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Group Decision-Making Model Based on Triangular Neutrosophic Sets for Service Quality Evaluation in Tourism Mobile E-Commerce

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Abstract: Triangular fuzzy numbers are frequently used by experts to assess their opinions in the group decision-making (GDM) paradigm. In this research, we used neutrosophic because preference connections with triangular fuzzy numbers are consistent. In GDM, it is crucial to consider the degree of consensus and the consistency of expert opinion. The idea of additive approximation consistency is put out for triangular neutrosophic Sets (TNSs) additive reciprocal matrices to differentiate the typical consistency. The GDM methodology is used to evaluate tourism mobile e-commerce services to select the best one. Two methods are used in this study such as SWARA is used to compute the criteria weights and the WASPAS method is used to rank the alternatives. 12 criteria and 7 alternatives are collected in this study to be evaluated. The results of the sensitivity analysis which is applied in this study show the stability of the rank of alternatives under different cases.

Keywords: Triangular Neutrosophic Sets (TNSs); Uncertainty; WASPAS; SWARA; Tourism Mobile E-Commerce.

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1. Introduction

Group decision-making (GDM) is the process by which many businesses use several specialists to achieve a judgment because of the growing complexity of today's decision-making situations. An expert finds it challenging to consider every facet of a decision-making issue. Using preference representation forms, such as fuzzy preference relations, multiplicative preference relations, interval preference relations, and language frameworks for modeling GDM problems, all professionals can assess their conclusions[1], [2]. Furthermore, other formats of incomplete preference relations have also been used to address problems involving incomplete information. The imprecise understanding of the expert's preference level cannot be accurately reflected by a numerical value[3], [4]. Fuzzy set theory was created to explain the uncertainty that comes with vagueness. It uses set memberships to handle ambiguous data. L-R fuzzy numbers, trapezoidal fuzzy numbers, triangular fuzzy numbers, interval numbers, and others are examples of these set memberships. Some of the fuzzy formats mentioned above have been used by experts in the GDM process[5], [6]. The fuzzy set has been expanded to create the intuitionistic fuzzy set to address ambiguity and uncertainty even more. Atanassov introduced the idea of intuitionistic fuzzy preference relations. The consistency of preference relations is one of the most crucial aspects of GDM problems to prevent decision-makers from contradicting themselves[7], [8]. In earlier research, the multiplicative consistency of intuitionistic fuzzy preference relations was the focus. By putting out a collective decision-making model in a neutrosophic setting, we were able to overcome all the shortcomings. The decision-making process appears to be characterized by confirmation, rejection, and indeterminacy since the problem domain should be precisely known; otherwise, people are unsure when determining the values for the preference evaluation. To distinguish between truth-membership function, indeterminacy-membership function, and falsity-membership function, Smarandache proposed the idea of a neutrosophic set[9], [10]. Therefore, the neutrosophic set theory ought to be applied to justify ambiguity-related uncertainty in a way that is comparable to human cognition. In terms of set memberships, it handles ambiguous data as possibility distributions. To ascertain their preference relations, the specialists ought to employ the neutrosophic set. The triangular neutrosophic additive reciprocal preference relation's approximate consistency is applied to the GDM problem in this study, and neutrosophic preference relations that lacked consistency have been fixed. The ideal method for group decision-making is consensus since it considers worries and opposing viewpoints without hostility or dread, but it is also far more difficult to resolve because of the divergent expert opinions and the varying weights given to them during the decision-making process[11], [12].

1.1 Research Gaps

It is clear from examining the earlier research that:

1. Because of the fuzzy set limitations, fuzzy preference relations have certain disadvantages.

2. In many real-world scenarios, a fuzzy set's single-valued function is employed to simultaneously represent evidence of acceptance and rejection.

3. The preference interactions with triangular fuzzy numbers are inherently inconsistent.

4. A few methods for enhancing consistency in intuitionistic fuzzy preference relations were also proposed.

1.2 Contributions of this study are organized as follows:

- ✓ We applied the GDM methodology to evaluate the types of Tourism Mobile E-Commerce Services.
- ✓ Two methods are used in this study, such as the SWARA methodology to compute the criteria weights and the WASPAS methodology is used to rank the alternatives.
- ✓ Twelve criteria and seven alternatives are collected to be evaluated by three experts and decision-makers.

✓ The sensitivity analysis is conducted to show the stability of rank in this study.

2. Preliminaries

Some definitions of the triangular neutrosophic sets (TNSs) are outlined in this part to show the operations of this uncertainty framework[11], [13].

2.1.Definition 1

TNSs can be defined as:

$$a = \left((a_1, a_2, a_3); T_a, I_a, F_a\right) \tag{1}$$

Three membership functions of TNSs as Truth, Indeterminacy, and Falsity can be defined:

$$T_a(x) = \begin{cases} T_a\left(\frac{x-a_1}{a_2-a_1}\right) & if\ a_1 \le x \le a_2 \\ T_a & if\ x = a_2 \\ T_a\left(\frac{a_3-x}{a_3-a_2}\right) & if\ a_2 \le x \le a_3 \\ 0 & otherwise \end{cases} \tag{2}$$

$$I_a(x) = \begin{cases} \frac{(a_2-x+I_a(x-a_1))}{(a_2-a_1)} & if\ a_1 \le x \le a_2 \\ I_a & if\ x = a_2 \\ \frac{(x-a_2+I_a(a_3-x))}{(a_3-a_2)} & if\ a_2 \le x \le a_3 \\ 1 & otherwise \end{cases} \tag{3}$$

$$F_a(x) = \begin{cases} \frac{(a_2-x+F_a(x-a_1))}{(a_2-a_1)} & if\ a_1 \le x \le a_2 \\ F_a & if\ x = a_2 \\ \frac{(x-a_2+F_a(a_3-x))}{(a_3-a_2)} & if\ a_2 \le x \le a_3 \\ 1 & otherwise \end{cases} \tag{4}$$

2.2. Definition 2

Let $a = \left((a_1, a_2, a_3); T_a, I_a, F_a\right)$ and $b = \left((b_1, b_2, b_3); T_b, I_b, F_b\right)$ Two triangular neutrosophic numbers (TNNs).

Addition

$$a + b = \left((a_1 + b_1, a_2 + b_2, a_3 + b_3);\ T_a \wedge T_b, I_a \vee I_b, F_a \vee F_b\right) \tag{5}$$

Subtraction

$$a - b = \left((a_1 - b_3, a_2 - b_2, a_3 - b_1);\ T_a \wedge T_b, I_a \wedge I_b, F_a \wedge F_b\right) \tag{6}$$

Inverse

$$a^{-1} = \left(\left(\frac{1}{a_3}, \frac{1}{a_2}, \frac{1}{a_{31}}\right);\ T_a, I_a, F_a\right) \tag{7}$$

Multiplication by constant

$$\sigma a = \begin{cases} \left((\sigma a_1, \sigma a_2, \sigma a_3);\ T_a, I_a, F_a\right) & if\ \sigma > 0 \\ \left((\sigma a_3, \sigma a_2, \sigma a_1);\ T_a, I_a, F_a\right) & if\ \sigma < 0 \end{cases} \tag{8}$$

Multiplication

$$ab = \begin{cases} \left((a_1 b_1, a_2 b_2, a_3 b_3); T_a \wedge T_b, I_a \vee I_b, F_a \vee F_b\right) & if (a_3 > 0, b_3 > 0) \\ \left((a_1 b_3, a_2 b_2, a_3 b_1); T_a \wedge T_b, I_a \vee I_b, F_a \vee F_b\right) & if (a_3 < 0, b_3 > 0) \\ \left((a_3 b_3, a_2 b_2, a_1 b_1); T_a \wedge T_b, I_a \vee I_b, F_a \vee F_b\right) & if (a_3 < 0, b_3 < 0) \end{cases} \tag{9}$$

Multiplication

$$\frac{a}{b} = \begin{cases} \left(\left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right); T_a \wedge T_b, I_a \vee I_b, F_a \vee F_b\right) & if (a_3 > 0, b_3 > 0) \\ \left(\left(\left(\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right)\right); T_a \wedge T_b, I_a \vee I_b, F_a \vee F_b\right) & if (a_3 < 0, b_3 > 0) \\ \left(\left(\left(\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_3}{b_3}\right)\right); T_a \wedge T_b, I_a \vee I_b, F_a \vee F_b\right) & if (a_3 < 0, b_3 < 0) \end{cases} \tag{10}$$

3. Methodology

In our study, we integrated the WASPAS and SWARA methods with TNSs to compute the criteria weights and rank the alternatives. Fig 1 shows the steps of the proposed approach.

3.1 SWARA Method

The SWARA method is used to compute the criteria weights.

Step 1. Initial prioritizing of the criteria

The criteria are ranked based on their importance by the decision-makers and experts.

Step 2. Compute the coefficient value

$$K_j = \begin{cases} 1 & if\ j = 1 \\ S_j + 1 & if\ j > 1 \end{cases} \tag{11}$$

Step 3. Compute the initial weight

$$U_j = \begin{cases} 1 & if\ j = 1 \\ \frac{U_j}{K_j} & if\ j > 1 \end{cases} \tag{12}$$

Step 4. Compute the criteria weights.

$$w_j = \frac{U_j}{\sum_{j=1}^{n} U_j} \tag{13}$$

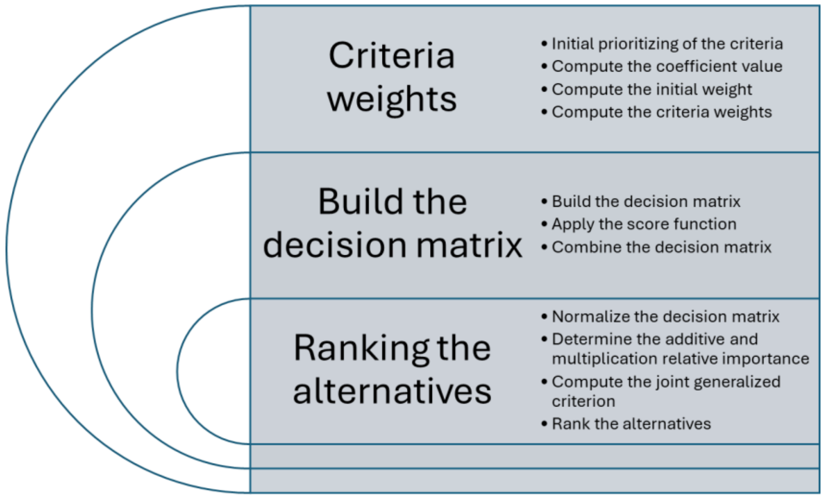

Fig. 1. The steps of the SWARA and WASPAs methodology

3.2 WASPAS Method

This method is used to rank the alternatives. The steps of the WASPAS method are outlined such as:

Step 1. Build the decision matrix

The decision matrix is built using the opinions of the experts and decision-makers.

Step 2. Apply the score function

The score function is applied to convert the TNNs into single numbers.

Step 3. Combine the decision matrix.

The decision matrix is combined using the average method.

Step 4. Normalize the decision matrix

The decision matrix is normalized for positive and negative criteria.

$$n_{ij} = \frac{x_{ij}}{\max r_{ij}}; i = 1, \dots, m; j = 1, \dots., n \tag{14}$$

$$n_{ij} = \frac{\min x_{ij}}{x_{ij}}; i = 1, \dots, m; j = 1, \dots., n \tag{15}$$

Step 5. Determine the additive and multiplication relative importance

$$V_i^{(1)} = \sum_{j=1}^{n} n_{ij} w_j \quad (16)$$

$$V_i^{(2)} = \prod_{j=1}^{n} \left(n_{ij}\right)^{w_j} \quad (17)$$

Step 6. Compute the joint generalized criterion

$$V_i = \pi V_i^{(1)} + (1-\pi) V_i^{(2)} \quad (18)$$

Value of π between 0 and 1.

Step 7. Rank the alternatives.

4. An Empirical Application

Mobile e-commerce service quality evaluation focuses on assessing the user experience and satisfaction with services provided through mobile platforms. Key factors influencing service quality include usability, reliability, responsiveness, and personalization. Usability refers to how easily users can navigate and interact with the mobile app or website, including interface design and functionality. Reliability ensures that the platform performs consistently without errors, providing accurate information and secure transactions. Responsiveness addresses the speed at which services are delivered, including loading times and customer support responses. Personalization involves tailoring the user experience based on preferences, behavior, or location, which can enhance customer satisfaction and loyalty. Additionally, trust and security play significant roles, as users expect safe payment systems and data protection. Effective evaluation often employs customer feedback, surveys, or performance metrics to identify areas for improvement and maintain competitive advantages. By prioritizing service quality, mobile e-commerce platforms can build stronger relationships with users and drive long-term success. This section shows the results of the case study. This study used the GDM approach for ranking the types of Tourism Mobile E-Commerce Services to select the best one. Three experts are using TNSs to evaluate the criteria and alternatives. These experts and decision-makers have experience in the field of mobile e-commerce services. We collected 12 criteria and seven alternatives [14], [15], [16], [17]in this study as shown in Table 1.

Table 1. The list of criteria and alternatives.

Criteria	Alternatives
Sustainability	Hotel Apps
Usability and Interface Design	Sustainable Travel Platforms
Loyalty Programs	Multi-Service Super Apps
Performance and Speed	Online Travel Agencies
Virtual Tours	Tour Booking Platforms
Personalization	Local Guide Apps
Responsiveness	Transportation Booking Apps
Reliability	
Integration with Other Services	
Payment Security	

User Feedback Integration Accuracy	

Step 1. We ranked the criteria based on the opinions of the experts and decision-makers.

Step 2. Eq. (11) is used to compute the coefficient value

Step 3. Eq. (12) is used to compute the initial weight

Step 4. Then Eq. (13) is used to compute the criteria weights as shown in Table 2.

Table 2. The criteria weights.

Criteria	K_j	U_j	w_j	Rank
C_1	1	1	0.032363	1
C_2	4.4625	4.4625	0.14442	12
C_3	5.5	1.232493	0.039887	3
C_4	5.4	4.381364	0.141794	11
C_5	4.9	1.118373	0.036194	2
C_6	4.075	3.643685	0.117921	9
C_7	6.225	1.708435	0.05529	6
C_8	5.2125	3.051037	0.098741	7
C_9	4.4625	1.462617	0.047335	4
C_{10}	5.5	3.760382	0.121697	10
C_{11}	5.8875	1.565665	0.05067	5
C_{12}	5.5	3.512884	0.113688	8

Then we apply the WASPAS method to rank the alternatives.

Step 1. We build the decision matrix using the TNNs as shown in Tables 3-5.

Step 2. Then we apply the score function to a single number.

Step 3. Then we combine the decision matrix into a single matrix.

Step 4. All criteria are positive. Then we normalize the decision matrix using Eq. (14) as shown in Table 6.

Step 5. Then we determine the additive and multiplication relative importance using Eqs. (16 and 17).

Step 6. Then we compute the joint generalized criterion using Eq. (18).

Step 7. Then rank the alternatives as shown in Table 7.

Table 3. First decision matrix.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7

C_1	((1,2,3);0.4,0.60,0.65)	((4,5,6);0.8,0.15,0.20)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((1,2,3);0.4,0.60,0.65)	((9,9,9);1.00,0.00,0.00)	((6,7,8);0.9,0.10,0.10)
C_2	((2,3,4);0.3,0.75,0.70)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)	((2,3,4);0.3,0.75,0.70)	((4,5,6);0.8,0.15,0.20)
C_3	((4,5,6);0.8,0.15,0.20)	((1,2,3);0.4,0.60,0.65)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)	((2,3,4);0.3,0.75,0.70)
C_4	((6,7,8);0.9,0.10,0.10)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((4,5,6);0.8,0.15,0.20)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)	((1,1,1);0.5,0.5,0.5)
C_5	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((4,5,6);0.8,0.15,0.20)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)	((9,9,9);1.00,0.00,0.00)	((1,2,3);0.4,0.60,0.65)
C_6	((1,2,3);0.4,0.60,0.65)	((4,5,6);0.8,0.15,0.20)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)	((5,6,7);0.70,0.25,0.30)	((1,2,3);0.4,0.60,0.65)	((9,9,9);1.00,0.00,0.00)
C_7	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((4,5,6);0.8,0.15,0.20)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)	((6,7,8);0.9,0.10,0.10)
C_8	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)	((2,3,4);0.3,0.75,0.70)	((5,6,7);0.70,0.25,0.30)	((4,5,6);0.8,0.15,0.20)
C_9	((1,1,1);0.5,0.5,0.5)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)	((1,1,1);0.5,0.5,0.5)	((2,3,4);0.3,0.75,0.70)
C_{10}	((2,3,4);0.3,0.75,0.70)	((3,4,5);0.35,0.60,0.40)	((1,2,3);0.4,0.60,0.65)	((4,5,6);0.8,0.15,0.20)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)	((1,1,1);0.5,0.5,0.5)
C_{11}	((4,5,6);0.8,0.15,0.20)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)	((4,5,6);0.8,0.15,0.20)	((5,6,7);0.70,0.25,0.30)
C_{12}	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)	((5,6,7);0.70,0.25,0.30)	((6,7,8);0.9,0.10,0.10)	((3,4,5);0.35,0.60,0.40)

Table 4. Second decision matrix.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7
C_1	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)	((9,9,9);1.00,0.00,0.00)	((6,7,8);0.9,0.10,0.10)
C_2	((2,3,4);0.3,0.75,0.70)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((1,2,3);0.4,0.60,0.65)	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)
C_3	((4,5,6);0.8,0.15,0.20)	((1,2,3);0.4,0.60,0.65)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)	((2,3,4);0.3,0.75,0.70)
C_4	((6,7,8);0.9,0.10,0.10)	((1,2,3);0.4,0.60,0.65)	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)
C_5	((9,9,9);1.00,0.00,0.00)	((1,2,3);0.4,0.60,0.65)	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)	((9,9,9);1.00,0.00,0.00)	((1,2,3);0.4,0.60,0.65)
C_6	((1,2,3);0.4,0.60,0.65)	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((5,6,7);0.70,0.25,0.30)	((1,2,3);0.4,0.60,0.65)	((9,9,9);1.00,0.00,0.00)
C_7	((3,4,5);0.35,0.60,0.40)	((1,2,3);0.4,0.60,0.65)	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)	((3,4,5);0.35,0.60,0.40)	((6,7,8);0.9,0.10,0.10)
C_8	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)	((1,2,3);0.4,0.60,0.65)	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)	((4,5,6);0.8,0.15,0.20)
C_9	((1,1,1);0.5,0.5,0.5)	((5,6,7);0.70,0.25,0.30)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)
C_{10}	((2,3,4);0.3,0.75,0.70)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)	((1,1,1);0.5,0.5,0.5)
C_{11}	((4,5,6);0.8,0.15,0.20)	((1,2,3);0.4,0.60,0.65)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)
C_{12}	((6,7,8);0.9,0.10,0.10)	((9,9,9);1.00,0.00,0.00)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)	((3,4,5);0.35,0.60,0.40)

Table 5. Third decision matrix.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7
C_1	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((5,6,7);0.70,0.25,0.30)	((3,4,5);0.35,0.60,0.40)	((1,2,3);0.4,0.60,0.65)	((9,9,9);1.00,0.00,0.00)	((6,7,8);0.9,0.10,0.10)
C_2	((2,3,4);0.3,0.75,0.70)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)	((2,3,4);0.3,0.75,0.70)	((4,5,6);0.8,0.15,0.20)
C_3	((4,5,6);0.8,0.15,0.20)	((1,2,3);0.4,0.60,0.65)	((1,1,1);0.5,0.5,0.5)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((4,5,6);0.8,0.15,0.20)	((2,3,4);0.3,0.75,0.70)
C_4	((6,7,8);0.9,0.10,0.10)	((9,9,9);1.00,0.00,0.00)	((2,3,4);0.3,0.75,0.70)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((6,7,8);0.9,0.10,0.10)	((1,1,1);0.5,0.5,0.5)
C_5	((9,9,9);1.00,0.00,0.00)	((6,7,8);0.9,0.10,0.10)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((3,4,5);0.35,0.60,0.40)	((9,9,9);1.00,0.00,0.00)	((1,2,3);0.4,0.60,0.65)
C_6	((1,2,3);0.4,0.60,0.65)	((4,5,6);0.8,0.15,0.20)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((5,6,7);0.70,0.25,0.30)	((1,2,3);0.4,0.60,0.65)	((9,9,9);1.00,0.00,0.00)
C_7	((3,4,5);0.35,0.60,0.40)	((2,3,4);0.3,0.75,0.70)	((9,9,9);1.00,0.00,0.00)	((5,6,7);0.70,0.25,0.30)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((6,7,8);0.9,0.10,0.10)
C_8	((5,6,7);0.70,0.25,0.30)	((1,1,1);0.5,0.5,0.5)	((1,2,3);0.4,0.60,0.65)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((5,6,7);0.70,0.25,0.30)	((4,5,6);0.8,0.15,0.20)
C_9	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((3,4,5);0.35,0.60,0.40)	((1,2,3);0.4,0.60,0.65)	((4,5,6);0.8,0.15,0.20)	((1,1,1);0.5,0.5,0.5)	((2,3,4);0.3,0.75,0.70)
C_{10}	((2,3,4);0.3,0.75,0.70)	((3,4,5);0.35,0.60,0.40)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((6,7,8);0.9,0.10,0.10)	((2,3,4);0.3,0.75,0.70)	((1,1,1);0.5,0.5,0.5)
C_{11}	((4,5,6);0.8,0.15,0.20)	((1,2,3);0.4,0.60,0.65)	((1,1,1);0.5,0.5,0.5)	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((4,5,6);0.8,0.15,0.20)	((5,6,7);0.70,0.25,0.30)
C_{12}	((5,6,7);0.70,0.25,0.30)	((7,8,9);0.85,0.10,0.15)	((2,3,4);0.3,0.75,0.70)	((4,5,6);0.8,0.15,0.20)	((5,6,7);0.70,0.25,0.30)	((6,7,8);0.9,0.10,0.10)	((3,4,5);0.35,0.60,0.40)

Table 6. Normalized decision matrix.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7
C_1	0.346914	0.664815	0.385185	0.482716	0.075309	1	0.7
C_2	0.122596	0.620192	1	0.546474	0.134615	0.288462	0.416667
C_3	0.674312	0.126606	0.500917	1	0.965138	0.279817	0.140367
C_4	0.93719	0.697521	0.475207	0.628926	1	0.649587	0.07438
C_5	0.825926	0.518519	0.37716	0.649383	0.103704	1	0.085185
C_6	0.085185	0.369136	0.551852	0.532099	0.477778	0.085185	1
C_7	0.285714	0.313051	0.938272	0.671076	0.587302	0.488536	1
C_8	1	0.614987	0.607235	0.511628	0.936693	0.705426	0.949612
C_9	0.341202	1	0.839056	0.901288	0.410944	0.341202	0.141631
C_{10}	0.150888	0.467456	0.710059	0.758383	1	0.109467	0.088757
C_{11}	0.698669	0.3327	0.669202	1	0.526616	0.711027	0.519011
C_{12}	0.651603	1	0.500729	0.503644	0.56414	0.572886	0.236152

Table 7. The rank of alternatives.

	$V_i^{(1)}$	$V_i^{(2)}$	V_i	Ranks
A_1	0.487188	0.340673	0.41393	6
A_2	0.590135	0.539274	0.269637	1
A_3	0.651773	0.624326	0.312163	2
A_4	0.640364	0.624128	0.513726	7
A_5	0.619193	0.487046	0.374887	4
A_6	0.450826	0.347591	0.325877	3
A_7	0.439686	0.282643	0.391602	5

5. Analysis

This section shows the sensitivity analysis to show the different ranks of alternatives. In the ranking of the alternatives by the WASPAS method we the π value with 0.5 and we ranked the alternatives in the joint generalized criterion. But in this section, we change this value between 0 and 0.9 to show different ranks of alternatives. Table 8 shows the joint generalized criterion values of each alternative.

Table 8. The joint generalized criterion values of each alternative.

	$\pi = 0$	$\pi = 0.1$	$\pi = 0.2$	$\pi = 0.3$	$\pi = 0.4$	$\pi = 0.5$	$\pi = 0.6$	$\pi = 0.7$	$\pi = 0.8$	$\pi = 0.9$
A_1	0.340673	0.355325	0.369976	0.384627	0.399279	0.41393	0.428582	0.443233	0.457885	0.472536
A_2	0.539274	0.485347	0.431419	0.377492	0.323564	0.269637	0.21571	0.161782	0.107855	0.053927
A_3	0.624326	0.561893	0.499461	0.437028	0.374595	0.312163	0.24973	0.187298	0.124865	0.062433
A_4	0.7901	0.734825	0.67955	0.624275	0.569001	0.513726	0.458451	0.403176	0.347901	0.292627
A_5	0.749774	0.674797	0.599819	0.524842	0.449864	0.374887	0.29991	0.224932	0.149955	0.074977
A_6	0.651755	0.586579	0.521404	0.456228	0.391053	0.325877	0.260702	0.195526	0.130351	0.065175
A_7	0.66757	0.612376	0.557183	0.501989	0.446796	0.391602	0.336409	0.281215	0.226022	0.170828

Then we ranked the alternatives to show the best and the worst alternatives. We show that alternative 4 is the best of the seven cases as shown in Fig. 2. The alternative one is the best of the three cases as shown in Fig. 3.

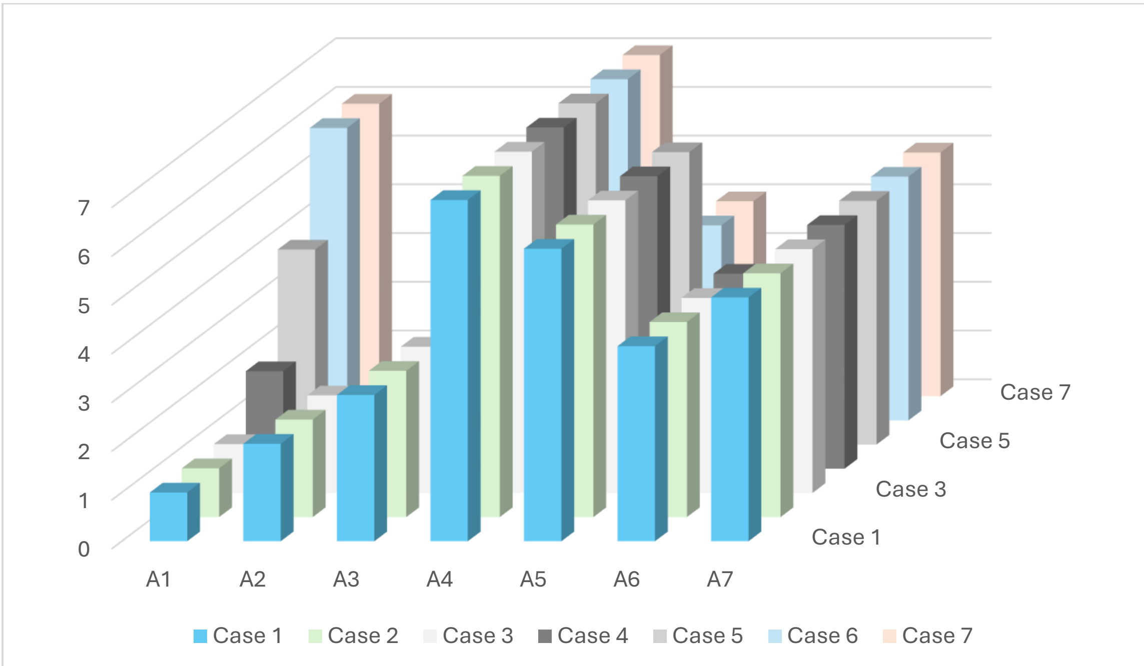

Fig. 2. The rank of seven cases.

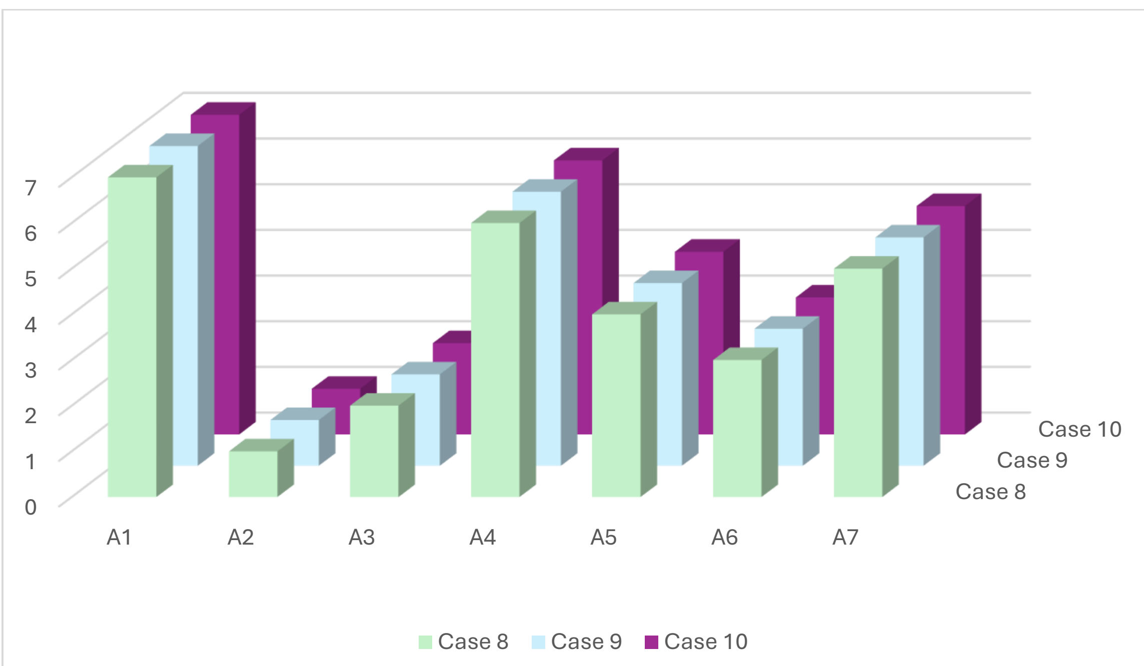

Fig. 3. The rank of three cases.

In the last three cases, we show alternative 1 is the best, followed by alternative 4, and alternative 2 is the worst.

6. Conclusions and Future Works.

This study proposed a GDM approach to evaluate tourism mobile e-commerce services with different criteria and rankings. Two GDM approaches are used in this study such as the SWARA method to compute the criteria weights and rank the alternatives. The WASPAS method is used to rank the alternatives. Three experts have evaluated the criteria and alternatives by using the triangular neutrosophic sets (TNSs) to deal with vague and uncertain data. 12 criteria and seven alternatives are collected to be evaluated in this study. The sensitivity analysis is conducted to show the different ranks of the alternatives. The results show the rank of alternatives is stable in different cases.

In future work, the proposed approach can be applied to different GDM issues to compute the criteria weights and rank the alternatives. The differences in neutrosophic extension can be used in this study to deal with vague data.

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