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Fermatean Neutrosophic Fuzzy Methodology for Teaching Quality Analysis in University Basketball Training

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Abstract: University basketball training plays a pivotal role in developing athletes' technical, tactical, and physical skills. Analysis of teaching quality in this context is essential for optimizing training methodologies, enhancing player performance, and ensuring long-term athletic success. This paper explores a structured approach to assessing teaching quality in university basketball training, considering factors such as coaching competence, training design, player engagement, and psychological preparation. The integration of modern performance analysis tools, feedback mechanisms, and facility assessments contributes to a comprehensive evaluation framework. By adopting a multi-dimensional assessment approach, universities can refine their training programs to create a more effective and engaging learning environment for student-athletes. We use multi-criteria decision-making (MCDM) to analysis these different criteria and alternatives. Two MCDM methods are used such as BWM to compute the criteria weights and the EDAS method to rank the alternatives. These methods are used under the Fermatean Neutrosophic Fuzzy sets to deal with uncertainty information. The sensitivity analysis is applied to show the stability of the ranks.

Keywords: Fermatean Neutrosophic Fuzzy; Basketball Training; Teaching Quality; Decision Making; MCDM Approach.

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1. Introduction

Basketball training at the university level plays a crucial role in developing athletes' technical skills, tactical awareness, physical conditioning, and teamwork. To ensure that training programs effectively enhance player performance, a structured and systematic evaluation of teaching quality is necessary. Teaching quality evaluation in university basketball training provides insights into the effectiveness of coaching methods, training curriculum, player development, and overall learning outcomes[1], [2]. By assessing various aspects such as instructional techniques, athlete engagement, and training intensity, universities can refine their coaching strategies to optimize performance and development. Evaluating the quality of basketball training requires a multi-dimensional approach that incorporates both qualitative and quantitative assessment methods. Traditional performance metrics such as win-loss records and player statistics only offer a limited perspective on training effectiveness[3], [4]. A comprehensive evaluation framework must consider factors like coaching competence, player motivation, training structure, and feedback mechanisms. Moreover, player progression over time, injury prevention strategies, and psychological preparedness must also be considered to provide a holistic view of training success. One of the key challenges in evaluating teaching quality in basketball training is balancing standardized assessment methods with the unique demands of sports education. Unlike conventional academic subjects, basketball training requires a dynamic, performance-based evaluation that accounts for skill execution under pressure, teamwork, and adaptability. Utilizing modern technology, such as video analysis, biometric tracking, and AI-driven performance analytics, can enhance the objectivity of evaluations[5], [6]. By integrating data-driven insights with traditional coaching observations, universities can establish a more comprehensive assessment system.

Another critical aspect of evaluating teaching quality in university basketball training is the feedback loop between coaches and players. Effective coaching is not just about instruction but also about adaptation based on player needs and performance data. Frequent feedback sessions, individualized training plans, and mentorship opportunities contribute to a more effective learning environment. When players receive personalized guidance tailored to their strengths and weaknesses, they are more likely to improve and reach their full potential.

Moreover, teaching quality evaluation must consider external factors such as facilities, equipment, and training conditions. The availability of well-maintained courts, strength and conditioning programs, and access to sports medicine and nutrition services can significantly impact training effectiveness[7], [8]. Universities that invest in high-quality infrastructure and support systems enable their basketball programs to compete at higher levels. Thus, facility assessment should be an integral part of the overall teaching quality evaluation.

The role of psychological training in university basketball coaching should also be emphasized in the evaluation process. Mental resilience, strategic decision-making, and stress management are essential components of high-performance basketball. Coaches who incorporate mental conditioning exercises, visualization techniques, and leadership training can significantly enhance player confidence and game performance. Evaluating how well coaches integrate psychological training into their programs is crucial in determining overall teaching effectiveness.

Analysis of the teaching quality of university basketball training requires a multifaceted approach that blends technical analysis, player development metrics, coaching methodologies, and environmental factors. By implementing structured evaluation criteria and leveraging modern assessment tools, universities can enhance their basketball programs and foster athlete growth. A robust evaluation framework not only improves current training standards but also ensures long-term sustainability in athletic excellence[9], [10]. Through continuous assessment and refinement, universities can create a more effective and engaging training environment that benefits both players and coaching staff.

This is achieved by applying a hybrid strategy that incorporates literature research on neutrosophic sets, weight finding techniques, and ranking algorithms to handle a Multi-Criteria Decision Making (MCDM) problem with multi-perspective analysis.

This idea is further expanded by neutrophilic sets, which have false, doubtful, and genuine membership degrees. This addendum greatly broadens the range of situations that may be handled successfully, and uncertainty here refers to the degree of ambiguity or ignorance regarding the element's belonging or non-belonging connection[11], [12]. Considering this, Antony and Jansi presented the Fermatean Neutrosophic Set (FNS), a noteworthy development that relaxes earlier restrictions and increases its applicability in pattern detection and decision-making. True, uncertain, and fake membership degrees are the three components that make up FNS. The square sum of these components in FNS is restricted between 0 and 2, in contrast to typical fuzzy sets or intuitionistic fuzzy sets. This relaxation enables a greater range of values to adjust to increased fuzziness and uncertainty[13], [14].

The amount of literature on Fermatean fuzzy sets has increased recently, and scholars have thoroughly examined many facets of this idea, including its definitions, features, operational rules, mathematical underpinnings, and applications. Nonetheless, there is very little study on FNS, particularly in decision-making. It is even less common to use FNS to create more resilient and adaptable decision support systems and to include the fuzziness and uncertainty that are inherent in decision-making difficulties[15], [16]. This gives future researchers a lot of room to improve a more thorough and realistic evaluation of potential solutions.

1.1 Motivation

To provide a BWM method for processing ambiguous data that respects FNFS and has a solid mathematical foundation and credibility.

To establish sustainability goals in terms to the needs and uncertainties of the future.

To assess the criteria and the alternatives of the MCDM issue.

To use the ranking results of MCDM alternative selection issue to illustrate the efficacy of the proposed MCDM approach BWM-MARCOS.

1.2 Contribution

Fermatean neutrosophic fuzzy methodology is used in this study for Teaching Quality Analysis in University Basketball Training. This framework is used to deal with uncertainty information in the decision-making process.

Two MCDM methods are used in this study such as BWM to compute the criteria weights and the EDAS method to rank the alternatives.

Ten alternatives and nine criteria are used in this study.

Sensitivity analysis is applied to show the stability of the ranks.

2. Fermatean neutrosophic fuzzy methodology (FNF)

In this section, we show definitions of FNF with the methodology of the MCDM methods. We show the steps of the BWM to compute the criteria weights and the steps of the EDAS method to rank the alternatives.

Definition 1[17]

Let Z be a universal set and has components named FNF and

$\Lambda_{\beta_i} = \left\{\left(f_{n_i}, T\left(f_{n_i}\right), I\left(f_{n_i}\right), F\left(f_{n_i}\right)\right) f_{n_i} \in Z\right\}$ and belongingness degree $T\left(f_{n_i}\right): Z \rightarrow [0,1]$, non-belongingness degree $F\left(f_{n_i}\right): Z \rightarrow [0,1]$, and indeterminacy degree $I\left(f_{n_i}\right): Z \rightarrow [0,1]$

$$0 \leq T\left(f_{n_i}\right)^3 + F\left(f_{n_i}\right)^3 \leq 1 \tag{1}$$

$$0 \leq I\left(f_{n_i}\right)^3 \leq 1 \tag{2}$$

$$0 \leq T\left(f_{n_i}\right)^3 + I\left(f_{n_i}\right)^3 + F\left(f_{n_i}\right)^3 \leq 2 \tag{3}$$

Definition 2

The score function can be defined as:

$$\left(\Lambda_{\beta_i}\right) = T\left(f_{n_i}\right)^3 \left(1 + I\left(f_{n_i}\right)^3 \left(1 - T\left(f_{n_i}\right)^3 - F\left(f_{n_i}\right)^3\right)\right) \tag{4}$$

Definition 3

Operations of FNF can be defined as:

$$\Lambda_{\beta_1}^c = \left\{F\left(f_{n_1}\right), \left(1 - I\left(f_{n_1}\right)\right), T\left(f_{n_1}\right)\right\} \tag{5}$$

$$\Lambda_{\beta_1} \cup \Lambda_{\beta_2} = \left\{\max\left(T\left(f_{n_1}\right), T\left(f_{n_2}\right)\right), \min\left(I\left(f_{n_1}\right), I\left(f_{n_2}\right)\right), \min\left(F\left(f_{n_1}\right), F\left(f_{n_2}\right)\right)\right\} \tag{6}$$

$$\Lambda_{\beta_1} \cap \Lambda_{\beta_2} = \left\{\min\left(T\left(f_{n_1}\right), T\left(f_{n_2}\right)\right), \max\left(I\left(f_{n_1}\right), I\left(f_{n_2}\right)\right), \max\left(F\left(f_{n_1}\right), F\left(f_{n_2}\right)\right)\right\} \tag{7}$$

$$\Lambda_{\beta_1} \oplus \Lambda_{\beta_2} = \left\{\sqrt[3]{T\left(f_{n_1}\right)^3 + T\left(f_{n_2}\right)^3 - T\left(f_{n_1}\right)^3 T\left(f_{n_2}\right)^3}, I\left(f_{n_1}\right)^3 I\left(f_{n_2}\right)^3, F\left(f_{n_1}\right)^3 F\left(f_{n_2}\right)^3\right\} \tag{8}$$

$\Lambda_{\beta_1} \otimes \Lambda_{\beta_2} =$
$$\left\{T(f_{n_1})^3 T(f_{n_2})^3, \sqrt[3]{I(f_{n_1})^3 + I(f_{n_2})^3 - I(f_{n_1})^3 I(f_{n_2})^3}, \sqrt[3]{F(f_{n_1})^3 + F(f_{n_2})^3 - F(f_{n_1})^3 F(f_{n_2})^3}\right\}$$
(9)

Steps of the BWM to compute the criteria weights.

The set of criteria are defined and collected by the opinions of the experts and decision makers to be evaluated.

Experts and decision makers can define the best and the worst criterion from the set of criteria and sub criteria.

Experts and decision makers can evaluate the best criterion compared to other criteria.

Experts and decision makers can evaluate the worst criterion compared to other criteria.

Then we compute the criteria weights based on:

$\min \max \left\{\left|w_B - C_{B_j} w_j\right|, \left|w_B - C_{W_j} w_W\right|\right\}$ subject to (10)

$\sum_j w_j = 1$ (11)

$w_j > 0;\ \forall_j$ (12)

Then we apply the steps of the EDAS method to rank the alternatives such as:

Create the decision matrix.

Experts and decision makers are using the Fermatean neutrosophic fuzz numbers (FNFNs) to create the decision matrix. Then we apply the score function to obtain crisp values. Then we combine the decision matrix.

Compute the average solution such as:

$A_j = \frac{\sum_{i=1}^{m} y_{ij}}{m}; i = 1, \ldots, m; j = 1, \ldots, n$
(13)

Where y_{ij} refers to the value in the combined decision matrix.

Determine the positive and negative distances from the average solutions such as

$PA_{ij} = \frac{\max\left(0, (y_{ij} - A_j)\right)}{A_j}$ (14)

$CA_{ij} = \frac{\max\left(0, (A_j - y_{ij})\right)}{A_j}$ (15)

And for negative criteria

$$PA_{ij} = \frac{\max\left(0,(A_j - y_{ij})\right)}{A_j} \tag{16}$$

$$CA_{ij} = \frac{\max\left(0,(y_{ij} - A_j)\right)}{A_j} \tag{17}$$

Determine the weighted PA_{ij} and CA_{ij}

$$SPA_{ij} = \sum_{j=1}^{n} PA_{ij}\, w_j \tag{18}$$

$$SCA_{ij} = \sum_{j=1}^{n} CA_{ij}\, w_j \tag{19}$$

Determine the weighted normalized PA_{ij} and CA_{ij}

$$NSPA_{ij} = \frac{SPA_{ij}}{\max(SPA_{ij})} \tag{20}$$

$$NSCA_{ij} = \frac{SCA_{ij}}{\max(SCA_{ij})} \tag{21}$$

Determine the appraisal score

$$L_i = \frac{NSCA_{ij} + NSPA_{ij}}{2} \tag{22}$$

Rank the alternatives.

3. Results

This section shows the results of the Teaching Quality Analysis in University Basketball Training under the MCDM approach to compute the criteria weights and ranking alternatives. Three experts are gathered the nine criteria and ten alternatives such as

- Assessment and Feedback
- Physical Conditioning
- Instructional Effectiveness
- Game Performance Improvement
- Injury Prevention and Safety
- Teamwork and Communication
- Technical Skill Development
- Tactical Understanding
- Motivational Strategies

✓ Technology-Assisted Training
✓ Game-Centered Learning Approach
✓ Hybrid Training Model
✓ Tactical Simulation Training
✓ Personalized Coaching Programs
✓ Traditional Drill-Based Training
✓ Peer-Led Collaborative Training

- ✓ Mental Resilience and Psychological Training
- ✓ Injury Prevention and Recovery-Oriented Training
- ✓ Strength and Conditioning-Based Training

We gathered nine criteria. Then experts and decision makers can select the best and the worst criterion.

Then they evaluate the best criterion compared to other criteria.

They evaluate the worst criterion compared to other criteria.

Then we compute the criteria weights using Eq. (10-12) as shown in Fig 1.

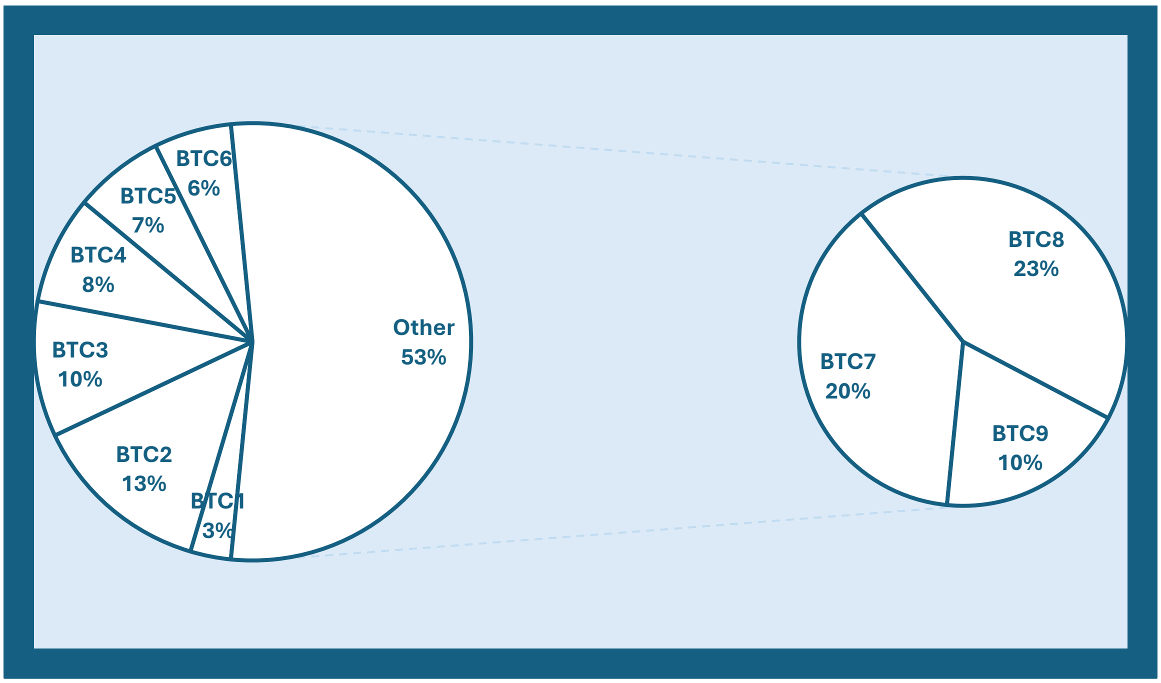

Fig 1. The importance of nine criteria.

Then we apply the steps of the EDAS method to rank the alternatives. Three experts are using the FNFNs to evaluate the criteria and alternatives as shown in Table 1. Then we use the score function in Eq. (4) to obtain crisp values. Then we combine the decision matrix.

Then we compute the average solution using Eq. (13).

Then we determine the positive and negative distances from the average solutions using Eqs. (14 and 15) as shown in Table 2 and 3.

Then we determine the weighted PA_{ij} and CA_{ij} using Eq. (18 and 19) as shown in Table 4 and 5.

Then we determine the weighted normalized PA_{ij} and CA_{ij} using Eqs. (20 and 21).

Then we determine the appraisal score using Eq. (22).

Then we rank the alternatives as shown in Fig 2.

Table 1. The decision matrix.

	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.7,0.3,0.35)	(0.8,0.2,0.25)	(0.7,0.3,0.35)	(0.7,0.3,0.35)	(0.2,0.8,0.75)
BTA_2	(0.8,0.2,0.25)	(0.1,0.9,0.85)	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.6,0.4,0.45)	(0.2,0.8,0.75)	(0.3,0.7,0.65)
BTA_3	(0.7,0.3,0.35)	(0.1,0.9,0.85)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.7,0.3,0.35)	(0.7,0.3,0.35)	(0.4,0.6,0.55)	(0.1,0.9,0.85)	(0.4,0.6,0.55)
BTA_4	(0.6,0.4,0.45)	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.2,0.8,0.75)	(0.1,0.9,0.85)	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.6,0.4,0.45)	(0.6,0.4,0.45)
BTA_5	(0.4,0.6,0.55)	(0.1,0.9,0.85)	(0.6,0.4,0.45)	(0.7,0.3,0.35)	(0.8,0.2,0.25)	(0.7,0.3,0.35)	(0.8,0.2,0.25)	(0.4,0.6,0.55)	(0.1,0.9,0.85)
BTA_6	(0.3,0.7,0.65)	(0.6,0.4,0.45)	(0.4,0.6,0.55)	(0.2,0.8,0.75)	(0.8,0.2,0.25)	(0.2,0.8,0.75)	(0.7,0.3,0.35)	(0.3,0.7,0.65)	(0.2,0.8,0.75)
BTA_7	(0.8,0.2,0.25)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.1,0.9,0.85)	(0.3,0.7,0.65)	(0.3,0.7,0.65)	(0.8,0.2,0.25)	(0.8,0.2,0.25)	(0.1,0.9,0.85)
BTA_8	(0.1,0.9,0.85)	(0.3,0.7,0.65)	(0.1,0.9,0.85)	(0.6,0.4,0.45)	(0.4,0.6,0.55)	(0.4,0.6,0.55)	(0.3,0.7,0.65)	(0.1,0.9,0.85)	(0.2,0.8,0.75)
BTA_9	(0.2,0.8,0.75)	(0.8,0.2,0.25)	(0.8,0.2,0.25)	(0.8,0.2,0.25)	(0.6,0.4,0.45)	(0.6,0.4,0.45)	(0.4,0.6,0.55)	(0.2,0.8,0.75)	(0.3,0.7,0.65)
BTA_{10}	(0.7,0.3,0.35)	(0.6,0.4,0.45)	(0.4,0.6,0.55)	(0.3,0.7,0.65)	(0.8,0.2,0.25)	(0.7,0.3,0.35)	(0.6,0.4,0.45)	(0.7,0.3,0.35)	(0.4,0.6,0.55)
	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	(0.1,0.9,0.85)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.7,0.3,0.35)	(0.2,0.8,0.75)	(0.7,0.3,0.35)	(0.1,0.9,0.85)	(0.8,0.2,0.25)
BTA_2	(0.2,0.8,0.75)	(0.7,0.3,0.35)	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.6,0.4,0.45)	(0.1,0.9,0.85)	(0.3,0.7,0.65)
BTA_3	(0.3,0.7,0.65)	(0.7,0.3,0.35)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.7,0.3,0.35)	(0.1,0.9,0.85)	(0.6,0.4,0.45)	(0.6,0.4,0.45)	(0.4,0.6,0.55)
BTA_4	(0.4,0.6,0.55)	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.8,0.2,0.25)	(0.1,0.9,0.85)	(0.8,0.2,0.25)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.6,0.4,0.45)
BTA_5	(0.6,0.4,0.45)	(0.7,0.3,0.35)	(0.6,0.4,0.45)	(0.1,0.9,0.85)	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.8,0.2,0.25)	(0.3,0.7,0.65)	(0.1,0.9,0.85)
BTA_6	(0.3,0.7,0.65)	(0.8,0.2,0.25)	(0.1,0.9,0.85)	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.7,0.3,0.35)	(0.2,0.8,0.75)	(0.2,0.8,0.75)
BTA_7	(0.8,0.2,0.25)	(0.3,0.7,0.65)	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.3,0.7,0.65)	(0.1,0.9,0.85)	(0.1,0.9,0.85)
BTA_8	(0.1,0.9,0.85)	(0.4,0.6,0.55)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.4,0.6,0.55)	(0.4,0.6,0.55)	(0.2,0.8,0.75)	(0.2,0.8,0.75)
BTA_9	(0.2,0.8,0.75)	(0.6,0.4,0.45)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.6,0.4,0.45)	(0.6,0.4,0.45)	(0.6,0.4,0.45)	(0.7,0.3,0.35)	(0.3,0.7,0.65)
BTA_{10}	(0.7,0.3,0.35)	(0.6,0.4,0.45)	(0.6,0.4,0.45)	(0.3,0.7,0.65)	(0.2,0.8,0.75)	(0.7,0.3,0.35)	(0.7,0.3,0.35)	(0.6,0.4,0.45)	(0.4,0.6,0.55)
	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	(0.8,0.2,0.25)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.6,0.4,0.45)	(0.2,0.8,0.75)	(0.7,0.3,0.35)	(0.7,0.3,0.35)	(0.2,0.8,0.75)
BTA_2	(0.8,0.2,0.25)	(0.6,0.4,0.45)	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.6,0.4,0.45)	(0.2,0.8,0.75)	(0.3,0.7,0.65)
BTA_3	(0.1,0.9,0.85)	(0.4,0.6,0.55)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.4,0.6,0.55)	(0.7,0.3,0.35)	(0.4,0.6,0.55)
BTA_4	(0.6,0.4,0.45)	(0.3,0.7,0.65)	(0.6,0.4,0.45)	(0.2,0.8,0.75)	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.3,0.7,0.65)	(0.6,0.4,0.45)	(0.6,0.4,0.45)
BTA_5	(0.4,0.6,0.55)	(0.8,0.2,0.25)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.6,0.4,0.45)	(0.2,0.8,0.75)	(0.2,0.8,0.75)	(0.4,0.6,0.55)	(0.7,0.3,0.35)

BTA_6	(0.3,0.7,0.65)	(0.6,0.4,0.45)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.4,0.6,0.55)	(0.6,0.4,0.45)	(0.7,0.3,0.35)	(0.3,0.7,0.65)	(0.7,0.3,0.35)
BTA_7	(0.2,0.8,0.75)	(0.4,0.6,0.55)	(0.2,0.8,0.75)	(0.3,0.7,0.65)	(0.3,0.7,0.65)	(0.4,0.6,0.55)	(0.2,0.8,0.75)	(0.2,0.8,0.75)	(0.7,0.3,0.35)
BTA_8	(0.7,0.3,0.35)	(0.3,0.7,0.65)	(0.7,0.3,0.35)	(0.8,0.2,0.25)	(0.8,0.2,0.25)	(0.3,0.7,0.65)	(0.3,0.7,0.65)	(0.7,0.3,0.35)	(0.8,0.2,0.25)
BTA_9	(0.2,0.8,0.75)	(0.2,0.8,0.75)	(0.2,0.8,0.75)	(0.2,0.8,0.75)	(0.6,0.4,0.45)	(0.2,0.8,0.75)	(0.4,0.6,0.55)	(0.2,0.8,0.75)	(0.3,0.7,0.65)
BTA_{10}	(0.1,0.9,0.85)	(0.6,0.4,0.45)	(0.4,0.6,0.55)	(0.3,0.7,0.65)	(0.2,0.8,0.75)	(0.7,0.3,0.35)	(0.6,0.4,0.45)	(0.7,0.3,0.35)	(0.4,0.6,0.55)

Table 2. The values of positive distances

	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0.037129	0	0	0.540852	0.699865	0.086439	0.699163	0.639986	0.542231
BTA_2	1.048808	0.215619	0	0	0	0.375278	0.099249	0	0
BTA_3	0	0	0	0.540852	0.346042	0	0	0.351006	0
BTA_4	0.037613	0	0	0.217238	0	0.133449	0	0.234225	0.952246
BTA_5	0	0.824661	0.746837	0.310456	0.381046	0	0.6864	0	0.013283
BTA_6	0	1.038383	0	0	0.145656	0	0.699163	0	0.065524
BTA_7	1.048808	0	0	0	0	0	0	0.233649	0.013283
BTA_8	0	0	0.273877	0.853736	0.499479	0	0	0	0.542231
BTA_9	0	0.583765	0.989739	0.707323	0.246388	0	0	0	0
BTA_{10}	0.378736	0.429341	0.245376	0	0	1.125834	0.299221	1.16649	0

Table 3. The values of negative distances.

	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0	0.787938	0.256084	0	0	0	0	0	0
BTA_2	0	0	0.896991	0.771393	0.587595	0	0	0.948473	0.710357
BTA_3	0.243323	0.103181	0.256084	0	0	0.137102	0.391104	0	0.354041
BTA_4	0	0.885654	0.028191	0	0.976248	0	0.836911	0	0
BTA_5	0.260252	0	0	0	0	0.202371	0	0.571031	0
BTA_6	0.801863	0	0.636585	0.78299	0	0.368887	0	0.818619	0
BTA_7	0	0.614019	0.181895	0.84468	0.739253	0.321876	0.094043	0	0
BTA_8	0.306841	0.700978	0	0	0	0.628618	0.770034	0.154244	0
BTA_9	0.938813	0	0	0	0	0.062145	0.391104	0.132989	0.710357
BTA_{10}	0	0	0	0.771393	0.015381	0	0	0	0.354041

Table 4. The weighted values of positive distances.

	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0.001117	0	0	0.043392	0.046791	0.004953	0.140233	0.147619	0.054378
BTA_2	0.031554	0.028832	0	0	0	0.021506	0.019907	0	0
BTA_3	0	0	0	0.043392	0.023136	0	0	0.080963	0
BTA_4	0.001132	0	0	0.017429	0	0.007647	0	0.054026	0.095497
BTA_5	0	0.11027	0.074898	0.024908	0.025476	0	0.137673	0	0.001332
BTA_6	0	0.138848	0	0	0.009738	0	0.140233	0	0.006571
BTA_7	0.031554	0	0	0	0	0	0	0.053893	0.001332
BTA_8	0	0	0.027466	0.068495	0.033394	0	0	0	0.054378
BTA_9	0	0.078058	0.099258	0.056748	0.016473	0	0	0	0
BTA_{10}	0.011395	0.05741	0.024608	0	0	0.064518	0.060016	0.269062	0

Table 5. The weighted values of negative distances.

	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0	0.105359	0.025682	0	0	0	0	0	0
BTA_2	0	0	0.089956	0.061888	0.039285	0	0	0.218774	0.071239
BTA_3	0.007321	0.013797	0.025682	0	0	0.007857	0.078445	0	0.035506
BTA_4	0	0.118426	0.002827	0	0.06527	0	0.167862	0	0
BTA_5	0.00783	0	0	0	0	0.011597	0	0.131714	0
BTA_6	0.024125	0	0.063841	0.062819	0	0.02114	0	0.188822	0
BTA_7	0	0.082104	0.018242	0.067768	0.049425	0.018446	0.018862	0	0
BTA_8	0.009232	0.093732	0	0	0	0.036024	0.154448	0.035578	0
BTA_9	0.028245	0	0	0	0	0.003561	0.078445	0.030675	0.071239
BTA_{10}	0	0	0	0.061888	0.001028	0	0	0	0.035506

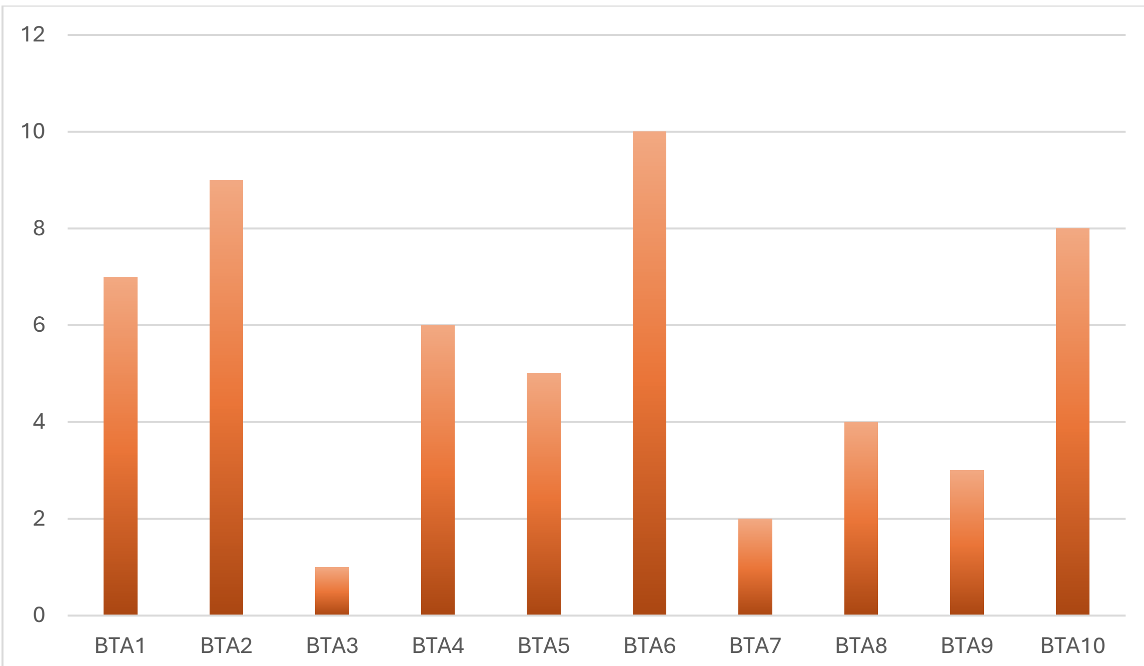

Fig 2. Rank of alternatives.

4. Analysis

Sensitivity analysis in MCDM is a vital process used to evaluate how variations in criteria weights and input parameters influence the final ranking of alternatives. Since MCDM models rely on assigning weights to different criteria to determine the most suitable choice, any changes in these weights can significantly impact decision outcomes. By systematically adjusting weights and observing fluctuations in rankings, decision-makers can assess the stability and reliability of their results. This approach helps in identifying whether small variations in input values lead to drastic shifts in rankings, ensuring that the decision process remains robust and consistent even under uncertain conditions.

Fig 3. Ten cases of criteria weights.

Beyond ranking stability, sensitivity analysis in MCDM enhances the credibility and transparency of decision-making models. It allows decision-makers to pinpoint which criteria exert the most influence on final outcomes, helping refine weight allocation strategies to align with real-world priorities. For instance, in evaluating transportation systems, if minor weight adjustments in "cost-efficiency" drastically alter rankings, it signals the need for careful calibration of this criterion. Similarly, in sustainability assessments, decision-makers can use sensitivity analysis to validate whether environmental, social, or economic factors have a disproportionate impact on the final choice. By integrating sensitivity analysis, MCDM methodologies become more adaptable and resilient, enabling more informed and justifiable decisions across various domains.

Table 6. Ten weighted positive distance.

	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0.004125	0	0	0.060095	0.077763	0.009604	0.077685	0.07111	0.004125
BTA_2	0.116534	0.023958	0	0	0	0.041698	0.011028	0	0.116534
BTA_3	0	0	0	0.060095	0.038449	0	0	0.039001	0
BTA_4	0.004179	0	0	0.024138	0	0.014828	0	0.026025	0.004179
BTA_5	0	0.091629	0.082982	0.034495	0.042338	0	0.076267	0	0
BTA_6	0	0.115376	0	0	0.016184	0	0.077685	0	0
BTA_7	0.116534	0	0	0	0	0	0	0.025961	0.116534
BTA_8	0	0	0.030431	0.09486	0.055498	0	0	0	0
BTA_9	0	0.064863	0.109971	0.078591	0.027376	0	0	0	0
BTA_{10}	0.042082	0.047705	0.027264	0	0	0.125093	0.033247	0.12961	0.042082
	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0.007426	0	0	0.054085	0.069986	0.008644	0.069916	0.063999	0.054223
BTA_2	0.209762	0.021562	0	0	0	0.037528	0.009925	0	0
BTA_3	0	0	0	0.054085	0.034604	0	0	0.035101	0
BTA_4	0.007523	0	0	0.021724	0	0.013345	0	0.023422	0.095225
BTA_5	0	0.082466	0.074684	0.031046	0.038105	0	0.06864	0	0.001328
BTA_6	0	0.103838	0	0	0.014566	0	0.069916	0	0.006552
BTA_7	0.209762	0	0	0	0	0	0	0.023365	0.001328
BTA_8	0	0	0.027388	0.085374	0.049948	0	0	0	0.054223
BTA_9	0	0.058377	0.098974	0.070732	0.024639	0	0	0	0
BTA_{10}	0.075747	0.042934	0.024538	0	0	0.112583	0.029922	0.116649	0
	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0.003713	0	0	0.054085	0.069986	0.008644	0.069916	0.063999	0.054223
BTA_2	0.104881	0.043124	0	0	0	0.037528	0.009925	0	0
BTA_3	0	0	0	0.054085	0.034604	0	0	0.035101	0
BTA_4	0.003761	0	0	0.021724	0	0.013345	0	0.023422	0.095225
BTA_5	0	0.164932	0.074684	0.031046	0.038105	0	0.06864	0	0.001328
BTA_6	0	0.207677	0	0	0.014566	0	0.069916	0	0.006552
BTA_7	0.104881	0	0	0	0	0	0	0.023365	0.001328
BTA_8	0	0	0.027388	0.085374	0.049948	0	0	0	0.054223
BTA_9	0	0.116753	0.098974	0.070732	0.024639	0	0	0	0
BTA_{10}	0.037874	0.085868	0.024538	0	0	0.112583	0.029922	0.116649	0
	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0.003713	0	0	0.054085	0.069986	0.008644	0.069916	0.063999	0.054223
BTA_2	0.104881	0.021562	0	0	0	0.037528	0.009925	0	0
BTA_3	0	0	0	0.054085	0.034604	0	0	0.035101	0
BTA_4	0.003761	0	0	0.021724	0	0.013345	0	0.023422	0.095225
BTA_5	0	0.082466	0.149367	0.031046	0.038105	0	0.06864	0	0.001328
BTA_6	0	0.103838	0	0	0.014566	0	0.069916	0	0.006552
BTA_7	0.104881	0	0	0	0	0	0	0.023365	0.001328
BTA_8	0	0	0.054775	0.085374	0.049948	0	0	0	0.054223
BTA_9	0	0.058377	0.197948	0.070732	0.024639	0	0	0	0
BTA_{10}	0.037874	0.042934	0.049075	0	0	0.112583	0.029922	0.116649	0
	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0.003713	0	0	0.10817	0.069986	0.008644	0.069916	0.063999	0.054223
BTA_2	0.104881	0.021562	0	0	0	0.037528	0.009925	0	0
BTA_3	0	0	0	0.10817	0.034604	0	0	0.035101	0
BTA_4	0.003761	0	0	0.043448	0	0.013345	0	0.023422	0.095225
BTA_5	0	0.082466	0.074684	0.062091	0.038105	0	0.06864	0	0.001328
BTA_6	0	0.103838	0	0	0.014566	0	0.069916	0	0.006552
BTA_7	0.104881	0	0	0	0	0	0	0.023365	0.001328
BTA_8	0	0	0.027388	0.170747	0.049948	0	0	0	0.054223
BTA_9	0	0.058377	0.098974	0.141465	0.024639	0	0	0	0
BTA_{10}	0.037874	0.042934	0.024538	0	0	0.112583	0.029922	0.116649	0
	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9

BTA_1	0.003713	0	0	0.054085	0.139973	0.008644	0.069916	0.063999	0.054223
BTA_2	0.104881	0.021562	0	0	0	0.037528	0.009925	0	0
BTA_3	0	0	0	0.054085	0.069208	0	0	0.035101	0
BTA_4	0.003761	0	0	0.021724	0	0.013345	0	0.023422	0.095225
BTA_5	0	0.082466	0.074684	0.031046	0.076209	0	0.06864	0	0.001328
BTA_6	0	0.103838	0	0	0.029131	0	0.069916	0	0.006552
BTA_7	0.104881	0	0	0	0	0	0	0.023365	0.001328
BTA_8	0	0	0.027388	0.085374	0.099896	0	0	0	0.054223
BTA_9	0	0.058377	0.098974	0.070732	0.049278	0	0	0	0
BTA_{10}	0.037874	0.042934	0.024538	0	0	0.112583	0.029922	0.116649	0
	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0.003713	0	0	0.054085	0.069986	0.017288	0.069916	0.063999	0.054223
BTA_2	0.104881	0.021562	0	0	0	0.075056	0.009925	0	0
BTA_3	0	0	0	0.054085	0.034604	0	0	0.035101	0
BTA_4	0.003761	0	0	0.021724	0	0.02669	0	0.023422	0.095225
BTA_5	0	0.082466	0.074684	0.031046	0.038105	0	0.06864	0	0.001328
BTA_6	0	0.103838	0	0	0.014566	0	0.069916	0	0.006552
BTA_7	0.104881	0	0	0	0	0	0	0.023365	0.001328
BTA_8	0	0	0.027388	0.085374	0.049948	0	0	0	0.054223
BTA_9	0	0.058377	0.098974	0.070732	0.024639	0	0	0	0
BTA_{10}	0.037874	0.042934	0.024538	0	0	0.225167	0.029922	0.116649	0
	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0.003713	0	0	0.054085	0.069986	0.008644	0.139833	0.063999	0.054223
BTA_2	0.104881	0.021562	0	0	0	0.037528	0.01985	0	0
BTA_3	0	0	0	0.054085	0.034604	0	0	0.035101	0
BTA_4	0.003761	0	0	0.021724	0	0.013345	0	0.023422	0.095225
BTA_5	0	0.082466	0.074684	0.031046	0.038105	0	0.13728	0	0.001328
BTA_6	0	0.103838	0	0	0.014566	0	0.139833	0	0.006552
BTA_7	0.104881	0	0	0	0	0	0	0.023365	0.001328
BTA_8	0	0	0.027388	0.085374	0.049948	0	0	0	0.054223
BTA_9	0	0.058377	0.098974	0.070732	0.024639	0	0	0	0
BTA_{10}	0.037874	0.042934	0.024538	0	0	0.112583	0.059844	0.116649	0
	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0.003713	0	0	0.054085	0.069986	0.008644	0.069916	0.127997	0.054223
BTA_2	0.104881	0.021562	0	0	0	0.037528	0.009925	0	0
BTA_3	0	0	0	0.054085	0.034604	0	0	0.070201	0
BTA_4	0.003761	0	0	0.021724	0	0.013345	0	0.046845	0.095225
BTA_5	0	0.082466	0.074684	0.031046	0.038105	0	0.06864	0	0.001328
BTA_6	0	0.103838	0	0	0.014566	0	0.069916	0	0.006552
BTA_7	0.104881	0	0	0	0	0	0	0.04673	0.001328
BTA_8	0	0	0.027388	0.085374	0.049948	0	0	0	0.054223
BTA_9	0	0.058377	0.098974	0.070732	0.024639	0	0	0	0
BTA_{10}	0.037874	0.042934	0.024538	0	0	0.112583	0.029922	0.233298	0
	BTC_1	BTC_2	BTC_3	BTC_4	BTC_5	BTC_6	BTC_7	BTC_8	BTC_9
BTA_1	0.003713	0	0	0.054085	0.069986	0.008644	0.069916	0.063999	0.108446
BTA_2	0.104881	0.021562	0	0	0	0.037528	0.009925	0	0
BTA_3	0	0	0	0.054085	0.034604	0	0	0.035101	0
BTA_4	0.003761	0	0	0.021724	0	0.013345	0	0.023422	0.190449
BTA_5	0	0.082466	0.074684	0.031046	0.038105	0	0.06864	0	0.002657
BTA_6	0	0.103838	0	0	0.014566	0	0.069916	0	0.013105
BTA_7	0.104881	0	0	0	0	0	0	0.023365	0.002657
BTA_8	0	0	0.027388	0.085374	0.049948	0	0	0	0.108446
BTA_9	0	0.058377	0.098974	0.070732	0.024639	0	0	0	0
BTA_{10}	0.037874	0.042934	0.024538	0	0	0.112583	0.029922	0.116649	0

We change the criteria weights by ten cases to show the rank of the alternatives. Fig 3 shows the change in the criteria weights under ten cases. Then we apply the steps of the EDAS methodology under ten cases. We compute the weighted positive distance as shown in Table 6. Then we compute the score of each alternative as shown in Fig 4. Then we rank the alternatives as shown in Fig 5.

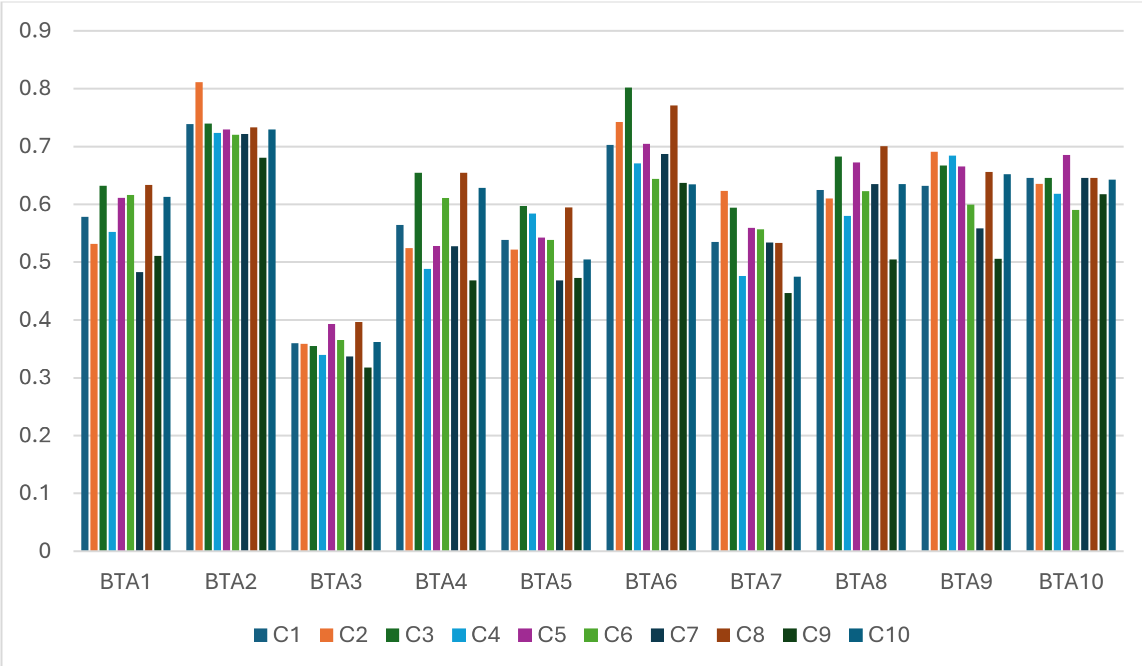

Fig 4. The score value of each alternative.

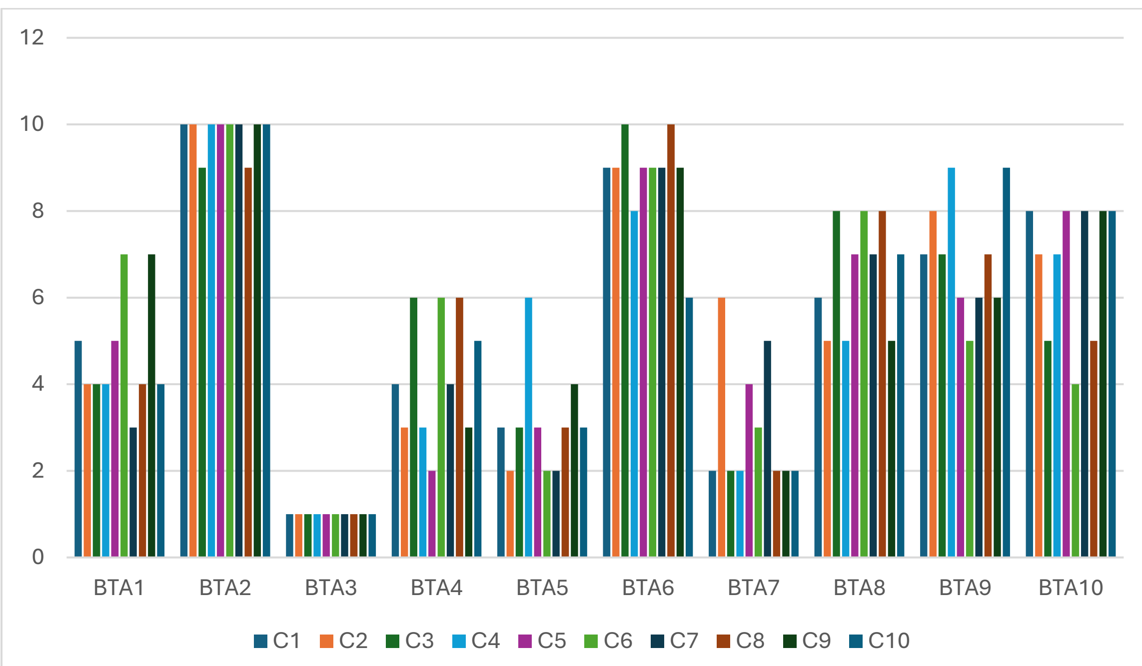

Fig 5. The ten ranks of the alternatives.

5. Conclusions

Teaching quality analysis in university basketball training is a multifaceted process that requires a balance between performance analysis, coaching methodologies, and external factors. By integrating advanced assessment techniques, personalized feedback mechanisms, and modern training tools, universities can enhance the effectiveness of their basketball programs. A structured evaluation framework not only improves player development and coaching strategies but also ensures long-term success and sustainability in university-level athletics. Future improvements in teaching quality assessment should focus on leveraging emerging technologies and evidence-based training methodologies to create a more effective, data-driven, and player-centric approach to basketball education. This study proposed a MCDM methodology to rank the alternatives. We used the BWM methodology to compute the criteria weights and the EDAS methodology to rank the alternatives. These methods used under the Fermatean neutrosophic fuzzy set to deal with uncertainty in the evaluation process. Nine criteria and ten alternatives in this study. The sensitivity analysis is conducted to show the different ranks of the alt6ernatives. The results show the rank of the alternatives is stable under ten cases.

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