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Elevating Service Quality in Mass Sports Events Through Trapezoidal Neutrosophic Weighted Product Models

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Abstract

The evaluation of service quality in mass sports events is a structured process assessing aspects such as event organization, venue facilities, safety measures, staff services, and information dissemination. This evaluation assists organizers in identifying strengths and weaknesses, enabling optimization of services to enhance participant and spectator satisfaction. This study applies to the Weighted Product Method (WPM) integrated with Trapezoidal Neutrosophic Numbers (TNN) to address uncertainties inherent in multi-attribute decision-making. By presenting numerical examples and comparative analyses, the study demonstrates the effectiveness of the TNN-WPM technique. The findings provide a reliable framework for systematically evaluating service quality in mass sports events, promoting their development and broader societal impact.

Keywords: Multiple-attribute group decision-making (MAGDM); TNN; TNN-WPM model; service quality evaluation

1. Introduction

As society progresses, the material living standards of people in China have greatly improved. Along with the high-pressure and fast-paced lifestyle, more and more people have begun to focus on their physical and mental well-being. Sports have become an integral part of many people's lives. An increasing number of individuals are engaging in sports, leading to a growing sports population, while various sports clubs and associations have sprung up like mushrooms after the rain, and the sports industry has developed rapidly. Local governments and enterprises have seized this opportunity, actively organizing various mass sports events, which not only promote local economic development but also enhance local visibility and contribute to the talent pool for competitive sports. The flourishing development of mass sports events holds great significance for achieving nationwide fitness and building a strong sporting nation. However, mass sports events are derivatives of competitive sports and differ from competitive sports in terms of both entertainment value and intrinsic worth. As such, their organization and management also differ. The development of mass sports events in China started relatively late, and there are still many issues in terms of organization and management. Analyzing strategies to optimize the organization and management of large-scale mass sports events in China is of great importance. It can help promote the institutionalization, standardization, and scientific management of these events, encourage more people to participate in sports activities, foster the development of the national fitness movement, and support the healthy growth of the sports industry. Wang, Dai and Cheng [1] examined the role of government in managing mass sports events in Shanghai. They used expert interviews and questionnaires to analyze the current state of government involvement, identifying gaps in government functions and proposing a governance model to better coordinate between stakeholders. Following this, Tan [2] explored the management models of large-scale mass sports events in China post-Beijing Olympics. The study highlighted the growing demand for mass sports events and identified weaknesses in the current organizational models, offering suggestions for optimizing management structures to support the expanding market. Moving into 2016, Li [3] explored the use of WeChat for promoting mass sports events. The study emphasized the importance of strategic content delivery, timing, and technical features, such as voting activities, to improve event marketing. Li's research suggested leveraging WeChat's unique features like service accounts and micro-communities to enhance ongoing event operations. The following year, Miao and Li [4] analyzed the role of new media in promoting mass sports events. They used case studies and expert interviews to investigate the reasons behind media path dependency and proposed that combining online and offline activities could be an innovative solution for future event promotion. In 2018, Zhou and Li [5] focused on large-scale mass sports events, identifying challenges such as limited event types, outdated operational models, and a lack of brand awareness. They proposed expanding event variety, enhancing administrative functions, and building stronger event brands to address these issues. The following year, Zhou and Li [6] examined the governance of mass sports events within the context of China's national fitness strategy. They advocated for a governance approach centered on precision, collaboration, legal protection, and sustainability to ensure the efficient and long-term development of mass sports events. In 2020, Hu and Jing [7] investigated the challenges faced by mass sports events in Guangdong Province, suggesting that the region should leverage its unique cultural and natural resources to create brand-specific events. They also emphasized the need for legislative support and a more coordinated management structure within the Guangdong-Hong Kong-Macao Greater Bay Area. Around the same time, Wu [8] examined the importance of linking mass sports events across the Greater Bay Area, suggesting that such integration could promote cultural exchange and provide a platform for the internationalization of Chinese mass sports. Wang [9] studied mass sports event governance from a social governance perspective. He proposed innovative governance models that would stimulate the active participation of multiple stakeholders, clarify roles, and create a co-governance framework for event management. In 2022, Zhang, Zhang, Zheng and Tian [10] explored the digital governance of mass sports events. They argued for the necessity of integrating digital tools to enhance management efficiency and suggested building information platforms to support precise supervision and service. More recently, Ma, Jiang and Wang [11] focused on the legal aspects of managing emergencies in mass sports events. They recommended clarifying the responsibilities of safety regulators, establishing qualification systems for event organizers, and enhancing legal frameworks to cover civil liability. Finally, in 2024, Zhang and Zhang [12] conducted a comprehensive analysis of the governance mechanisms of mass sports events from a multi-stakeholder perspective. Their study identified challenges such as unclear governance responsibilities and insufficient resource support, and they proposed further refining collaboration and risk assessment mechanisms to improve event governance.

The service quality evaluation of mass sports events presents a MAGDM. To address this, traditional WPM technique [13] has been utilized as a means to manage MAGDM. In the context of service quality evaluation of mass sports events, TNN [14] are administrated as valuable decision tool to handle uncertain information in light with neutrosophic sets [15-18]. While various techniques have been developed to optimize the traditional WPM technique [13], there is a scarcity of methods that apply the WPM technique to manage MAGDM using TNN. In this study, we propose the TNN-WPM approach, which integrates the traditional WPM method with TNN. This novel approach is applied to MAGDM for evaluating the service quality of mass sports events. To demonstrate the effectiveness and key advantages of the proposed technique, a numerical example focusing on the service quality evaluation of mass sports events is presented, followed by a comparative analysis with existing methods.

The key contributions of this study are outlined as follows:

- **Extension of the WPM Technique**: We extend the traditional WPM approach by incorporating TNN, which enhances its applicability in scenarios involving uncertainty and linguistic information.
- **Development of the TNN-WPM Technique for MAGDM**: A new TNN-WPM technique is developed specifically for MAGDM, utilizing TNN to better handle uncertainty and improve decision-making accuracy in complex environments.
- **Numerical Demonstration**: We illustrate the application of the TNN-WPM technique through a detailed numerical study on the service quality evaluation of mass sports events, providing practical insights into its implementation.
- **Comparative Analysis**: A comparative analysis is conducted to evaluate the performance of the TNN-WPM technique against existing methods. The results confirm the effectiveness and reliability of the proposed approach for service quality evaluation in mass sports events.

This study demonstrates that the TNN-WPM technique is a valuable tool for MAGDM, especially in scenarios where uncertainty and linguistic assessments play a significant role. The method offers a more comprehensive and accurate evaluation of service quality, making it a useful approach for decision-makers in the context of mass sports events.

To achieve this, the study follows a structured approach: Section 2 introduces the concept of TNN. Section 3 focuses on the application of the TNN-WPM technique for MAGDM. In Section 4, a numerical example is provided, specifically analyzing the service quality evaluation of mass sports events. Additionally, a comparative analysis is conducted to further validate and examine the results obtained from the TNN-WPM technique. This structure allows for a clear and systematic exploration of the method's effectiveness in MAGDM scenarios.

2. Preliminaries

In order to provide a trapezoidal neutrosophic set based on the combination of trapezoidal fuzzy numbers and a single-valued neutrosophic set, together with its score and accuracy functions, this section extends a trapezoidal intuitionistic fuzzy set—which is preferred in practice—to a single-valued neutrosophic set.

We provide the following concept of a trapezoidal neutrosophic set (TNS), which is an extension of a trapezoidal intuitionistic fuzzy set [23,24].

Definition 1

Let x be a universe of discourse, TNS can be defined as:

$$\boldsymbol{N} = \{(\boldsymbol{x}, \boldsymbol{T_N}(\boldsymbol{x}), \boldsymbol{N_N}(\boldsymbol{x}), \boldsymbol{F_N}(\boldsymbol{x}))|\boldsymbol{x} \in \boldsymbol{X}\} \quad (1)$$

Where $\boldsymbol{T_N}(\boldsymbol{x}) = \left(\boldsymbol{t_N^1}(\boldsymbol{x}), \boldsymbol{t_N^2}(\boldsymbol{x}), \boldsymbol{t_N^3}(\boldsymbol{x}), \boldsymbol{t_N^4}(\boldsymbol{x})\right): \boldsymbol{X} \to [\mathbf{0}, \mathbf{1}]$

$$\boldsymbol{I_N}(\boldsymbol{x}) = \left(\boldsymbol{i_N^1}(\boldsymbol{x}), \boldsymbol{i_N^2}(\boldsymbol{x}), \boldsymbol{i_N^3}(\boldsymbol{x}), \boldsymbol{i_N^4}(\boldsymbol{x})\right): \boldsymbol{X} \to [\mathbf{0}, \mathbf{1}] \quad (2)$$

$$\boldsymbol{T_N}(\boldsymbol{x}) = \left(\boldsymbol{f_N^1}(\boldsymbol{x}), \boldsymbol{f_N^2}(\boldsymbol{x}), \boldsymbol{f_N^3}(\boldsymbol{x}), \boldsymbol{f_N^4}(\boldsymbol{x})\right): \boldsymbol{X} \to [\mathbf{0}, \mathbf{1}] \quad (3)$$

$$\mathbf{0} \leq \boldsymbol{t_n^4}(\boldsymbol{x}) + \boldsymbol{i_n^4}(\boldsymbol{x}) + \boldsymbol{f_n^4}(\boldsymbol{x}) \leq \mathbf{3}, \boldsymbol{x} \in \boldsymbol{X} \quad (4)$$

Definition 2

Let $\boldsymbol{n_1} = ((\boldsymbol{a_1}, \boldsymbol{b_1}, \boldsymbol{c_1}, \boldsymbol{d_1}), (\boldsymbol{e_1}, \boldsymbol{f_1}, \boldsymbol{g_1}, \boldsymbol{h_1}), (\boldsymbol{l_1}, \boldsymbol{m_1}, \boldsymbol{n_1}, \boldsymbol{p_1}))$ and

$\boldsymbol{n_2} = ((\boldsymbol{a_2}, \boldsymbol{b_2}, \boldsymbol{c_2}, \boldsymbol{d_2}), (\boldsymbol{e_2}, \boldsymbol{f_2}, \boldsymbol{g_2}, \boldsymbol{h_2}), (\boldsymbol{l_2}, \boldsymbol{m_2}, \boldsymbol{n_2}, \boldsymbol{p_2}))$

$$\boldsymbol{n_1} \oplus \boldsymbol{n_2} = \begin{Bmatrix} (\boldsymbol{a_1} + \boldsymbol{a_2} - \boldsymbol{a_1 a_2}, \boldsymbol{b_1} + \boldsymbol{b_2} - \boldsymbol{b_1 b_2}, \boldsymbol{c_1} + \boldsymbol{c_2} - \boldsymbol{c_1 c_2}, \boldsymbol{d_1} + \boldsymbol{d_2} - \boldsymbol{d_1 d_2}), \\ (\boldsymbol{e_1 e_2}, \boldsymbol{f_1 f_2}, \boldsymbol{g_1 g_2}, \boldsymbol{h_1 h_2}), (\boldsymbol{l_1 l_2}, \boldsymbol{m_1 m_2}, \boldsymbol{n_1 n_2}, \boldsymbol{p_1 p_2}) \end{Bmatrix} \quad (5)$$

$$\boldsymbol{n_1} \otimes \boldsymbol{n_2} = \begin{Bmatrix} (\boldsymbol{a_1 a_2}, \boldsymbol{b_1 b_2}, \boldsymbol{c_1 c_2}, \boldsymbol{d_1 d_2}), \\ (\boldsymbol{e_1} + \boldsymbol{e_2} - \boldsymbol{e_1 e_2}, \boldsymbol{f_1} + \boldsymbol{f_2} - \boldsymbol{f_1 f_2}, \boldsymbol{g_1} + \boldsymbol{g_2} - \boldsymbol{g_1 g_2}, \boldsymbol{h_1} + \boldsymbol{h_2} - \boldsymbol{h_1 h_2}), \\ (\boldsymbol{l_1} + \boldsymbol{l_2} - \boldsymbol{l_1 l_2}, \boldsymbol{m_1} + \boldsymbol{m_2} - \boldsymbol{m_1 m_2}, \boldsymbol{n_1} + \boldsymbol{n_2} - \boldsymbol{n_1 n_2}, \boldsymbol{p_1} + \boldsymbol{p_2} - \boldsymbol{p_1 p_2}) \end{Bmatrix} \quad (6)$$

$$\curlyvee \boldsymbol{n_1} = \begin{Bmatrix} (\mathbf{1} - (\mathbf{1} - \boldsymbol{a_1})^{\curlyvee}, \mathbf{1} - (\mathbf{1} - \boldsymbol{b_1})^{\curlyvee}, \mathbf{1} - (\mathbf{1} - \boldsymbol{c_1})^{\curlyvee}, \mathbf{1} - (\mathbf{1} - \boldsymbol{d_1})^{\curlyvee}), \\ (\boldsymbol{e_1^{\curlyvee}}, \boldsymbol{f_1^{\curlyvee}}, \boldsymbol{g_1^{\curlyvee}}, \boldsymbol{h_1^{\curlyvee}}), (\boldsymbol{l_1^{\curlyvee}}, \boldsymbol{m_1^{\curlyvee}}, \boldsymbol{n_1^{\curlyvee}}, \boldsymbol{p_1^{\curlyvee}}) \end{Bmatrix} \quad (7)$$

$$\boldsymbol{n_1^{\curlyvee}} = \begin{Bmatrix} (\boldsymbol{a_1^{\curlyvee}}, \boldsymbol{b_1^{\curlyvee}}, \boldsymbol{c_1^{\curlyvee}}, \boldsymbol{d_1^{\curlyvee}}), \\ (\mathbf{1} - (\mathbf{1} - \boldsymbol{e_1})^{\curlyvee}, \mathbf{1} - (\mathbf{1} - \boldsymbol{f_1})^{\curlyvee}, \mathbf{1} - (\mathbf{1} - \boldsymbol{g_1})^{\curlyvee}, \mathbf{1} - (\mathbf{1} - \boldsymbol{h_1})^{\curlyvee}), \\ (\mathbf{1} - (\mathbf{1} - \boldsymbol{l_1})^{\curlyvee}, \mathbf{1} - (\mathbf{1} - \boldsymbol{m_1})^{\curlyvee}, \mathbf{1} - (\mathbf{1} - \boldsymbol{n_1})^{\curlyvee}, \mathbf{1} - (\mathbf{1} - \boldsymbol{o_1})^{\curlyvee}) \end{Bmatrix} \quad (8)$$

Definition 3

The score function of trapezoidal neutrosophic number (TNN) can be computed as:

$$S(n) = \frac{1}{3}\left(2 + \frac{a+b+c+d}{4}\right) - \left(\frac{e+f+g+h}{4}\right) - \left(\frac{l+m+n+p}{4}\right) \quad (9)$$

Definition 4

The accuracy function of TNN can be computed as:

$$A(n) = \left(\frac{a+b+c+d}{4}\right) - \left(\frac{l+m+n+p}{4}\right) \quad (10)$$

3. Weighted Product Method (WPM) with Trapezoidal Neutrosophic Numbers (TNN)

The TNN-WPM (Trapezoidal Neutrosophic Number Weighted Product Method) framework combines the traditional Weighted Product Method (WPM) with Trapezoidal Neutrosophic Numbers (TNN) to address uncertainty and linguistic assessments in multi-attribute decision-making.

3.1 WPM

WPM evaluates alternatives based on a set of criteria by computing the product of the normalized performance scores raised to the power of their respective weights. It is particularly effective in decision-making where multiplicative relationships are meaningful, such as evaluating proportional contributions.

3.2 TNN

TNN extends traditional fuzzy and intuitionistic fuzzy sets by incorporating truth (T), indeterminacy (I), and falsity (F) memberships, each represented by trapezoidal numbers.

Example of TNN: $(a, b, c, d), (e, f, g, h), (i, j, k, l)$ (a,b,c,d),(e,f,g,h),(i,j,k,l), where:

a, b, c, d a,b,c,d: Membership to truth

e, f, g, h e,f,g,h: Membership to indeterminacy

i, j, k, l i,j,k,l: Membership to falsity.

This representation handles vagueness and uncertainty in data more effectively than crisp or fuzzy numbers.

3.3 Practical Applications

The practical implications of the TNN-WPM technique extend across multiple domains due to its capacity to process uncertain and linguistic information effectively. Key applications include:

- Cultural Event Management: Ensuring high service quality in cultural festivals by evaluating logistics, attendee satisfaction, and staff performance.
- Healthcare Services: Assessing patient satisfaction and service efficiency to improve overall healthcare delivery under uncertain feedback.
- Public Transport Systems: Enhancing service quality through the evaluation of scheduling, safety, and passenger satisfaction.

The adoption of TNN-WPM in these sectors facilitates precise, unbiased decision-making, fostering enhanced operational outcomes.

3.4 Comparative Analysis of Other Techniques

The TNN-WPM technique was benchmarked against similar MAGDM methods to assess its unique strengths:

Technique	Strengths	Weaknesses
TNN-WPM	Manages overall and individual uncertainty; Simplicity of application	Does not account for psychological factors
TNN-TODIM	Incorporates psychological behaviors	Complex structure and calculations
TNN-VIKOR	Balances compromise solutions	Limited capability for handling uncertainty

3.5 Advantages of TNN-WPM

- TNN allows modeling of truth, indeterminacy, and falsity, capturing nuanced uncertainties in decision-making.
- Effective in real-world situations with multiple conflicting criteria and vague inputs.
- Despite its robust modeling, the method remains computationally straightforward compared to other multi-attribute decision-making methods.
- TNN-WPM is adaptable to various fields, including sports management, healthcare, education, and urban planning.

3.6 Steps in the TNN-WPM Framework

The steps of TNN-WPM are:

A. Create a decision matrix.

The decision matrix is created between the criteria and alternatives by the opinions of decision makers.

$$K = \begin{bmatrix} k_{11} & \cdots & k_{1n} \\ \vdots & \ddots & \vdots \\ k_{m1} & \cdots & k_{mn} \end{bmatrix} \quad (11)$$

B. apply the score function to obtain one value.

C. Combined the decision matrix.

D. Compute the criteria weights.

The criteria weights are computed using the average method.

E. Normalize the decision matrix.

$$D_{ij} = \frac{k_{ij}}{\max k_{ij}} \text{ for positive criteria} \quad (12)$$

$$D_{ij} = \frac{\min k_{ij}}{k_{ij}} \text{ for cost criteria} \quad (13)$$

F. Compute the weighted normalized decision matrix.

$$y_{ij} = w_j D_{ij} \quad (14)$$

G. Rank the alternatives.

$$R_i = \prod_{j=1}^{n} y_{ij} \quad (15)$$

4. Numerical examples and comparative analysis

The evaluation of service quality in mass sports events refers to a systematic assessment of various aspects such as event organization, venue facilities, service personnel, information dissemination, and event safety, to comprehensively measure the overall quality of services and the performance of each component. The core goal of this evaluation is to ensure that participants and spectators have a positive experience, increase their satisfaction, and continuously improve and optimize the event. First, event organization is one of the key aspects of evaluation. The preparation of the event, scheduling, and contingency plans are directly related to the smooth operation of the entire event. Whether the event is organized rigorously and reasonably, and whether it can effectively handle unexpected situations, serves as a fundamental standard for evaluating service quality. Second, the completeness and safety of venue facilities are also important evaluation factors. Good venue conditions, clear signage systems, and reasonable seating arrangements can significantly enhance the experience of participants. At the same time, safety measures at the venue, such as first aid facilities, emergency exits, and security personnel, directly impact the service quality of the event. The professionalism and attitude of service personnel are crucial factors that directly affect service quality. Whether volunteers, referees, or the event's operational management team, their service attitude, professional competence, and communication skills have a direct impact on the satisfaction of participants and spectators. In addition, the timeliness and accuracy of information dissemination are also key aspects of service quality. By using effective communication channels to clearly convey event schedules, rules, transportation information, and other details, any confusion caused by information asymmetry can be avoided, thereby improving the efficiency of event organization. Finally, the service quality evaluation system for the event must include feedback from participants and spectators. By collecting their opinions and suggestions, organizers can deeply understand the shortcomings in the event services and make adjustments and optimizations based on the actual situation. Overall, the evaluation of service quality in mass sports events is not only a tool for assessing the success of the event but also provides valuable references and improvement directions for future event organizations. It effectively enhances the brand image of the event, promotes the continued development of mass fitness activities, and facilitates the widespread dissemination of sports culture. The service quality evaluation of mass sports events is MAGDM. Seven possible mass sports events are assessed with 18 attributes as shown in Figure 1.

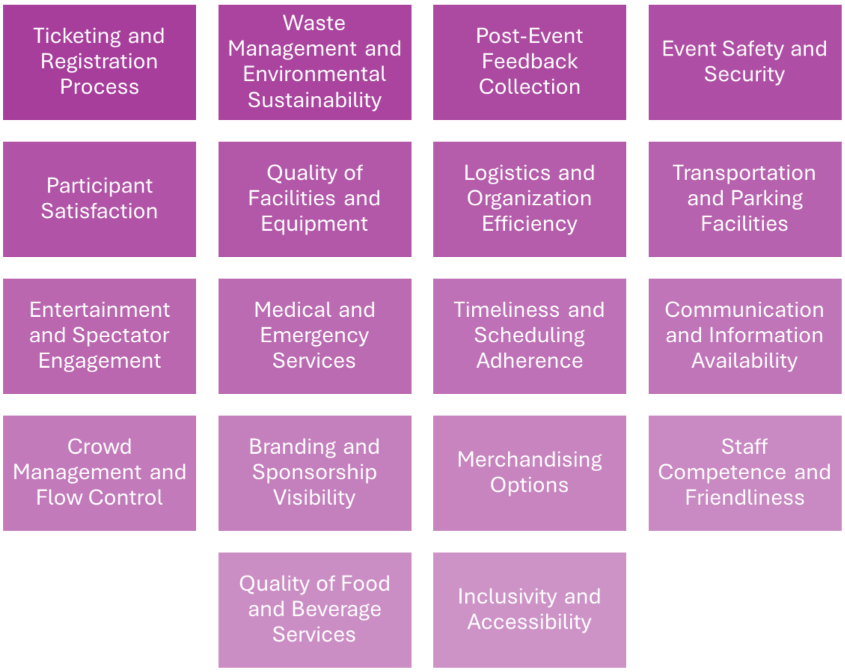

Figure 1. Detailed List of Selection Criteria

4.1 Illustrative Example

1. Problem:

A sports event organizer wants to evaluate three venues (A1, A2, A3) based on:

C1: Venue capacity.

C2: Accessibility.

C3: Cost.

2. Decision Matrix (TNN):

	C1 (Beneficial)	C2 (Beneficial)	C3 (Cost)
A1	(0.5,0.6,0.7,0.8) (0.5, 0.6, 0.7, 0.8) (0.5,0.6,0.7,0.8)	(0.4,0.5,0.6,0.7) (0.4, 0.5, 0.6, 0.7) (0.4,0.5,0.6,0.7)	(0.3,0.4,0.5,0.6) (0.3, 0.4, 0.5, 0.6) (0.3,0.4,0.5,0.6)
A2	(0.6,0.7,0.8,0.9) (0.6, 0.7, 0.8, 0.9) (0.6,0.7,0.8,0.9)	(0.5,0.6,0.7,0.8) (0.5, 0.6, 0.7, 0.8) (0.5,0.6,0.7,0.8)	(0.4,0.5,0.6,0.7) (0.4, 0.5, 0.6, 0.7) (0.4,0.5,0.6,0.7)
A3	(0.4,0.5,0.6,0.7) (0.4, 0.5, 0.6, 0.7) (0.4,0.5,0.6,0.7)	(0.6,0.7,0.8,0.9) (0.6, 0.7, 0.8, 0.9) (0.6,0.7,0.8,0.9)	(0.2,0.3,0.4,0.5) (0.2, 0.3, 0.4, 0.5) (0.2,0.3,0.4,0.5)

3. Steps:

Calculated Scores:

S(A1, C1)=0.65 , S(A1,C2)=0.55S(A1, C2) = 0.55S , S(A1,C3)=0.45 , etc.

Normalize Scores:

Normalize using beneficial or cost criteria formulas.

Apply Weights:

Assign weights to criteria (W_C1=0.4, W_C2=0.3, W_C3=0.3

Rank Alternatives:

Computing the final scores: VA1, V_{A2}, VA_3

Rank A2>A3>A1

4.2 Detailed Explanation of the Process

Step A: Creating a Decision Matrix Using TNN

The process begins by constructing a decision matrix, as shown in Table 1, where:

Rows represent alternatives such as different venues for a sports event.

Columns represent the evaluation criteria, such as safety, accessibility, and cost.

Each entry in the matrix is represented by a TNN, which captures uncertainty in the evaluation. The decision matrix in Table 1 provides a comprehensive overview of the alternatives and their performance under each criterion.

Step B: Applying the Score Function to Simplify Evaluations

The next step is to simplify the TNN values in Table 1 into single, representative scores using the score function. This function converts the complex TNN into a single numeric value, making it easier to compare alternatives.

For example: A venue evaluated as "mostly good with slight uncertainty" might be simplified to a score of 7.5 out of 10. The result is a revised decision matrix where each entry is now represented by a single score instead of a TNN.

Step C: Consolidating the Decision Matrix

After simplifying the evaluations in Step B, the decision matrix is updated into a consolidated format. This new matrix ensures that all the evaluations are now consistent, simplifying further analysis. The updated decision matrix retains the structure of Table 1, but now all entries are clear and comparable numerical scores.

Step D: Assigning Weights to Criteria

Not all criteria have the same level of importance. For instance, safety might be more critical than cost when evaluating venues. To account for this, weights are assigned to each criterion based on their significance. The weights are typically derived from expert opinions or stakeholder inputs. Figure 2 illustrates the assigned weights for each criterion, clearly showing how much influence each one has in the evaluation process.

For example: Safety might have a weight of 0.4, while cost might have a weight of 0.2.

These weights are crucial for ensuring that the final evaluation aligns with the priorities of the decision-makers.

Step E: Normalizing the Scores (Equation 12)

The scores from the consolidated decision matrix are normalized to ensure all criteria are measured on the same scale. This normalization process adjusts the scores so that they fall within a consistent range, typically between 0 and 1. For beneficial criteria (e.g., higher values are better), normalization ensures that the highest score is assigned a value of 1.

For cost criteria (e.g., lower values are better), normalization ensures that the lowest score is assigned a value of 1. The results of this normalization are shown in Table 2, where all scores have been adjusted for comparability.

Step F: Computing the Weighted Normalized Decision Matrix (Equation 14)

Using the normalized scores from Table 2, the next step is to calculate the weighted normalized scores by applying the weights from Figure 2. This involves multiplying each normalized score by the corresponding weight of the criterion.

The resulting weighted normalized decision matrix reflects both the performance of each alternative and the importance of the criteria.

Step G: Ranking the Alternatives

Finally, the scores for each alternative are aggregated to calculate an overall performance score. These overall scores are used to rank the alternatives.

The rankings, as shown in Figure 3, clearly identify the best-performing alternative based on the weighted normalized scores.

Table 1. Expert 1's Decision Matrix Analysis

	A_1	A_2	A_3	A_4	A_5	A_6	A_7
C_1	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))
C_2	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))
C_3	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))
C_4	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))
C_5	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))
C_6	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))
C_7	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))
C_8	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))
C_9	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))
C_{10}	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))
C_{11}	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))
C_{12}	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))
C_{13}	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))
C_{14}	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))
C_{15}	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))
C_{16}	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))
C_{17}	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))
C_{18}	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))	((0.4,0.5,0.6,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.3,0.4,0.5,0.5),(0.1,0.2,0.3,0.4),(0.0,0.1,0.1,0.1))	((0.1,0.1,0.1,0.1),(0.1,0.1,0.1,0.1),(0.6,0.7,0.8,0.9))	((0.7,0.7,0.7,0.7),(0.0,0.1,0.2,0.3),(0.1,0.1,0.1,0.1))	((0.2,0.3,0.4,0.5),(0.0,0.1,0.2,0.3),(0.0,0.1,0.2,0.3))	((0.6,0.7,0.7,0.8),(0.1,0.1,0.1,0.1),(0.0,0.1,0.1,0.2))

Figure 2. Weighted Analysis of Criteria

Table 2. Data Normalization Results

	A_1	A_2	A_3	A_4	A_5	A_6	A_7
C_1	0.943262	1	0.879433	0.978723	0.950355	0.77305	0.929078
C_2	0.851351	0.831081	1	0.756757	0.851351	0.810811	1
C_3	0.5	1	0.853333	0.886667	0.66	0.993333	0.5
C_4	0.98	0.946667	1	0.853333	0.84	0.826667	0.94
C_5	0.88	0.86	0.893333	0.826667	0.966667	1	0.92
C_6	0.94	0.78	0.94	0.92	0.833333	0.873333	1
C_7	0.938776	1	0.904762	0.884354	0.959184	0.843537	0.891156
C_8	0.857143	0.897959	0.884354	0.789116	0.789116	0.673469	1
C_9	0.627586	0.97931	0.855172	1	0.965517	0.806897	0.682759
C_{10}	1	0.898649	0.736486	0.777027	0.837838	0.932432	0.851351
C_{11}	0.825503	0.899329	0.966443	0.95302	0.731544	1	0.926174
C_{12}	0.946309	0.61745	0.993289	0.95302	0.899329	0.718121	1
C_{13}	0.932432	1	0.864865	0.851351	0.837838	1	0.831081
C_{14}	0.904762	0.877551	0.959184	0.680272	0.891156	0.510204	1
C_{15}	0.5	1	0.913333	0.886667	0.82	0.94	0.5
C_{16}	1	0.904762	0.938776	0.931973	0.904762	0.795918	0.904762

C_{17}	0.825503	0.899329	0.751678	0.892617	0.771812	1	0.926174
C_{18}	0.959184	0.911565	0.904762	0.680272	1	0.836735	0.965986

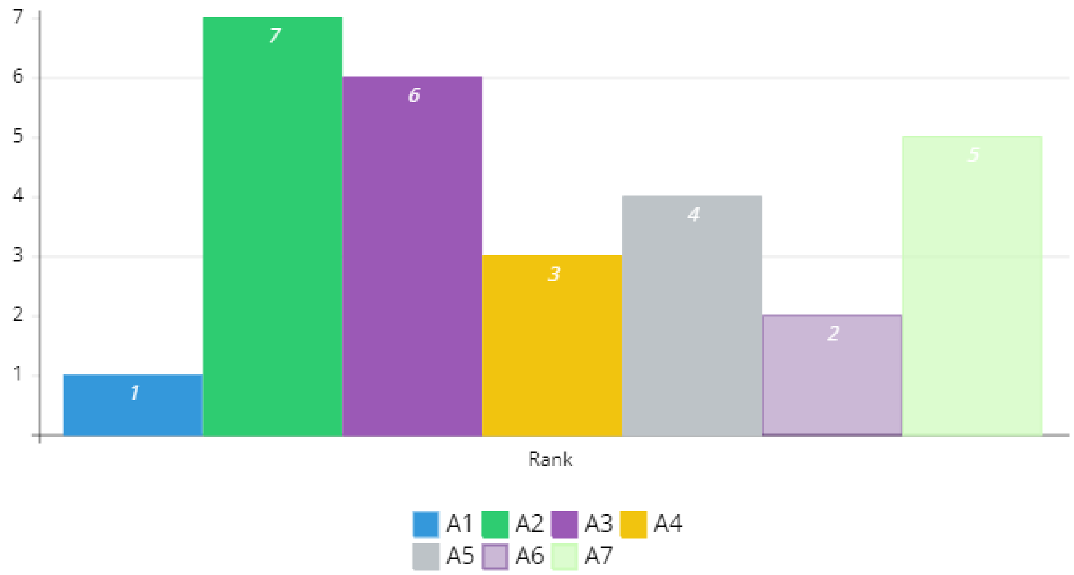

Figure 3. Evaluation Results: Alternative Rankings

Figure 4 shows comparative analysis. When comparing the results of the TNN-WPM model with those of existing models, slight differences in the calculated outcomes are observed. Despite these minor variations, the identification of both the best and the worst mass sports events remains consistent across all models. This consistency demonstrates that the TNN-WPM technique is an effective and reliable approach for MAGDM. The subtle differences in results can be attributed to distinct factors. For instance, the TNN-VIKOR technique addresses the influence of individual decision-makers on the final outcome, while the TNN-TODIM model accounts for the psychological behaviors of DMs. By contrast, the TNN-WPM technique incorporates both individual and overall uncertainty within the framework of TNN.

However, despite its strengths, the TNN-WPM technique does have a limitation. It does not account for the psychological behavior of decision-makers, a factor that can play a significant role in real-world decision-making scenarios, especially in MAGDM contexts. Techniques like the TNN-WPM model, which explicitly consider decision-makers' psychological tendencies, may be better suited for situations where such behavior is a critical factor. Nonetheless, the TNN-WPM technique remains a highly effective tool for addressing uncertainty, offering a reliable and straightforward approach to MAGDM, even if it does not fully capture the complexity of human decision-making behaviors.

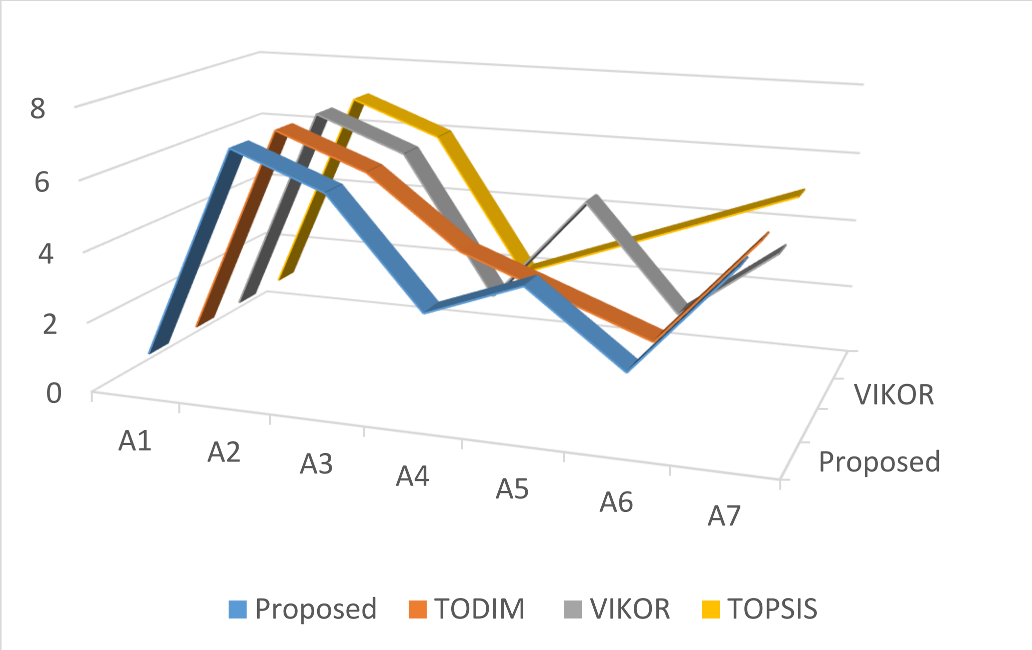

Figure 4. Rankings of Alternatives: Comparative Analysis

6. Conclusion

The evaluation of service quality in mass sports events involves a comprehensive and systematic assessment of various aspects to ensure a positive experience for participants and spectators. It specifically examines event organization, venue facilities, safety measures, the service provided by volunteers and staff, as well as event promotion and information dissemination. By gathering feedback from participants, spectators, and other stakeholders, the strengths and weaknesses of the event services are analyzed. This evaluation not only helps event organizers optimize service processes and improve the overall quality of the event but also enhances public engagement and satisfaction, promoting word-of-mouth and brand building. Additionally, it contributes to the development of mass fitness initiatives and increases the influence and popularity of sports culture in society. A high-quality event service evaluation system encourages more people to participate in sports activities and elevates the public perception of the event. The problem of service quality evaluation of mass sports events is MAGDM. This study presents the application of TNN-WPM technique, which is based on the traditional WPM technique with TNN. By incorporating WPM technique along with TNN, TNN-WPM technique is implemented for MAGDM with TNN. Additionally, numerical example focusing on the service quality evaluation of mass sports events is provided to validate the advantages of TNN-WPM. Comparative analysis is administrated to highlight the strengths of this technique. The key contributions of this study are summarized: (1) Extension of WPM technique to encompass TNN, expanding its applicability; (2)

Implementation of TNN-WPM technique for MAGDM, utilizing the advantages of TNN; (3) Demonstration of TNN-WPM technique through numerical example involving the service quality evaluation of mass sports events. Comparative analysis is administrated to further illustrate the advantages of TNN-WPM technique.

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