time-series analysis or dynamic fuzzy decision-making techniques, to enhance the model’s ability to cope with these changes. A third direction for further research is to investigate how subjective and objective weights can be more effectively combined. Future studies could explore methods for integrating these subjective and objective factors, potentially through the use of multi-criteria decision-making techniques, expert systems, or even machine learning, to improve the rationality and accuracy of the evaluation process.

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