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Tree Soft Set and Decision-Making Approaches for Tourist Satisfaction Assessment of Tourist Attractions

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Abstract: One of the most precise decision-making techniques is multi-criteria decision-making (MCDM), which has been dubbed a revolution in the area. The act of choosing alternatives by considering several criteria to ascertain which is optimal is known as multicriteria decision-making, or MCDM. The techniques and tools developed by MCDM have a wide range of applications in engineering, design, and finance. To address the ambiguity of possibilities in application-oriented issues with many criteria, Smarandache developed Tree soft sets, which are an extension of hypersoft sets. To determine the optimal desalination technique utilizing one of the MCDM approaches, we will examine the real-world application-oriented issue of Tourist Satisfaction Evaluation of Tourist Attractions in the context of tree soft sets in this work.

Keywords: Tree Soft Set; Decision making; Tourist Satisfaction; Tourist Attractions; MCDM Methodology.

1. Introduction

Tourist satisfaction plays a crucial role in the competitiveness and sustainability of tourist destinations worldwide. As travelers seek memorable and enriching experiences, their perceptions of a destination are shaped by various factors such as scenic beauty, accessibility, service quality, available activities, and cost-effectiveness. A positive tourism experience enhances the reputation of an attraction, leading to increased visitor numbers, economic growth, and long-term destination success. Conversely, dissatisfaction due to poor service, inadequate facilities, or high costs can result in negative reviews and declining tourist interest[1], [2]. Therefore, evaluating tourist satisfaction is essential for tourism operators and policymakers to enhance destination management and improve overall visitor experience. To comprehensively evaluate tourist satisfaction, a multi-criteria assessment approach is required. Factors such as natural and cultural appeal, ease of transportation, quality of facilities, variety of recreational activities, and affordability significantly impact visitor experiences. Different types of attractions—ranging from natural landscapes offer diverse experiences, necessitating tailored evaluation frameworks. By systematically analyzing these criteria, tourism planners can identify strengths and weaknesses, allowing for strategic improvements that align with visitor expectations and industry trends[3], [4]. Modern evaluation techniques, particularly multi-criteria decision-making (MCDM) methods, provide structured approaches to ranking tourist attractions based on performance indicators. These methods help in quantifying subjective experiences by incorporating expert opinions and visitor feedback, resulting in objective and data-driven rankings. Additionally, with the rise of digital platforms and social media, analyzing tourist reviews and sentiment analysis further refine satisfaction assessments. By leveraging these evaluation models, decision-makers can prioritize infrastructure enhancements, optimize tourism marketing strategies, and improve overall service delivery to maximize visitor satisfaction. As global tourism continues to evolve, driven by technological advancements and changing traveler preferences, the importance of systematic tourist satisfaction evaluation will only grow. Sustainable tourism development requires a balance between preserving cultural and natural heritage while ensuring high-quality visitor experiences. By continuously assessing and improving tourism attractions based on visitor feedback and performance evaluations, stakeholders can create more inclusive, enjoyable, and sustainable tourism destinations that cater to the expectations of modern travelers[5], [6]. Making decisions is a complex intellectual process that entails resolving issues while accounting for several variables to reach a desired result. Both explicit and implicit assumptions may be used in this process, which might be illogical or reasonable and influenced by social, cultural, physiological, and biological variables. These elements, along with the degree of risk and power involved, affect how complicated decisions are. Using mathematical equations, various statistics, mathematics, and economic theories, computer technology may help automatically calculate and estimate answers to decision-making difficulties in the modern world. By considering several factors throughout the selection process, MCDM seeks to identify the optimal choice.

Numerous MCDM tools and methods may be used in a variety of fields, including robotics, engineering, and finance. Regardless of the extent of missing data, periodic mathematics (PM), fuzzy set theory (FST), probabilistic set theory (PST), and rough set theory (RST) are thought to be the scientific methods for handling incomplete data. Zadeh initially introduced fuzzy sets to deal with ambiguity, which made them beneficial for a variety of applications like pattern recognition, medical diagnosis, and decision-making. Numerous fuzzy set generalizations, including rough sets, soft sets, intuitionistic fuzzy sets, bipolar fuzzy sets, bipolar soft sets, m-polar soft sets, hypersoft sets, and many more, have been created because of their popularity[7], [8]. At the maximum level of incompleteness, soft sets (Ss) are an interesting extension of fuzzy sets with further ambiguity and vagueness characteristics. Soft sets handle ambiguous, imprecise, and vague components. The function of parameters is important in all decision-making situations, but professionals must assess them when they are ambiguous. A multi-argument approximation function was employed by the hypersoft sets, a soft set extension, to address the drawbacks of the existing structures for attribute-valued disjoint sets. Eventually, to handle ambiguous situations in real-world problems, MultiSoft sets were introduced to soft sets[9].

Additionally, tree soft sets—which are quite like hypersoft sets—have recently been developed as an expansion of MultiSoft sets. Hypersoft sets deal with criteria and sub- criteria, whereas tree soft sets deal with criteria, sub- criteria, sub- criteria, and so on. The capacity of tree soft sets to have many sub- criteria, represented as level 0, level 1, level 2,…, level n, is one of its distinctive features. Using tree soft sets will significantly reduce uncertainty in real-world applications[10], [11].

2. Tree Soft Set (TSS)

This section shows the definitions of the TSS. Let U as a universal set and $P(U)$ is a power set of U. Let a set of criteria such as $c_1, c_2, \dots c_n and\ n \geq 1\ for\ the\ first\ level$ and intersection of these criteria are non-empty set. Every criterion $C_i, 1 \leq 1 \leq n$, is formed by sub criteria[12], [13]:

$$\begin{gathered}
C_1 = \{C_{11}, C_{12}, C_{13}, C_{14}, C_{15}\} \\
C_2 = \{C_{21}, C_{22}, C_{23}, C_{24}, C_{25}\} \\
C_3 = \{C_{31}, C_{32}, C_{33}, C_{34}, C_{35}\} \\
C_4 = \{C_{41}, C_{42}, C_{43}, C_{44}, C_{45}\} \\
C_5 = \{C_{51}, C_{52}, C_{53}, C_{54}, C_{55}\} \\
C_6 = \{C_{61}, C_{62}, C_{63}, C_{64}, C_{65}\} \\
C_7 = \{C_{71}, C_{72}, C_{73}, C_{74}, C_{75}\} \\
\vdots \\
C_n = \{C_{n1}, C_{n2}, C_{n3}, C_{n4}, C_{n5}\}
\end{gathered} \tag{1}$$

Where C_{ij} are sub criteria and these criteria are formed as level in tree. The first level presents the root nodes, the second level presents the main criteria, and the third level presents the sub criteria values. Fig 1 shows the tree nodes.

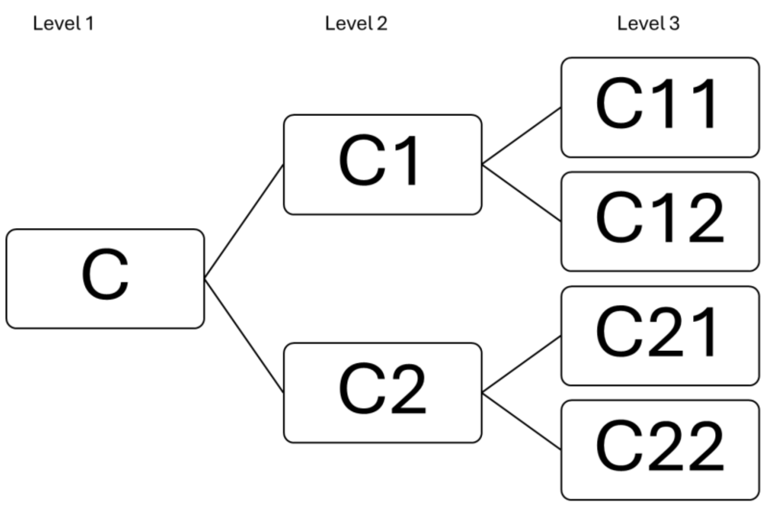

Fig 1. The tree nodes.

The TSS can be formed as:

$$F: P\big(Tree(A)\big) \rightarrow P(H) \tag{2}$$

Example:

The criteria of Tourist Satisfaction can be considered as a TSS, and the node of this problem is shown as levels of the tree as shown in Fig 2.

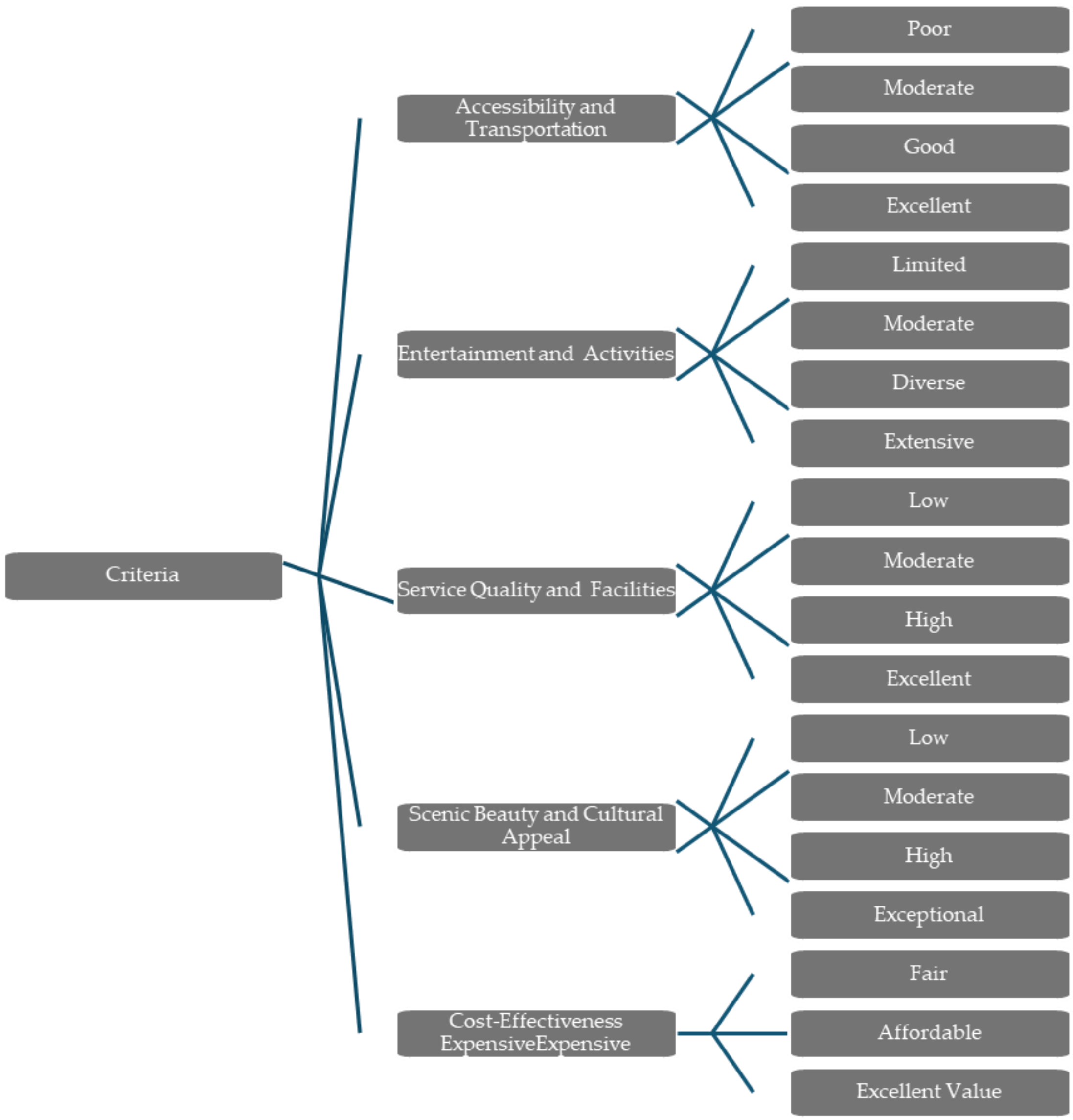

Fig 2. The Tourist Satisfaction tree.

3. MCDM Approach

This section shows the steps of the proposed approach. We use two MCDM methods in this study. We use the ITARA methodology to compute the criteria weights [14], [15]and the MABAC methodology to rank the alternatives.

ITARA Methodology

Build the decision matrix.

The decision matrix is built using the opinions of the experts. Then we combine these values into one matrix.

Set the indifference threshold h_j.

The experts formulate the indifference threshold

Compute the normalized matrix

$$n_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (3)$$

Sort the elements in the decision matrix

Compute the dispersion degree of the adjacent elements

$$u_{ij} = n_{i+1,j} - n_{ij} \quad (4)$$

Compute the distance between the u_{ij} and h_j.

$$p_{ij} = \begin{cases} u_{ij} - Nh_j, u_{ij} > Nh_j \\ 0, \qquad u_{ij} \le Nh_j \end{cases} \quad (5)$$

Compute the criteria weights

$$w_j = \frac{\left(\sum_{i=1}^{m-1} P_{ij}^{b}\right)^{\frac{1}{b}}}{\sum_{i=1}^{n}\left(\sum_{i=1}^{m-1} P_{ij}^{b}\right)^{\frac{1}{b}}} \quad (6)$$

MABAC Methodology

This section shows the steps of the MABAC Methodology to rank the alternatives[16], [17].

Normalize the decision matrix

$$t_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \quad (7)$$

$$t_{ij} = \frac{x_{ij} - \max x_{ij}}{\min x_{ij} - \max x_{ij}} \quad (8)$$

Compute the weighted decision matrix

$$o_{ij} = w_j + w_j t_{ij} \quad (9)$$

Compute the border approximation area matrix

$$q_j = \left(\prod_{i=1}^{m} o_{ij}\right)^{\frac{1}{m}} \quad (10)$$

Compute the distance from the border q_j

$$e_{ij} = o_{ij} - q_j \quad (11)$$

Compute the total distance

$$s_i = \sum_{j=1}^{n} e_{ij} \quad (12)$$

Rank the alternatives.

4. Results

This section shows the results of two MCDM methods. We are obtaining the criteria weights and ranking the alternatives. Three experts have evaluated the criteria and alternatives. They used linguistic terms as Very High, High, Medium High, Medium, Medium Low, Low, Very Low by using values between 0.1 to 0.9. We used the concept of TSS by dividing the criteria and sub criteria into three levels as shown in Fig 2. We select the values of each criterion as excellent, moderate, excellent, high, and fair.

Build the decision matrix.

Three experts are building the decision matrix as shown in Table 1.

Then we set the indifference threshold h_j.

Then we compute the normalized matrix as shown in Fig 3 using Eq. (3).

Then we sort the elements in the decision matrix

Then we compute the dispersion degree of the adjacent elements using Eq. (4).

Then we compute the distance between the u_{ij} and h_j using Eq. (5).

Then we compute the criteria weights using Eq. (6) as shown in Fig 4.

Table 1. Linguistic terms by experts.

	C_1	C_2	C_3	C_4	C_5
A_1	High	Medium High	Medium	Medium Low	Low
A_2	Very Low	Very High	High	Medium High	Medium
A_3	Low	Very High	Medium	Medium Low	Low
A_4	Medium Low	High	Medium High	High	Very High
A_5	Medium	Very High	Medium Low	Low	Very Low
A_6	Medium High	Medium Low	Medium	High	Very Low
A_7	Very Low	Medium	Medium Low	Very High	Medium High
A_8	Very High	Medium High	Very High	Medium Low	Medium
A_9	High	Very Low	Very Low	Very Low	Medium Low
A_{10}	Low	Medium Low	Medium	Medium High	Very Low
	C_1	C_2	C_3	C_4	C_5
A_1	Very High	Medium High	Medium	Medium Low	Low
A_2	High	Low	High	Medium High	Medium
A_3	Medium High	Low	Medium	Medium Low	Low
A_4	Medium	High	Medium High	Very Low	Very High

A_5	Medium Low	Low	Medium Low	Very High	High
A_6	Medium High	Very Low	Very High	High	Medium High
A_7	Very Low	Medium High	High	Medium High	Medium
A_8	Very High	Medium	Medium High	Medium	Medium Low
A_9	High	Medium Low	Medium	Medium Low	Medium Low
A_{10}	Low	Medium Low	Medium Low	Medium High	High
	C_1	C_2	C_3	C_4	C_5
A_1	Very Low	Medium High	Medium	Medium Low	Medium Low
A_2	Very Low	Medium Low	High	Medium High	Medium
A_3	Very High	Medium	Medium	Medium Low	Medium High
A_4	Medium Low	Medium High	Medium Low	High	High
A_5	Medium	Very Low	Medium	Medium Low	Medium Low
A_6	Medium High	Medium Low	Medium High	Medium	Medium
A_7	High	Medium	High	Medium High	Medium High
A_8	Low	Medium High	Low	Very Low	Very Low
A_9	High	High	High	High	Medium Low
A_{10}	Very High	Medium Low	Medium	Medium High	High

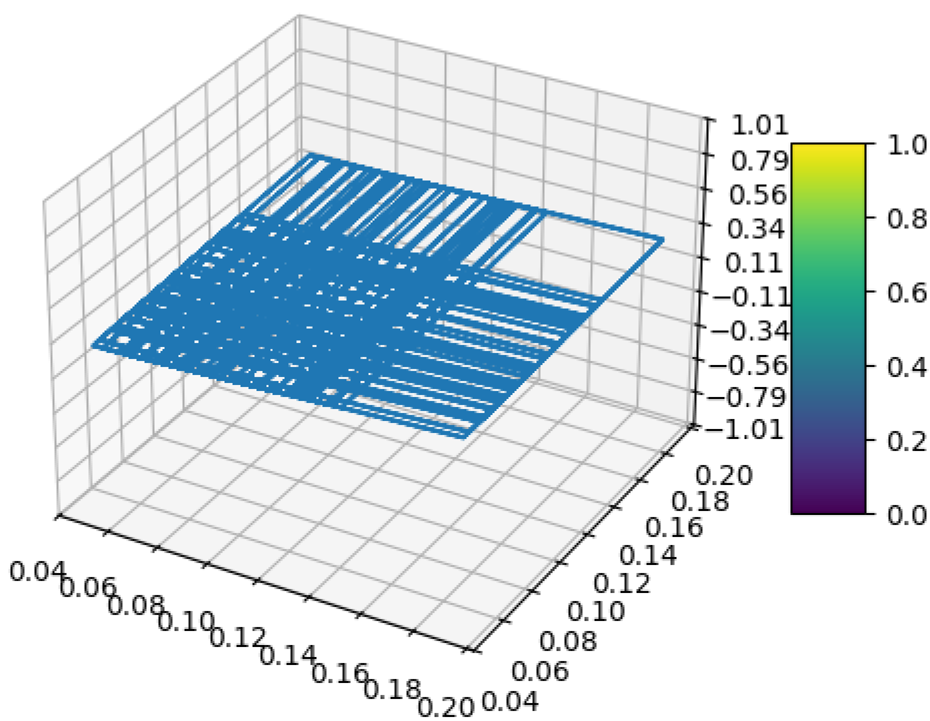

Fig 3. The normalization matrix by weighting method.

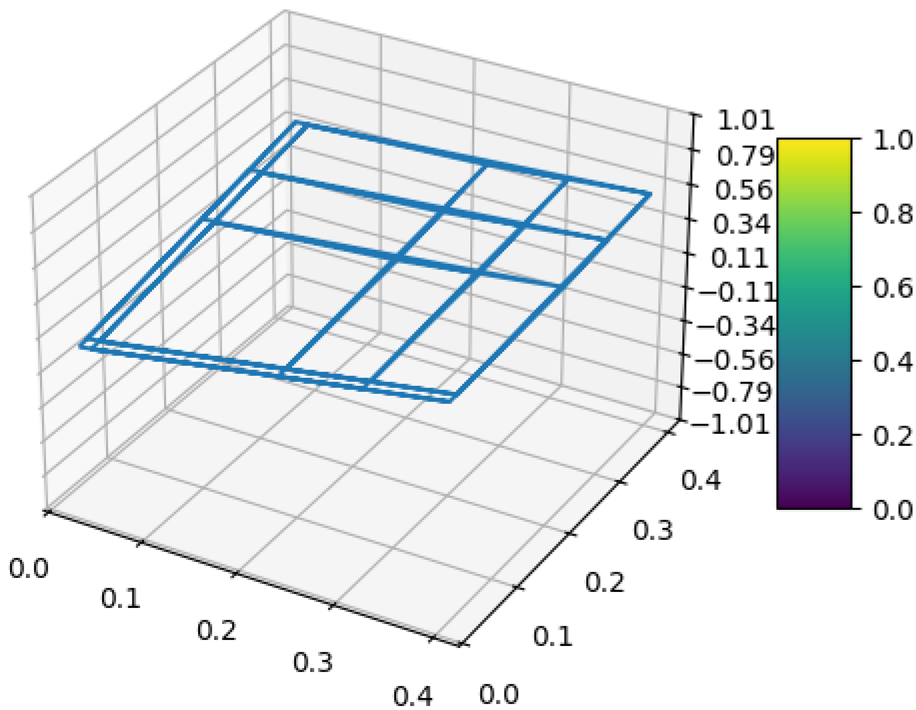

Fig 4. The criteria weights.

MABAC Methodology

We used Eq. (7) to normalize the decision matrix as shown in Fig 5.

Then we compute the weighted decision matrix as shown in Fig 6.

Then we compute the border approximation area matrix using Eq. (10) as shown in Fig 7.

Then we compute the distance from the border q_j using Eq. (11) as shown in Fig 8.

Then we compute the total distance using Eq. (12) as shown in Fig 9.

Finally, we ranked the alternatives as shown in Fig 10.

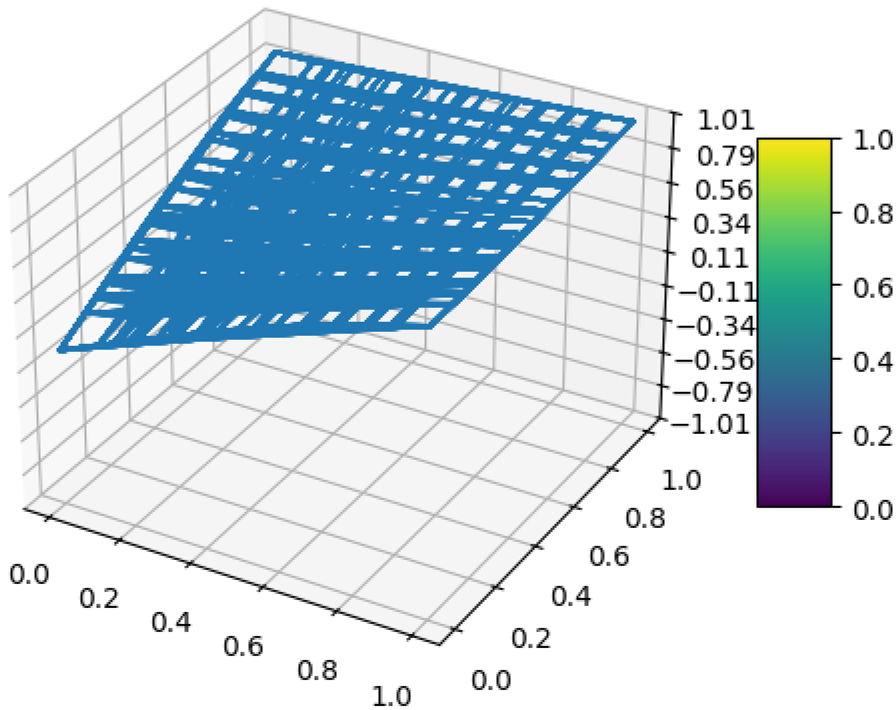

Fig 5. The normalization values are by the MABAC method.

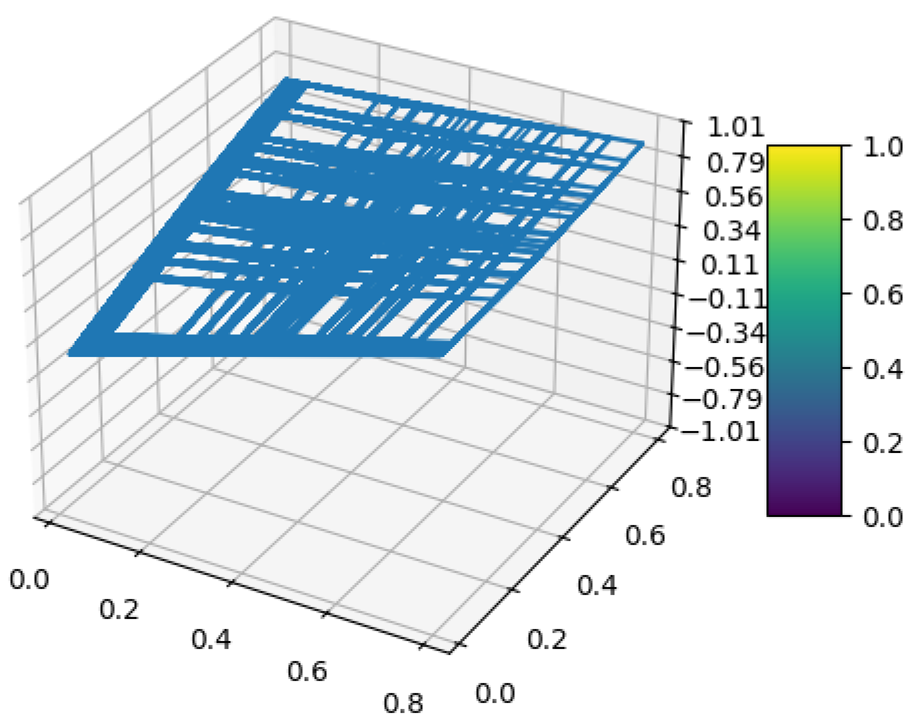

Fig 6. The weighted decision values.

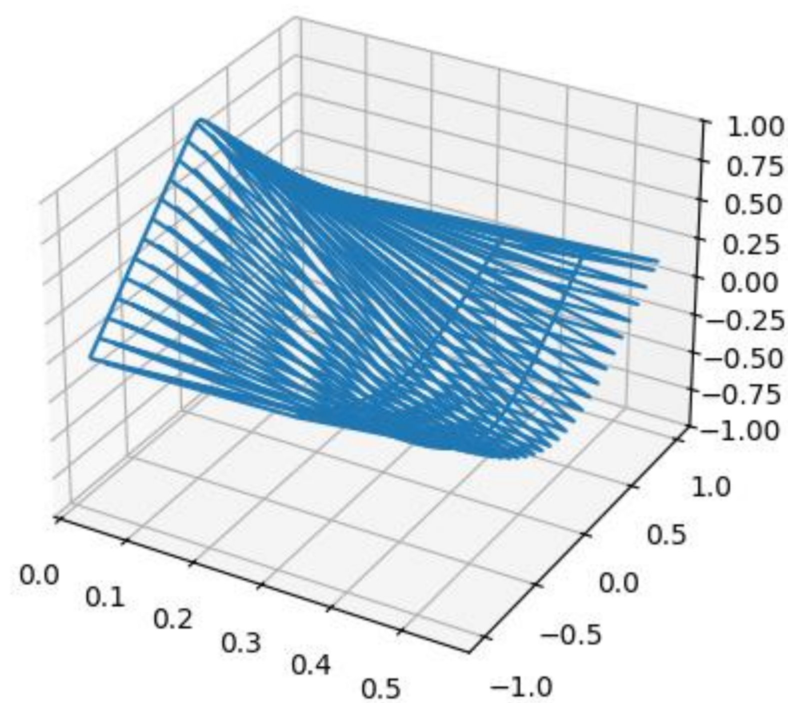

Fig 7. The border approximation values.

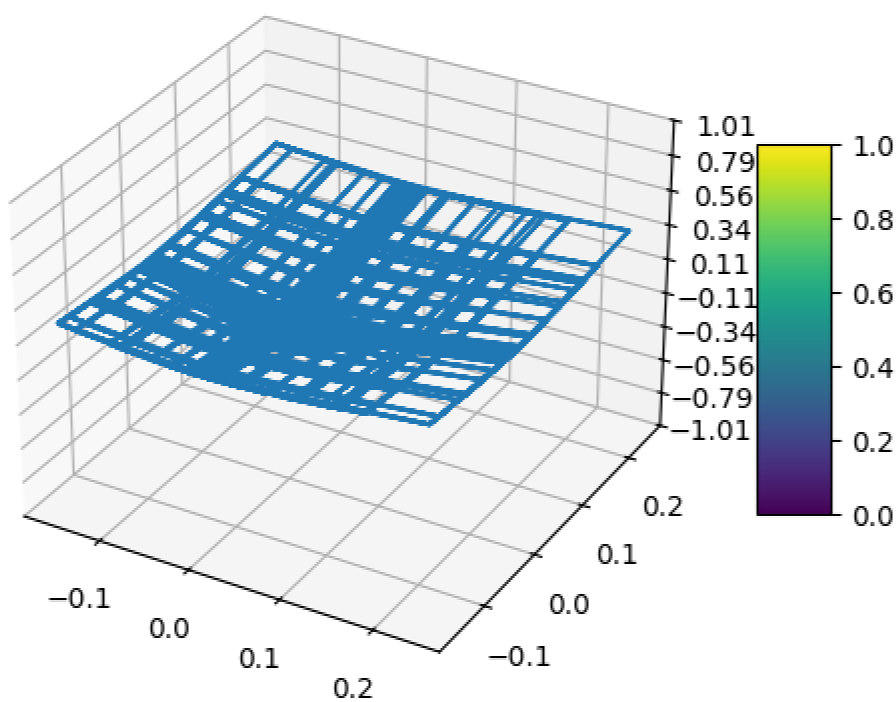

Fig 8. The values of distances.

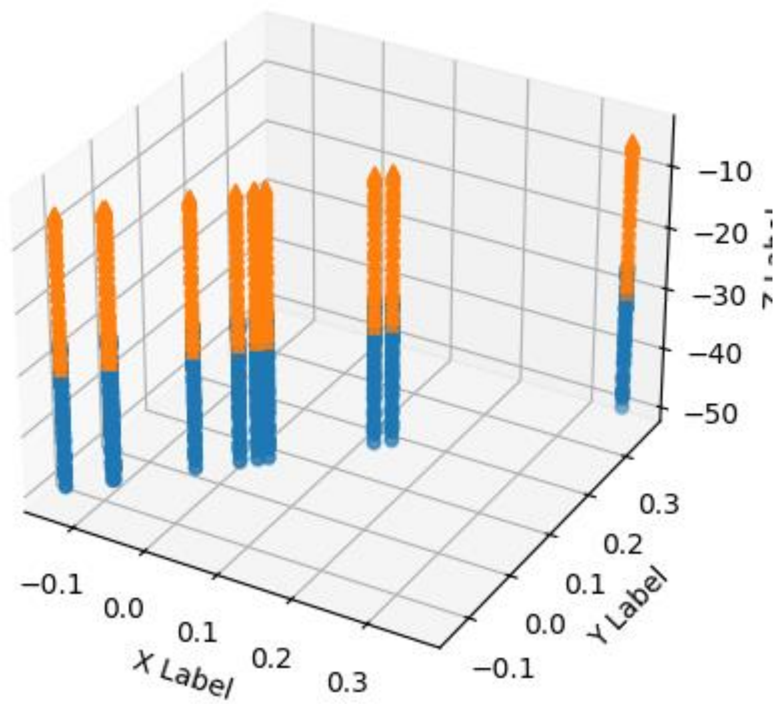

Fig 9. The total distances.

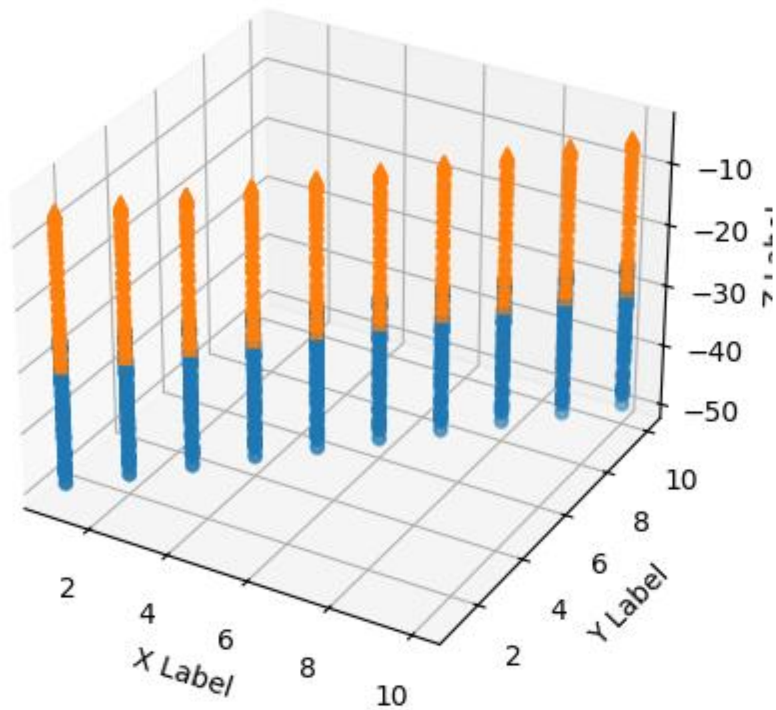

Fig 10. The rank of alternatives.

Comparative analysis

We compare the proposed approach by different MCDM methods to show the effectiveness of the proposed approach. We compared the proposed approach by four different MCDM methods. All methods agree with the best alternative and worst alternative. We show alternative 6 is the best and alternative 5 is the worst in all methods. Fig 11 shows the results of comparative analysis. The results show the proposed approach is effective compared to other MCDM methods.

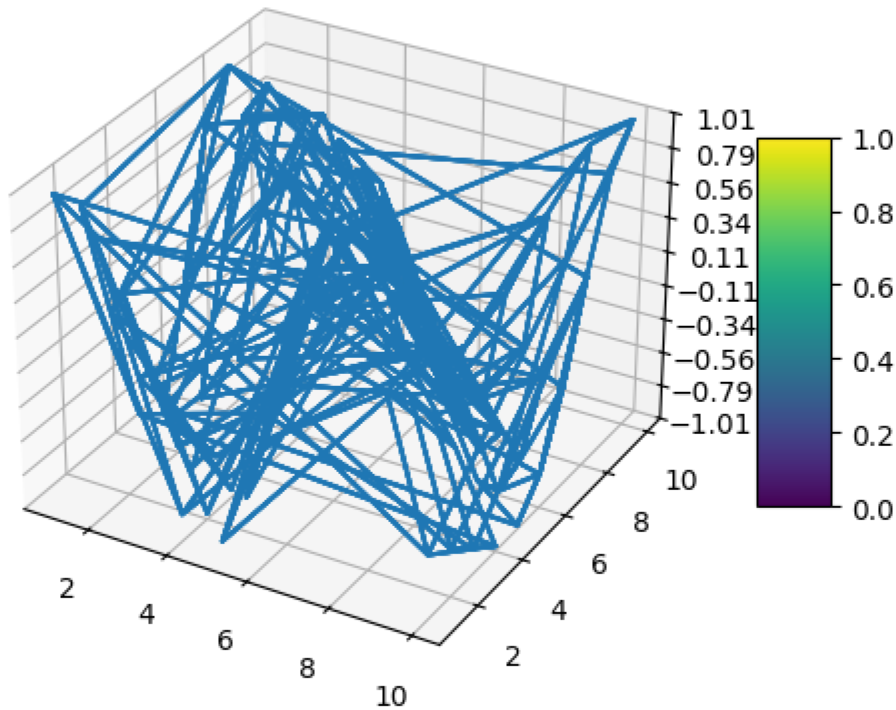

Fig 11. The ranks of different MCDM methods.

5. Conclusions

This study tackles a real-world problem of Tourist Satisfaction Evaluation of Tourist Attractions method using one of the MCDM methodologies to talk about the Tree soft set environment. The associated properties are likewise prioritized while selecting the procedure. Performance has already been improved in issues involving multiple criterion outranking using the MABAC technique. Additionally, by using Tree soft sets, we may resolve more complex and multi-attribute issues. In subsequent studies, tree soft sets may be applied to all other fuzzy settings, including intuitionistic, pythagorean, neurosophic, and others.

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