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Quality Review of Computer Digital Media Art Design using Neutrosophic Logic: A Case Study

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Abstract: Evaluating the quality of Computer Digital Media Art Design is complex because it involves both subjective artistic elements and objective technical criteria. This study uses the multi-criteria decision making (MCDM) method to deal with different criteria. Two MCDM methods are used in this study such as Preference Selection Index (PSI) Method to compute the criteria weights and the RATGOS method to rank the alternatives. These methods are used neutrosophic sets to dela with vague and uncertainty information. Eight criteria and seven alternatives are used to select the best alternatives. Four experts have evaluated these criteria and alternatives. An example is conducted to show the validation of the proposed approach. The sensitivity analysis and comparative analysis are applied in this study to show the stability of the ranks and the effectiveness of the proposed approach.

Keywords: Trapezoidal interval valued neutrosophic set (TIVNS); Computer Digital Media; Art Design; Neutrosophic Logic.

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1. Introduction and Related Works

Computer Digital Media Art Design is a multidisciplinary field that blends artistic creativity with digital technology to create visually compelling and interactive media content. It encompasses graphic design, animation, visual effects (VFX), digital painting, 3D modeling, augmented reality (AR), virtual reality (VR), and interactive media. This field is widely applied in advertising, film, gaming, web design, user experience (UX) design, and immersive technologies[1], [2].

With the rise of digital transformation, AI-assisted design tools, real-time rendering engines, and interactive platforms have further expanded the capabilities of digital media artists. These technological advancements have made digital media art design more dynamic, immersive, and accessible across multiple devices and platforms.

Evaluating the quality of Computer Digital Media Art Design is complex because it involves both subjective artistic elements and objective technical criteria. Traditional evaluation methods may rely on human judgment, which can be biased and inconsistent[3], [4]. Therefore, a structured approach such as Multi-Criteria Decision-Making (MCDM) is beneficial for quality assessment.

Key challenges include:

- Creativity & Subjectivity: Art and aesthetics are difficult to quantify.
- Technical Complexity: Requires knowledge of digital tools and techniques.
- Cross-Platform Adaptability: Digital art must perform well across different screens, resolutions, and interfaces.
- Industry Relevance: Trends in digital media change rapidly, requiring continuous updates.
- User Experience & Interaction: Evaluating how well the design engages users.

For evaluating Computer Digital Media Art Design, MCDM methods can systematically analyze both qualitative and quantitative factors, ensuring a more objective and reliable decision-making process. In 1965, the term fuzzy set (FS) was used to describe a set whose components have degrees of membership. It primarily addresses a variety of real-world scenarios where the data has some degree of ambiguity[5], [6].

Only the components' membership value—not their non-membership value—is addressed by the FS notion. Atannasov's 1975 introduction of intuitionistic FS (IFS), which permits both the membership function (MF) and non-membership function, resolved this problem. Data indeterminacy may be present in real-world scenarios, which is why FS and IFS are unable to handle it. Smarandache's introduction of the neutrosophic set (NS), a generalization of FS and IFS, solved this issue.

All the components in NS have varying degrees of membership, indeterminacy, and non-membership, and the sum of these MFs must be less than or equal to three[7], [8]. Each of the three MFs operates independently of the others. Wang et al. created single valued NSs since the NSs are hard to use in practical situations. Fuzzy numbers and intuitionistic fuzzy numbers can be used to represent elemental uncertainty. Neutroposophic numbers are also highly helpful in expressing the components' indeterminacy and uncertainty. As a result, the NS's enhancement of the real number domain to neutrosophic numbers is a specific case.

Numerous approaches, including FS, IFS, interval valued IFS, triangular IFS, trapezoidal IFS, and NS, have been suggested by researchers to address inconsistency, uncertainty, ambiguity, impreciseness, and indeterminacy. In each of these environments, the information can be represented as a triangle or a trapezoid. Additionally, the membership values fall within the range of [0, 1] for real units. Therefore, in real-world situations when the information is ambiguous and indeterminate within a few ranges of permitted behavior, the trapezoidal interval valued neutrosophic number (TIVNN) is helpful. TIVNN is therefore the key to extracting the MFs of truth, indeterminacy, and falsehood, whose values rely on the intervals as well as the trapezoidal neutrosophic numbers.

Decision-makers find it difficult to articulate their opinions and judgments with a precise number for a single valued membership degree in a neutrophilic setting because of the intricacy of the decision-making process. Despite being a unique case of the neutrosophic, the interval number did not provide a definitive solution to the MCDM issue. The score function and accuracy function of trapezoidal interval valued neutrosophic numbers, together with their illustrative qualities, have thus been described by Broumi et al. [9]. These characteristics provide the trapezoidal interval valued neutrosophic number a crucial theoretical foundation. To address the neutrosophic MCDM issue in network analysis, they also suggested a clever technique known as the trapezoidal interval valued neutrosophic variant of Bellman's algorithm. Additionally, a comparison with the current algorithm has been conducted.

It has been shown that a single valued neutrosophic set may encompass the indeterminacy in real-world decision-making problems. It is an expansion of the neutrosophic set with interval values. Most real-world issues contain some degree of uncertainty, and determining the network's MCDM issue is one of the most well-known examples. In study of Broumi et al [10], interval valued neutrosophic numbers are used to solve MCDM issue and a new scoring function for these numbers is provided. By considering interval-valued neutrosophic numbers, trapezoidal, and triangular interval-valued neutrosophic numbers with an illustrated example, new methods are also presented to determine the neutrosophic MCDM. A comparison between the suggested algorithm and the current approach has been conducted.

The interval-valued intuitionistic fuzzy number (IVIFN), the trapezoidal fuzzy number (TrFN), the neutrosophic set and its operational laws, and the trapezoidal neutrosophic set (TrNS) and its operational laws are all covered in Kiran Khatter [11]. A suggested interval valued trapezoidal neutrosophic set (IVTrNS) and its operating rules are based on the combination of IVIFN and TrNS. The accuracy and scoring functions for the suggested interval valued trapezoidal neutrosophic number (IVTrNN) are also included. Then, to aggregate the neutrosophic trapezoidal information in the unit interval of real numbers, an interval valued trapezoidal neutrosophic operator is introduced. Following a numerical example of NFRs prioritizing a technique is finally devised to address the issues in the MCDM environment.

2. Trapezoidal interval valued neutrosophic set (TIVNS)

The neutrosophic set can be defined as $A = \left(x: T_A(x), I_A(x), F_A(x)\right)$, where T, I, F refer to the truth, indeterminacy, and falsity membership functions where satisfy the condition:[9]

$$-0 \leq T_A(x) + T_A(x) + T_A(x) \leq 3 + \quad (1)$$

TIVNN with truth, indeterminacy, and falsity

$$T_x(Z)=\begin{cases}\frac{(Z-a)t_x}{(b-a)}, & a\le z<b\\ t_x, & b\le z<c\\ \frac{(d-z)t_x}{(d-c)}, & c\le z<d\\ 0, & otherwise\end{cases} \quad (2)$$

$$i_x(Z)=\begin{cases}\frac{(b-z)+(z-a)i_x}{(b-a)}, & a\le z<b\\ i_x, & b\le z<c\\ \frac{(z-c)+(d-z)i_x}{(d-c)}, & c\le z<d\\ 0, & otherwise\end{cases} \quad (3)$$

$$f_x(Z)=\begin{cases}\frac{(b-z)+(z-a)f_x}{(b-a)}, & a\le z<b\\ f_x, & b\le z<c\\ \frac{(z-c)+(d-z)i_x}{(d-c)}, & c\le z<d\\ 0, & otherwise\end{cases} \quad (4)$$

The score function can be defined as:

$$S(x)=\frac{1}{16}(a+b+c+d)(t_{-}-t^{-}-i_{-}-i^{-}-f_{-}-f^{-}) \quad (5)$$

Where $S(x)\in[0,1]$ and $0\le a\le b\le c\le d\le 1, t_x, i_x, f_x$ are $subset$ of $[0,1]$

$where$ $t_x=[t_{-},t^{-}], i_x=[i_{-},i^{-}], f_x=[f_{-},f^{-}]$

Ranking Method

Let two TIVNNs such as a and b, the ranking of the two numbers by the score and accuracy function such as:

$$if\ s(r^N)<s(s^N)\ then\ r^N<s^N \quad (6)$$

$$if\ s(r^N)=s(s^N)\ and\ if \quad (7)$$

$$a(r^N)<a(s^N)\ then\ r^N<s^N \quad (8)$$

$$a(r^N)>a(s^N)\ then\ r^N>s^N \quad (9)$$

$$a(r^N)=a(s^N)\ then\ r^N=s^N \quad (10)$$

3. Materials and Methods

This section shows the steps of the proposed approach under the neutrosophic sets. We used two MCDM methods such as PSI to compute the criteria weights and RATGOS method to rank the alternatives.

TIVNNs- Preference Selection Index (PSI)

We use the PSI method to compute the criteria weights[12], [13].

a) Preparing the decision matrix.

b) Normalizing the decision matrix.

The normalized decision matrix is computed for the positive and cost criteria.

$$B_{ij}=\frac{x_{ij}}{\max x_{ij}} \tag{11}$$

$$B_{ij}=\frac{\min x_{ij}}{x_{ij}} \tag{12}$$

c) Compute the mean value of each criterion.

$$E=\frac{1}{N}\sum_{i=1}^{m} B_{ij} \tag{13}$$

d) Compute the preference variation value

$$Q_j = \sum_{i=1}^{m}\left[B_{ij}-E\right]^2 \tag{14}$$

e) Compute the deviation of preference value

$$U_j - 1-Q_j \tag{15}$$

f) Compute the criteria weights.

$$w_j=\frac{U_j}{\sum_{j=1}^{n} U_j} \tag{16}$$

TIVNNs-RATGOS

This part shows the rank of the alternatives under the TIVNNs to deal with uncertainty and vague information[14], [15].

a) Compute the optimal value

The optimal value of each criterion is computed for positive and cost criteria such as:

$$Optimal = \max x_j \tag{17}$$

$$Optimal = \max 1/x_j \tag{18}$$

b) Compute the normalization values for positive and cost value

$$A=\frac{x_{ij}}{optimal} \tag{19}$$

$$A=\frac{optimal}{x_{ij}} \tag{20}$$

c) Compute the weighted normalized decision matrix.

$$R_{ij}=W_jA \tag{21}$$

d) Compute the geometric mean.

f) Rank the alternatives.

4. Results and Discussion

This section shows the results of the proposed approach to obtaining the criteria weights and ranking the alternatives. This study are evaluated using four experts and decision makers. We collected eight criteria and seven alternatives in this study. The criteria of this study are Content Relevance and Message Clarity, Aesthetic Appeal, Creativity and Originality, Market and Industry Relevance, User Experience and Interactivity, Adaptability and Cross-Platform Compatibility, Efficiency of Workflow and Production Process, Technical Proficiency. The alternatives of this study are: Interactive Media, 3D Modeling, Motion Graphics, UX-Focused Design, Generative Art, AI-Integrated Digital Design, Cross-Platform.

TIVNNs- Preference Selection Index (PSI)

a) We build the decision matrix using the TIVNNs as shown in Tables 1-4. Then we apply the score function. Then we combined the decision matrix.

b) We used Eq. (11) to normalize the decision matrix as shown in Table 5.

c) Then we compute the mean value of each criterion using Eq. (13).

d) Then we compute the preference variation value using Eq. (14).

e) Then we compute the deviation of preference value using Eq. (15).

f) Then we compute the criteria weights using Eq. (16) as shown in Fig 1.

Table 1. The first decision matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])
A_2	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])
A_3	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])
A_4	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])
A_5	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])
A_6	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])
A_7	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])

Table 2. The second decision matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8

A_1	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])
A_2	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])
A_3	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])
A_4	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])
A_5	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])
A_6	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])
A_7	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])

Table 3. The third decision matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])
A_2	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])
A_3	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])
A_4	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])
A_5	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])
A_6	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])
A_7	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])

Table 4. The fourth decision matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	((0.3,0.4,0.5,1);[0.3,0.6],[0.1,0.2],[0.1,0.4])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])
A_2	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])
A_3	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])
A_4	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])
A_5	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])
A_6	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])
A_7	((0.1,0.2,0.3,0.4);[0.1,0.2],[0.2,0.3],[0.4,0.5])	((0.3,0.7,0.8,0.9);[0.3,0.4],[0.1,0.2],[0.3,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.1,0.5,0.7,0.9);[0.1,0.3],[0.3,0.4],[0.2,0.3])	((0.2,0.4,0.8,0.9);[0.2,0.3],[0.2,0.5],[0.4,0.5])	((0.2,0.5,0.7,0.8);[0.2,0.4],[0.3,0.5],[0.1,0.2])	((0.7,0.8,0.9,1);[0.4,0.6],[0.2,0.4],[0.1,0.3])

Table 5. The normalized decision matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.481403	0.784038	0.973653	0.775962	0.506732	0.790988	1	0.947552
A_2	1	1	0.883832	0.40485	0.646267	0.82838	0.196324	0.857809
A_3	0.957492	0.602817	0.881437	0.619926	0.991432	0.63279	0.651471	0.613636
A_4	0.473433	0.879812	0.646707	0.377965	1	0.287632	0.526103	0.928322
A_5	0.659405	0.507042	0.978443	0.316289	0.875153	0.738255	0.327574	0.965618
A_6	0.841126	0.637559	1	1	0.809058	1	0.45625	1
A_7	0.698193	0.746479	0.799401	0.839747	0.732558	0.627037	0.619853	0.758159

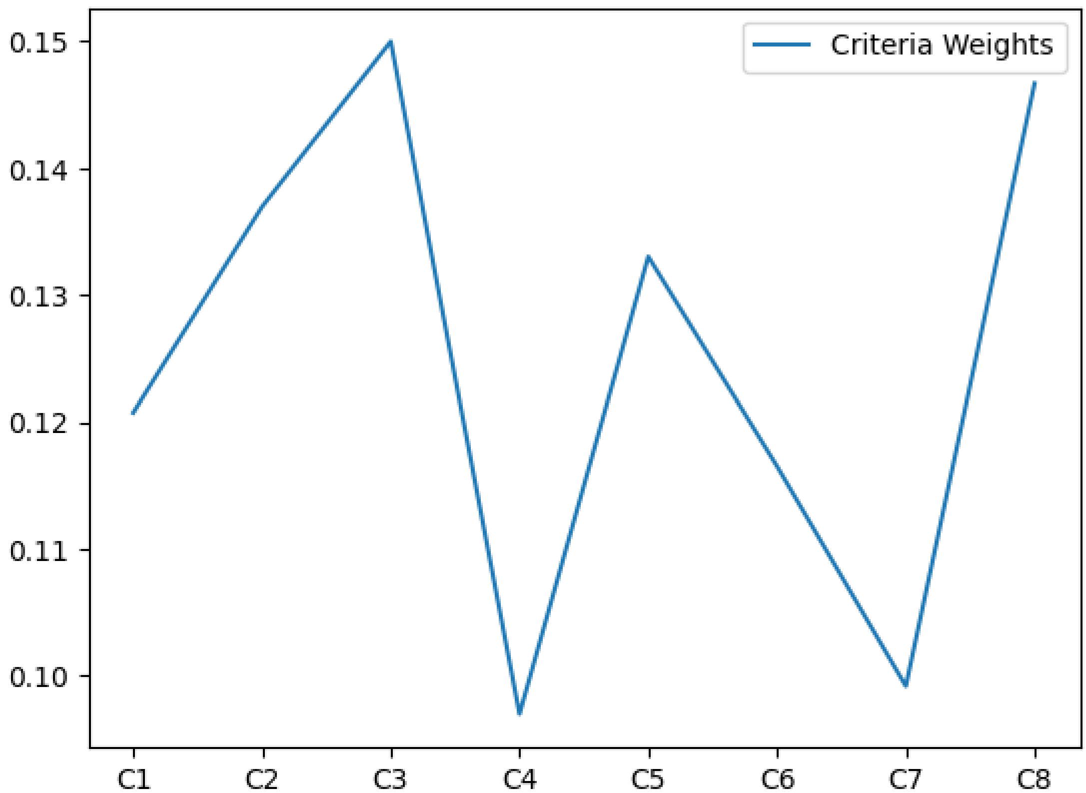

Fig 1. The criteria weights.

TIVNNs-RATGOS

a) We compute the optimal value using Eq. (17).

b) We compute the normalization values for positive and cost value using Eq. (19).

c) Eq. (21) is used to compute the weighted normalized decision matrix as shown in Table 6.

d) Then we compute the geometric mean.

f) Then we rank the alternatives as shown in Fig 2.

Table 6. The weighted normalized decision matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1								
A_2	0.05811643	0.107367	0.146039	0.075247	0.067404	0.092154	0.099169	0.138989
A_3	0.120723091	0.136941	0.132566	0.039259	0.085964	0.09651	0.019469	0.125825
A_4	0.115591397	0.08255	0.132207	0.060116	0.131877	0.073723	0.064606	0.090009
A_5	0.057154237	0.120482	0.097	0.036652	0.133017	0.033511	0.052173	0.136168
A_6	0.079605396	0.069435	0.146757	0.030671	0.11641	0.086011	0.032485	0.141639
A_7	0.101543386	0.087308	0.14999	0.096972	0.107618	0.116505	0.045246	0.146682

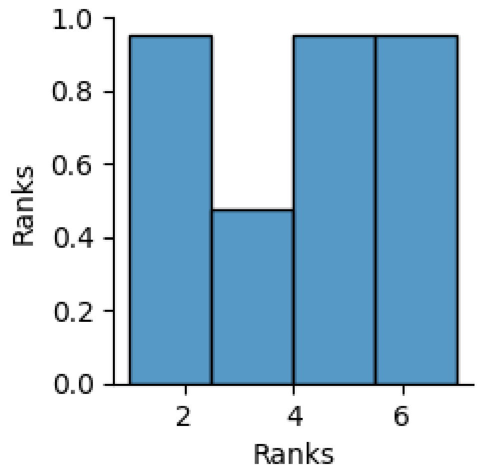

Fig 2. The ranks of alternatives.

Comparative analysis

This study compared the proposed approach with different MCDM methods to show the effectiveness of the proposed approach. The proposed approach is compared with the same weight of the CRITIC method. Then we compared the proposed approach with different MCDM methods with TOPSIS, COPRAS, MARCOS, and MABAC. Fig 3 shows the different ranks of alternatives under comparative analysis.

The results show the proposed approach is effectiveness compared other MCDM methods and the proposed approach has high correlation between other MCDM methods.

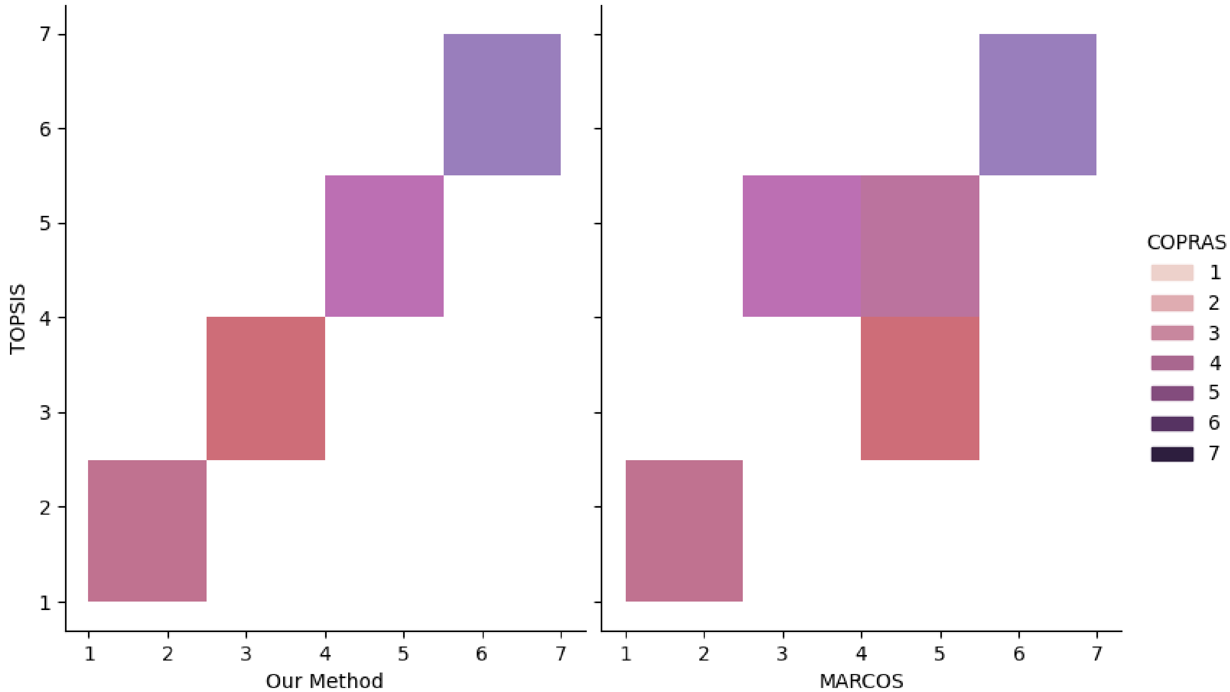

Fig 3. Comparative analysis results.

Sensitivity Analysis

We conducted sensitivity analysis by nine cases in criteria weights. We change the criteria weights by nine cases, then we ranked the alternatives under different criteria weights. Fig 4 shows the different criteria for weights. The first case, we put all criteria with the same weights. Then in the second case, we change the first criterion with 16% weights and all other criteria have ethe same weights. Then in the third case, we change the second criterion with 16% weights and other criteria have the same weights. Fig 5 and 6 shows the nine ranks of alternatives.

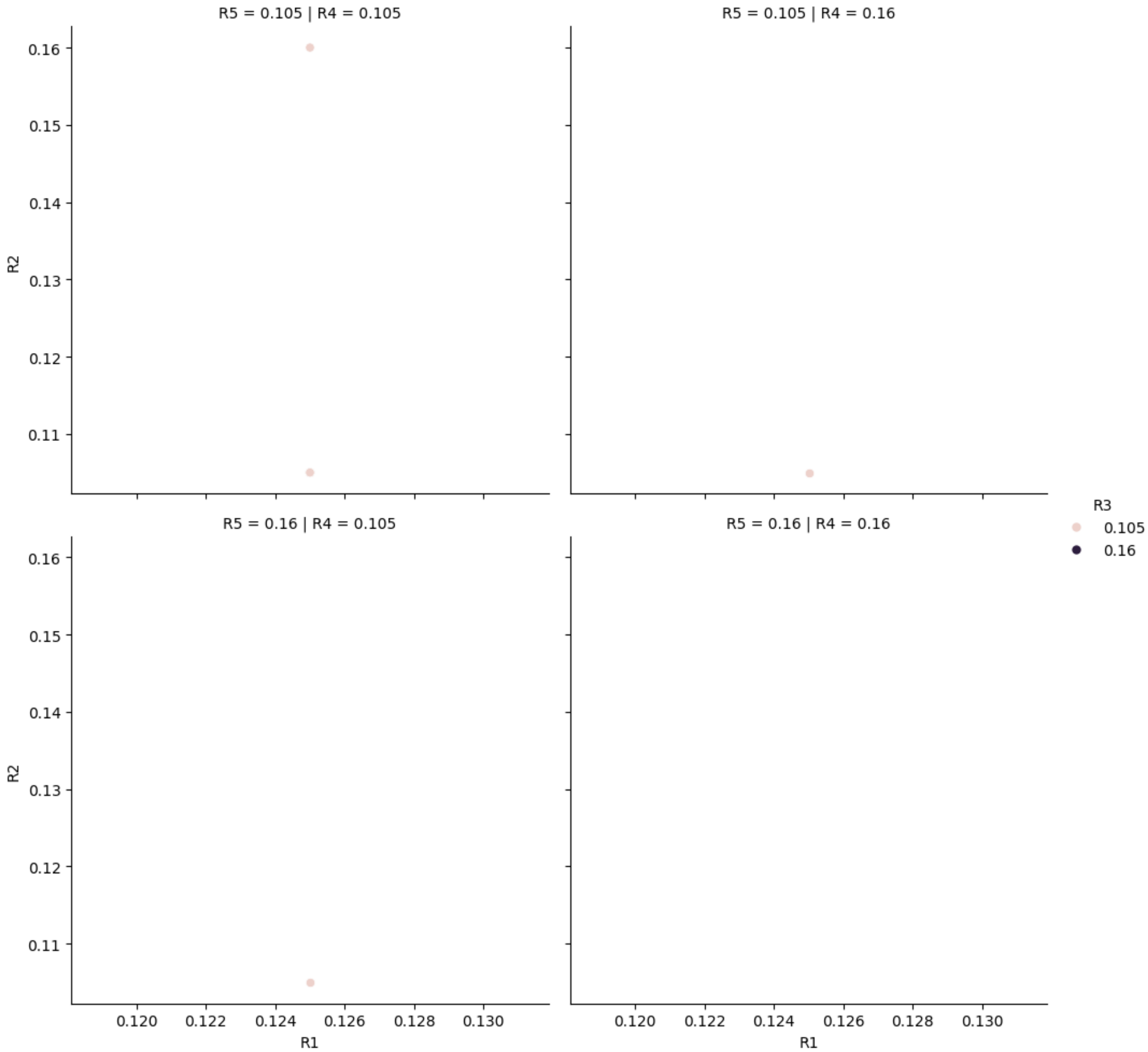

Fig 4-a. The nine criteria weights

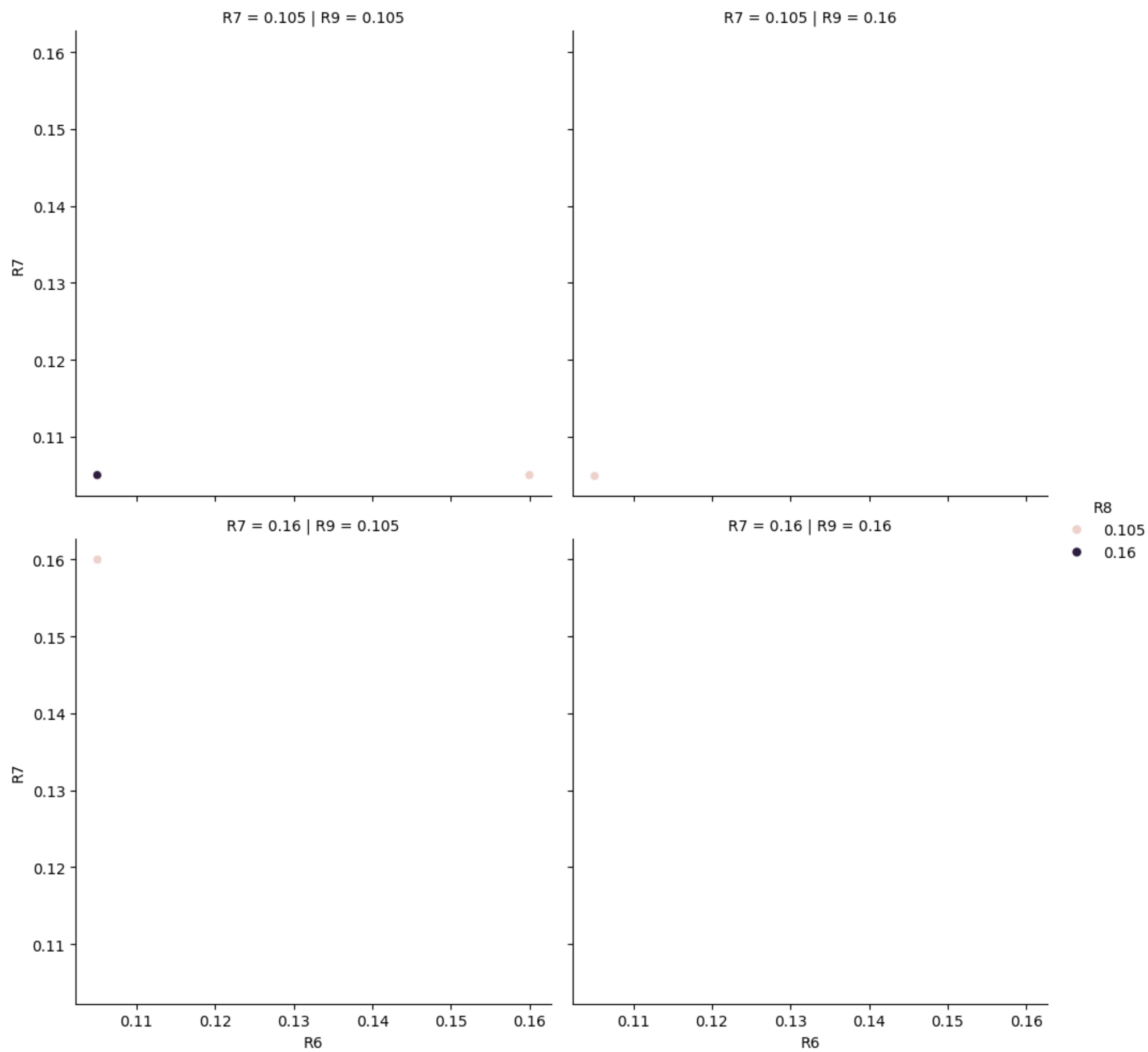

Fig 4-b. The nine criteria weights.

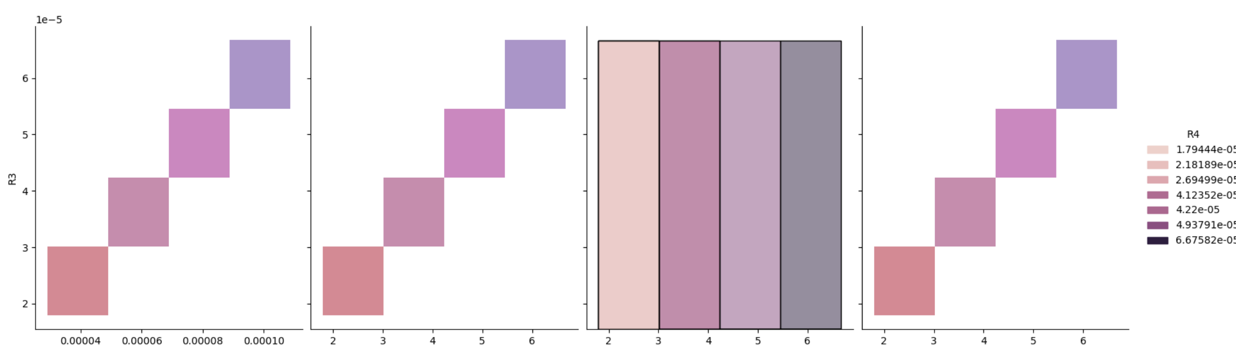

Fig 5-a. The ranking results under different cases.

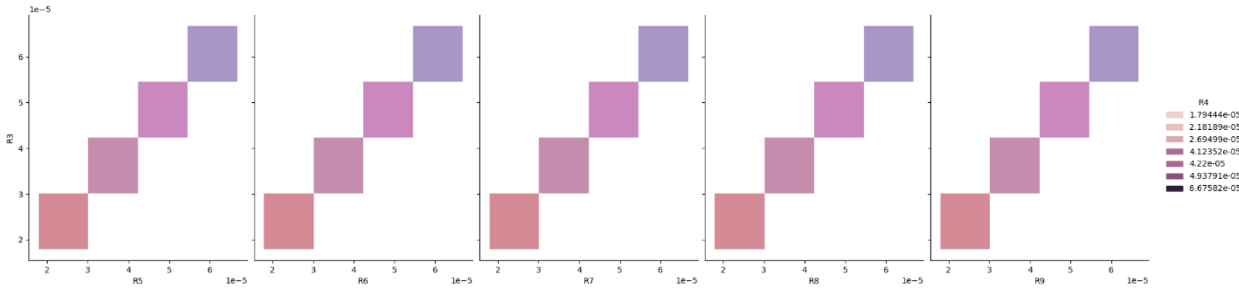

Fig 5-b. The ranking results under different cases.

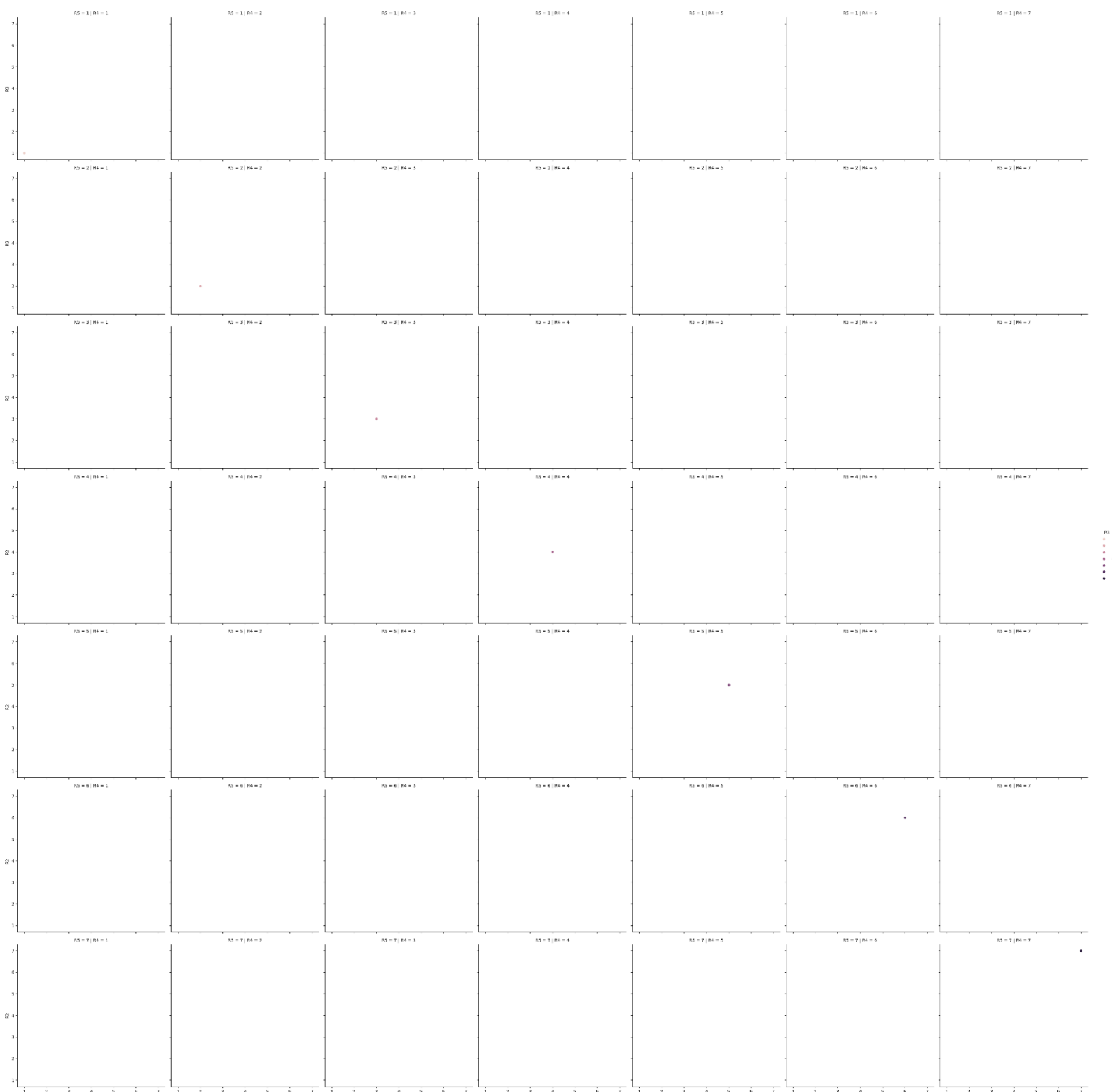

Fig 6. The nine ranks of alternatives.

The results show alternative 4 is the best and alternative 6 is the worst. The results show the ranks of alternatives are stable in different cases.

5. Conclusions and Future Directions

This study proposed MCDM approach to compute the criteria weights and rank the alternatives. The PSI method is used to compute the criteria weights. The RATGOS method is used to rank alternatives. The Trapezoidal interval valued neutrosophic set is used in this study to deal with vague and uncertainty information. Four experts are evaluated the criteria and alternatives. We compared the proposed approach under different MCDM methods. The results show the proposed approach is effective compared with MCDM methods. We conducted sensitivity analysis to show different ranks of alternatives. The results show the ranks of alternatives are stable in different cases.

In the future study, the criteria weights can be applied in different MCDM methods to compute the criteria weights and the ranking method to rank the alternatives. The proposed approach with the neutrosophic method can be extended with different criteria and alternatives to show different dimensions of the MCDM issues.

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