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Hybrid SuperHyperSoft Model for Evaluation of Comprehensive Transportation Efficiency: Analysis and Results

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Abstract: In this research, we investigate the features of comprehensive transportation efficiency assessment. Optimizing the energy-saving and efficient comprehensive transportation structure is essential to further lowering logistics costs. We evaluate the transportation efficiency using the decision making model based on a set of criteria and alternatives. We used two methods. named BWM and MABAC methods. The BWM is used to compute the criteria weights and the MABAC method is used to rank the alternatives. These methods are used under the neutrosophic set to solve the uncertainty information. These methods are used with SuperHyperSoft to treat various criteria and sub criteria by using a set of sets. Eight criteria and nine alternatives are used in this study. The sensitivity analysis shows the proposed approach rank in stable under different cases. The comparative analysis shows the proposed approach is effective compared to other methods.

Keywords: SuperHyperSoft; Transportation Efficiency; Neutrosophic Set; Transportation Costs.

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1. Introduction and Literature Review

A thorough and scientific transport structure may raise the general level of transportation development, lower transportation costs, and increase transportation efficiency. At the same time, protecting the environment through energy conservation and pollution reduction is very important[1], [2]. The cost, profit, and energy consumption of various means of transportation vary greatly; for example, long-distance road transportation is expensive and inefficient[3], [4]. In the transportation system, developing an efficient network assessment technique is crucial. Jin et al. [5]proposed the integration of transportation as a means of building a comprehensive transportation system; A thorough analysis of the features, operations, and makeup of the transportation system was conducted by Lu et al.[6]. Additionally, the source originated from the optimization dynamic of the transportation system, and the external and internal factors of structural dynamic optimization of the system are investigated, with further depiction discussed from four aspects: acquisition, technology, fund, quality, and environment, respectively; Franco [7] examined a spatial general equilibrium model of a closed monocentric city with two means of transportation and suggested that parking improvements at the central business district might improve welfare and encourage more compact urban space. The concept of a fuzzy set (FS) was introduced to the world by Zadeh. According to FS theory, a real integer from the closed interval [0, 1] designates the membership grade of each element in a set. The concept of an intuitionistic FS (IFS) was later established by Atanassov as an expansion of FS. It is assumed that the components in IFS theory have both membership and non-membership grades, provided that their aggregate is less than or equal to unity[8], [9]. Atanassov also established several IFS properties. In addressing decision-making issues, both the FS and IFS theories play important roles. However, choosing the best alternative based on several exact or vague criteria is the main goal of decision-makers (DMs) in today's decision-making scenarios[10]. Experts may struggle to choose the appropriate object because they lack a sufficient level of cognitive understanding of the issue. The concept of a neutrosophic set (NS), which is defined by the membership grades of truth, indeterminacy, and falsehood for each element of the set, is used to get around this problem[11], [12]. Smarandache introduced the idea of NS. To demonstrate the significance of truth, indeterminacy, and falsity information on which people make judgments, DMs frequently use this notion[13]. To circumvent the limitations of neutrosophic theory and enable real-world applications, Wang et al. established the idea of single-valued NS (SVNS) with limited restrictions for the membership grades. Chinnadurai et al [14] proposed a study with three pieces. They started by talking about the idea of an intuitionistic neutrosophic soft set with interval values. To ensure that the supremum sum of the truth and falsity membership grades does not surpass unity, they applied an intuitionistic condition between them. Likewise, the membership grade for indeterminacy falls outside of the closed interval [0, 1].

Therefore, in their instance, the total of the truth, indeterminacy, and falsity membership grades does not surpass two. They defined some of its characteristics and introduced the concepts of necessity, possibility, concentration, and dilation operators. Secondly, we establish the similarity metric between two intuitionistic neutrosophic soft sets with interval values. Additionally, they compared it to current approaches to demonstrate its superiority.

Lastly, they created an algorithm and used the diagnosis of mental illnesses as an example. Even though similarity measures are essential for identifying mental illnesses, current techniques are rarely used to do so. Naturally, Ambivalence characterizes most psychiatric disease behaviors. Therefore, it is essential to use an interval-valued intuitionistic neutrosophic soft set to record the membership grades. They offer a method for identifying mental illnesses in this publication, and the suggested similarity metric is useful and appropriate for diagnosing mental illnesses in any neutrophilic setting.

Aliya et al. [15] presented two new types of operational rules for pairs of linguistic IVIN fuzzy numbers, which are called neutrality addition and scalar multiplication. These operations' primary concept is to incorporate the decision-maker's and scoring function's linguistic IVIN fuzzy number. They establish the operational rules and IVIN fuzzy number. Lastly, using a variety of numerical examples, an MCDM technique based on the suggested operators is introduced and examined.

Fahmi et al. [16] introduced the idea of a IVIN fuzzy number. After a quick review of relevant features, they defined some score and accuracy functions for LIVINFNs. Additionally, as part of the geometric operators, they provided the geometric forms of the LIVINDFWG, LIVINDFOWG, and LIVINDFHWG operators.

They then go over its features and a few unique situations. Additionally, they proposed two novel MCDM techniques based on the LIVINDFWG and LIVINDFOWG operators that were created. Lastly, a typical example is given to compare the suggested approach with several other representative MCDM methods that are currently in use to confirm its superiority and efficacy.

The rest of this part is organized as follows: Section 2 shows some definitions of IVINNs. Section 3 shows the steps of the proposed approach. Section 4 shows the results of the proposed approach with sensitivity analysis and comparative analysis. Section 5 shows the conclusions of this study.

2. Preliminaries

This section shows some definitions of the Interval Valued Intuitionistic Neutrosophic Set (IVINS).

Definition 1

An IVINS in V can be defined as: $A = \{(V, T_A(V), I_A(V), F_A(V))\}$, where $T_A(V), I_A(V), F_A(V)$ are sub intervals of [0,1] and shows the functions of truth, indeterminacy, and falsity. The lower and upper of $T_A(V), I_A(V), F_A(V)$ can be defined as: $T_A^U(V), T_A^L(V), I_A^U(V), I_A^L(V), F_A^U(V), F_A^L(V)$.

$$0 \leq T_A^U(V) + F_A^U(V) \leq 1 \tag{1}$$

$$T_A^U(V), I_A^U(V), F_A^U(V) \geq 0 \tag{2}$$

$$0 \leq T_A^U(V) + I_A^U(V) + F_A^U(V) \leq 2 \tag{3}$$

Example 1

We can define the Interval Valued Intuitionistic Neutrosophic number (IVINN) as:

$$A = \begin{Bmatrix} ([0.3,0.4],[0.7,0.8],[0.1,0.2]), \\ ([0.4,0.5],[0.8,0.9],[0.2,0.3]), \\ ([0.6,0.7],[0.2,0.3],[0.2,0.3]) \end{Bmatrix} \tag{4}$$

Definition 2

Let two IVINNs as: $(A_1, S_1) and\ (A_2, S_2)$, then

$(A_1, S_1)\ Or\ (A_2, S_2)\ is\ an\ IVINN$ shown as $(A_1, S_1) \vee (A_2, S_2) = A_{\vee}, S_1 \times S_2$ where

$$A_{\vee}\ (q_1 \times q_2) = A_1(q_1) \cup A_2(q_2) \forall (q_1, q_2) \in S_1 \times S_2 \tag{5}$$

$$A_{\vee}\ (q_1, q_2) = \begin{pmatrix} \left[\vee\left(T^{U}_{A_1(q_1)}, T^{U}_{A_1(q_2)}\right), \vee\left(T^{L}_{A_1(q_1)}, T^{L}_{A_1(q_2)}\right)\right], \\ \left[\vee\left(I^{U}_{A_1(q_1)}, I^{U}_{A_1(q_2)}\right), \vee\left(I^{L}_{A_1(q_1)}, I^{L}_{A_1(q_2)}\right)\right], \\ \left[\vee\left(F^{U}_{A_1(q_1)}, F^{U}_{A_1(q_2)}\right), \vee\left(F^{L}_{A_1(q_1)}, F^{L}_{A_1(q_2)}\right)\right] \end{pmatrix} \tag{6}$$

$(A_1, S_1)\ and\ (A_2, S_2)\ is\ an\ IVINN$ shown as $(A_1, S_1) \wedge (A_2, S_2) = A_{\wedge}, S_1 \times S_2$ where

$$A_{\wedge}\ (q_1 \times q_2) = A_1(q_1) \cap A_2(q_2) \forall (q_1, q_2) \in S_1 \times S_2 \tag{7}$$

$$A_{\wedge}\ (q_1, q_2) = \begin{pmatrix} \left[\wedge\left(T^{U}_{A_1(q_1)}, T^{U}_{A_1(q_2)}\right), \wedge\left(T^{L}_{A_1(q_1)}, T^{L}_{A_1(q_2)}\right)\right], \\ \left[\wedge\left(I^{U}_{A_1(q_1)}, I^{U}_{A_1(q_2)}\right), \wedge\left(I^{L}_{A_1(q_1)}, I^{L}_{A_1(q_2)}\right)\right], \\ \left[\wedge\left(F^{U}_{A_1(q_1)}, F^{U}_{A_1(q_2)}\right), \wedge\left(F^{L}_{A_1(q_1)}, F^{L}_{A_1(q_2)}\right)\right] \end{pmatrix} \tag{8}$$

Definition 3

Let two IVINNs as: $(A_1, S_1) and\ (A_2, S_2)$, then

$(A_1, S_1)\ union\ (A_2, S_2)\ is\ an\ IVINN$ shown as $(A_1, S_1) \cup (A_2, S_2) = A_{\cup}, S_{\cup}$ where

$$S_{\cup}\ (S_1 \cup S_2) = \forall q \in A_{\cup} \tag{9}$$

$$A_{\cup}\ (q) = \begin{Bmatrix} \left(v, \left(T_{A_{1(q)}}, I_{A_{1(q)}}, F_{A_{1(q)}}\right)\right); \quad if\ q \in S_1 - S_2, \\ \left(v, \left(T_{A_{2(q)}}, I_{A_{2(q)}}, F_{A_{2(q)}}\right)\right); \quad if\ q \in S_2 - S_1, \\ \begin{Bmatrix} \left[\vee\left(T^{U}_{A_1(q_1)}, T^{U}_{A_1(q_2)}\right), \vee\left(T^{L}_{A_1(q_1)}, T^{L}_{A_1(q_2)}\right)\right], \\ \left[\vee\left(I^{U}_{A_1(q_1)}, I^{U}_{A_1(q_2)}\right), \vee\left(I^{L}_{A_1(q_1)}, I^{L}_{A_1(q_2)}\right)\right], \\ \left[\wedge\left(F^{U}_{A_1(q_1)}, F^{U}_{A_1(q_2)}\right), \wedge\left(F^{L}_{A_1(q_1)}, F^{L}_{A_1(q_2)}\right)\right] \end{Bmatrix} \quad if q \in S_2 \cup S_1 \end{Bmatrix} \tag{10}$$

$(A_1, S_1)\ intersection\ (A_2, S_2)\ is\ an\ IVINN$ shown as $(A_1, S_1) \cap (A_2, S_2) = A_{\cap}, S_{\cap}$ where

$$S_{\cap}\ (S_1 \cap S_2) = \forall q \in A_{\cap} \tag{11}$$

$$A_{\cup}\ (q) = \begin{Bmatrix} \left(v, \left(T_{A_{1(q)}}, I_{A_{1(q)}}, F_{A_{1(q)}}\right)\right); \quad if\ q \in S_1 - S_2, \\ \left(v, \left(T_{A_{2(q)}}, I_{A_{2(q)}}, F_{A_{2(q)}}\right)\right); \quad if\ q \in S_2 - S_1, \\ \begin{Bmatrix} \left[\wedge\left(T^{U}_{A_1(q_1)}, T^{U}_{A_1(q_2)}\right), \wedge\left(T^{L}_{A_1(q_1)}, T^{L}_{A_1(q_2)}\right)\right], \\ \left[\wedge\left(I^{U}_{A_1(q_1)}, I^{U}_{A_1(q_2)}\right), \wedge\left(I^{L}_{A_1(q_1)}, I^{L}_{A_1(q_2)}\right)\right], \\ \left[\vee\left(F^{U}_{A_1(q_1)}, F^{U}_{A_1(q_2)}\right), \vee\left(F^{L}_{A_1(q_1)}, F^{L}_{A_1(q_2)}\right)\right] \end{Bmatrix} \quad if q \in S_2 \cap S_1 \end{Bmatrix} \tag{12}$$

Definition 4 (SuperHyperSoft Set (SHSS))

The SHSS is an extension of HyperSoft set and has several HyperSoft set. The SHSS is used in this study to compute the criteria and sub criteria for selecting the best alternative based on the set of criteria.

Let the universe set $U = \{C_1, C_2, \dots. C_n\}$. The power set of U is a $P(U)$ and Q_1, Q_2, Q_3 are select as a criteria. $P(Q_1) \times P(Q_2)$ and $P(Q_3)$ $are\ powersets\ of\ Q_1, Q_2, Q_3$

Let $F: P(Q_1) \times P(Q_2) \times P(Q_3) \to P(Q)$ $where\ \times refers\ to\ cartesian\ product$, and this called SHSS over Q.

$$P(Q_1) \times P(Q_2) \times P(Q_3) = \left\{ \begin{array}{c} \{Q_{11}\}, \{Q_{12}\}, \{Q_{11}, Q_{12}\} \times \\ \{Q_{21}\}, \{Q_{22}\}, \{Q_{21}, Q_{22}\} \times \\ \{Q_{31}\}, \{Q_{32}\}, \{Q_{33}\}, \{Q_{31}, Q_{32}\}, \{Q_{31}, Q_{33}\}, \\ \{Q_{32}, Q_{33}\}, \{Q_{31}, Q_{32}, Q_{33}\} \end{array} \right\} \tag{13}$$

3. IVIN-BWM-MABAC Approach

This section shows the steps of the proposed approach. This section includes three parts, in the first part, we define the criteria and alternatives with a set of experts. In the second part, we compute the criteria weights by the BWM approach. In the third part, we rank the alternatives by the MABAC approach. These methods are used under the IVINS to dela with vague information.

IVIN-BWM

BWM, one of the newest MADM techniques, effectively addresses the inconsistency resulting from pairwise comparisons. Compared to the other methods, this approach is more reliable. BWM has been used in several research projects.

The BWM method's basic phases and structure are as follows:

Step 1: Common methods for choosing and selecting criteria, such as literature reviews, expert opinions, and other likely approaches.

Step 2: Using the thoughts and views of experts, determine which criteria are the best and worst.
Step 3: Using IVINNs, create the preferences matrix by comparing the best criterion to all others.

Step 4: Using IVINNs, create the preferences matrix by comparing the worst criterion to all others.

Step 5: Determine the relative relevance of the criteria by solving the next optimization model and calculating the final value and best weights (w1*, w2*, w3*, ….wn*).

$$minmax_j \left\{ \left| (W_b/W_j) - a_{B_j} \right|, \left| (W_j/W_w) - a_{j_W} \right| \right\} \tag{14}$$

The optimal value of reliability level

$$\sum_j W_j = 1 \tag{15}$$

$\min d$

$$\left|\left(W_B/W_j\right) - a_{B_j}\right| \leq d \; for \; all \; j \tag{16}$$

$$\left|\left(W_j/W_w\right) - a_{j_w}\right| \leq d \; for \; all \; j \tag{17}$$

$$\sum_j W_j = 1$$

$$W_j \geq 0 \; for \; all \; j \tag{18}$$

IVIN-MABAC

This part shows the steps of the MABAC methods.

Step 1. Create the assessment matrix.

We used the IVINNs to create the assessment matrix. Then we apply the score function to obtain crisp values. Then we combine the opinions of experts.

Step 2. Normalize the decision matrix

We can normalize the decision matrix based on the positive and cost criteria such as:

$$n_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \tag{19}$$

$$n_{ij} = \frac{x_{ij} - \max x_{ij}}{\min x_{ij} - \max x_{ij}} \tag{20}$$

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

Step 3. Compute the weighted decision matrix.

$$f_{ij} = w_j + w_j n_{ij} \tag{21}$$

Step 4. Compute the border approximation method.

$$t_j = \left(\prod_{i=1}^{m} f_{ij}\right)^{\left(\frac{1}{m}\right)} \tag{22}$$

Step 5. Compute the distance from t_j

$$g_{ij} = f_{ij} - t_j \tag{23}$$

Step 6. Obtain the total distance

$$E_i = \sum_{j=1}^{n} g_{ij} \tag{24}$$

Step 7. Rank the alternatives.

4. Case Study

This section shows the results of the proposed approach to computing the criteria weights and rank alternatives. This study invited three experts to assess the criteria and alternatives. We collected eight criteria and nine alternatives. The criteria and suitable values: Economic Efficiency:

(Efficiency index less than 0.5, more than 0.5), Infrastructure Development: (index score less than 0.5, more than 0.5), Traffic Flow: (optimal or not optimal), Environmental Sustainability: (Sustainability index less than 0.5, more than 0.5), Public Transport Accessibility: (Efficiency index less than 0.5, more than 0.5), Smart Transportation Integration: (fully integrated, not integrated), Safety and Reliability: (low, middle, high), Government Policies: (low, middle, high)

The alternatives are: Ride-Sharing Services, Bicycle & Pedestrian Networks, Autonomous Vehicle Systems, High-Speed Rail Systems, Air Transport, Traditional Road Transport, Urban Metro Systems, Electric Bus Transit, Water Transport Systems

Each expert can select the best and worst criterion.

We use the IVINNs to create the preferences matrix by comparing the best criterion to all others.

We use the IVINNs to create the preferences matrix by comparing the worst criterion to all others.

We determine the relative relevance of the criteria using Eqs. (14-18). Then we compute the criteria weights as shown in Fig 1.

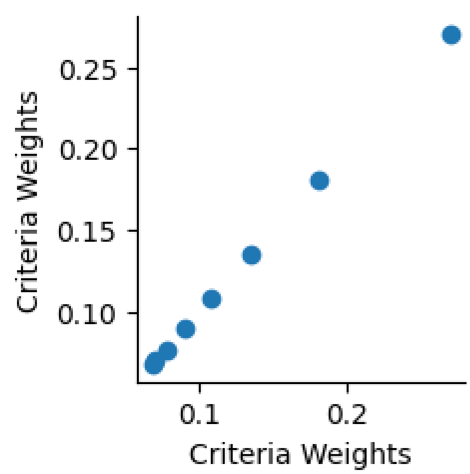

Fig 1. The importance of each criterion.

4.1. IVIN-MABAC

Based on the SHSS, we can suggest several sets for sub-criteria to rank the alternatives such as:

(Efficiency index more than 0.5) , (index score less than 0.5, more than 0.5), (optimal), (Sustainability more than 0.5), (Efficiency index more than 0.5), (fully integrated), (middle, high), (middle)

We proposed two sets such as:

Set 1: (Efficiency index more than 0.5) , (index score less than 0.5, more than 0.5), (optimal), (Sustainability more than 0.5), (Efficiency index more than 0.5), (fully integrated), (middle), (middle)

Set 2: (Efficiency index more than 0.5) , (index score less than 0.5, more than 0.5), (optimal), (Sustainability more than 0.5), (Efficiency index more than 0.5), (fully integrated), (high), (middle)

We applied the MABAC method based on the two sets. Based on Set 1:

Step 1. We create three assessment matrices between the criteria and alternatives using the IVINN as shown in Tables 1-3. Then we obtain crisp values. Then we combine the decision matrix.

Step 2. Eq. (19) is used to normalize the decision matrix

Step 3. Eq. (21) is used to compute the weighted decision matrix as shown in Fig 2.

Step 4. Then we compute the border approximation method using Eq. (22) as shown in Fig 3.
Step 5. Eq. (23) is used to compute the distance from t_j as shown in Fig 4.

Step 6. Eq. (24) is used to obtain the total distance

Step 7. We rank the alternatives as shown in Fig 5.

Table 1. The first IVINNs.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])
A_2	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])
A_3	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])
A_4	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])
A_5	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])
A_6	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])
A_7	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])
A_8	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])
A_9	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])

Table 2. The second IVINNs.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])
A_2	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])
A_3	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])
A_4	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])
A_5	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])
A_6	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])
A_7	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])
A_8	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])
A_9	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])

Table 3. The third IVINNs.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])
A_2	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])
A_3	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])
A_4	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])
A_5	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])
A_6	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.3, 0.4], [0.5, 0.6], [0.3, 0.4])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])
A_7	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])
A_8	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.6, 0.7], [0.8, 0.9], [0.2, 0.3])	([0.8, 0.9], [0.7, 0.8], [0.0, 0.1])
A_9	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.3])	([0.2, 0.3], [0.4, 0.5], [0.1, 0.2])	([0.7, 0.8], [0.6, 0.7], [0.1, 0.2])

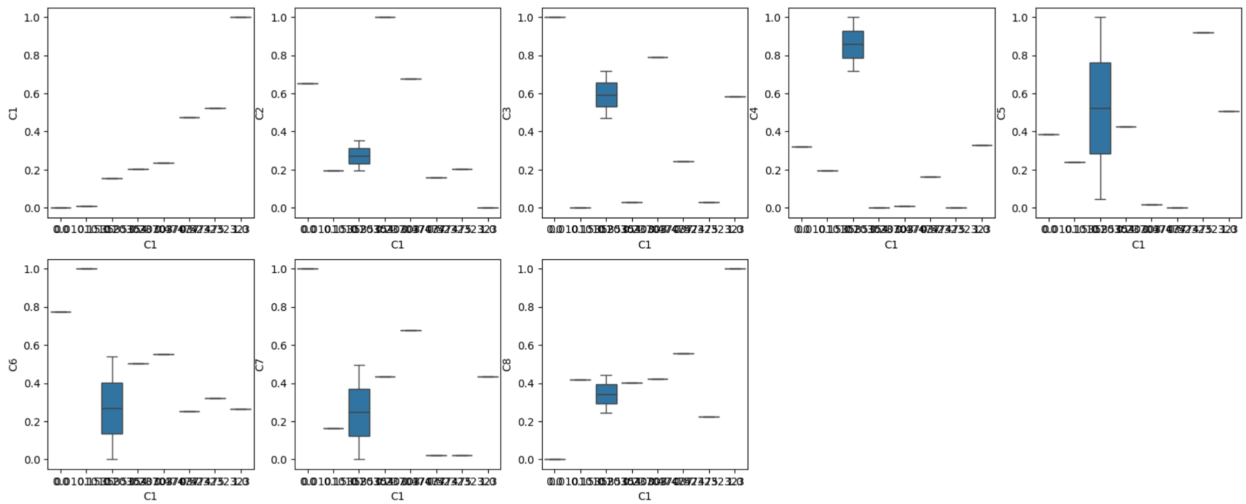

Fig 2. The normalization matrix.

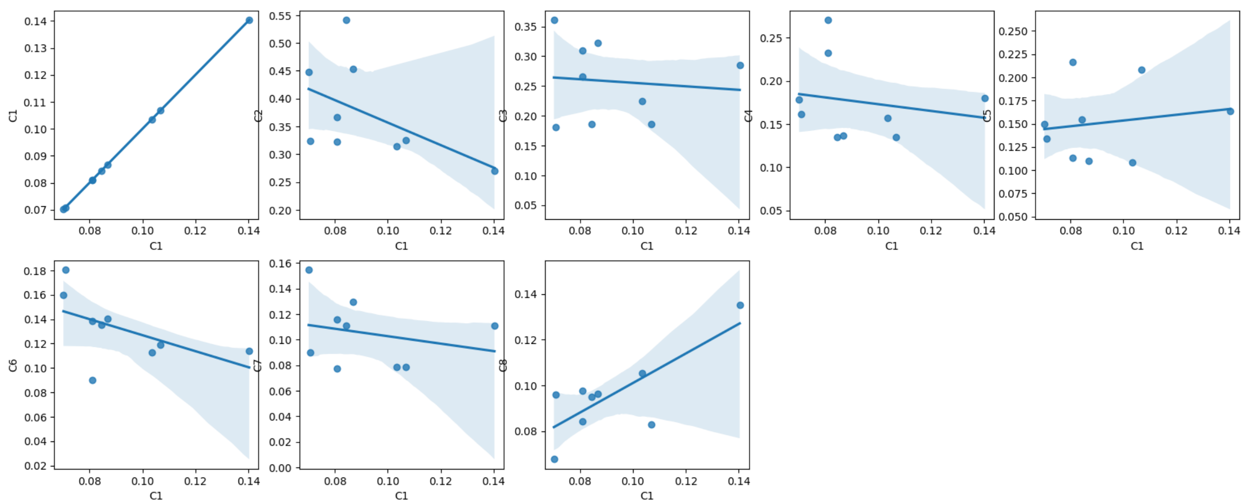

Fig 3. The weighted normalized matrix.

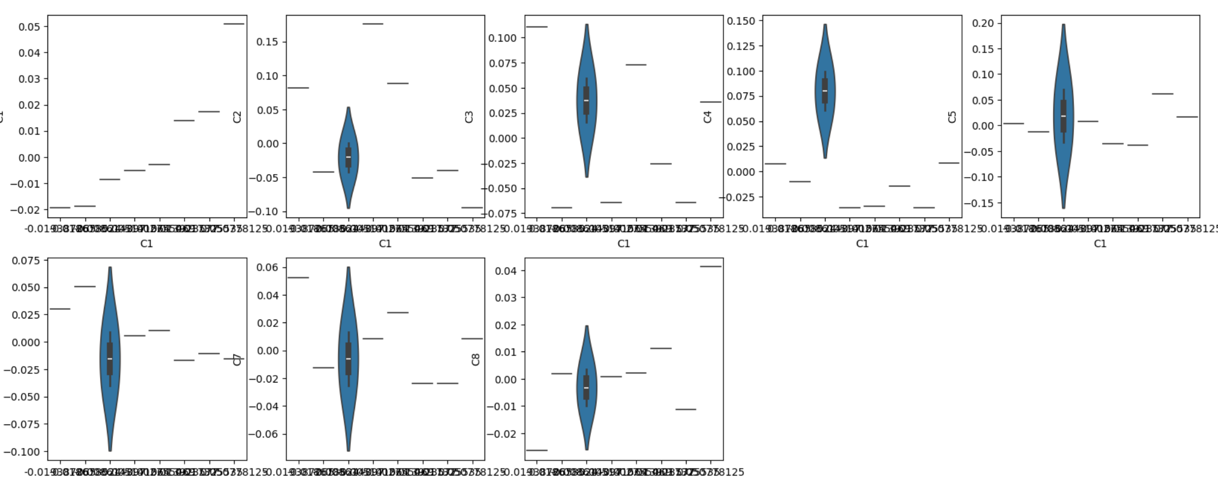

Fig 4. The total distances.

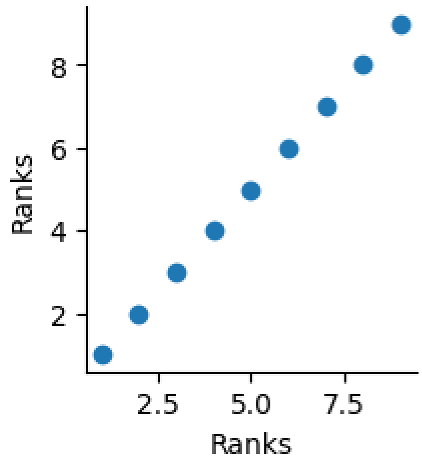

Fig 5. The ranks of alternatives.

Based on the Second set, we compute the normalization matrix as shown in Fig 6.

Then we compute the weighted normalized decision matrix as shown in Fig 7. Then we compute the border areas and total distance as shown in Fig 8.

Finally, we obtain the final ranks of alternatives as shown in Fig 9. We show the alternative 4 is the best and alternative 9 is the worst.

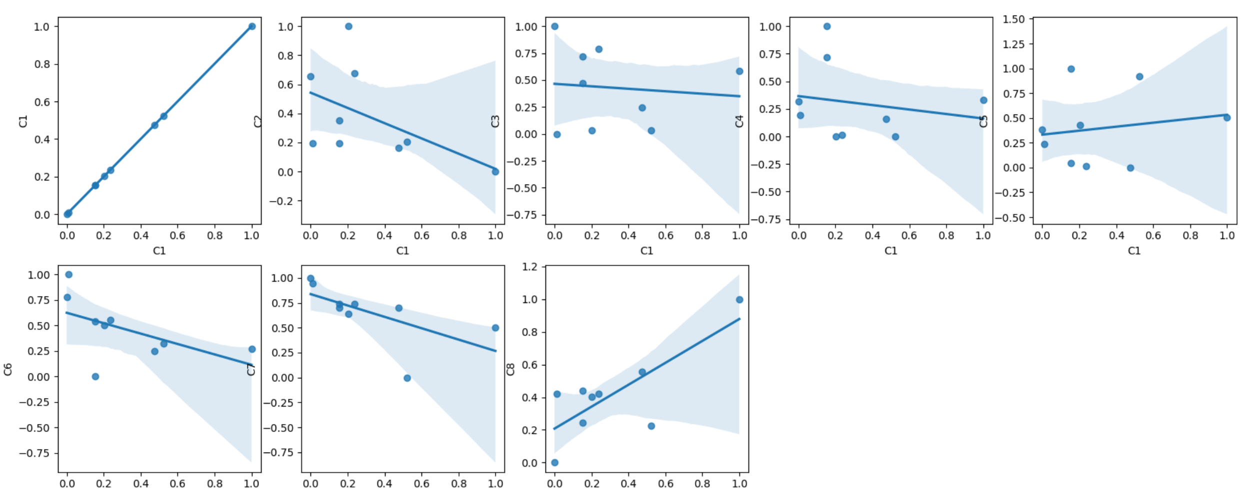

Fig 6. The normalization matrix.

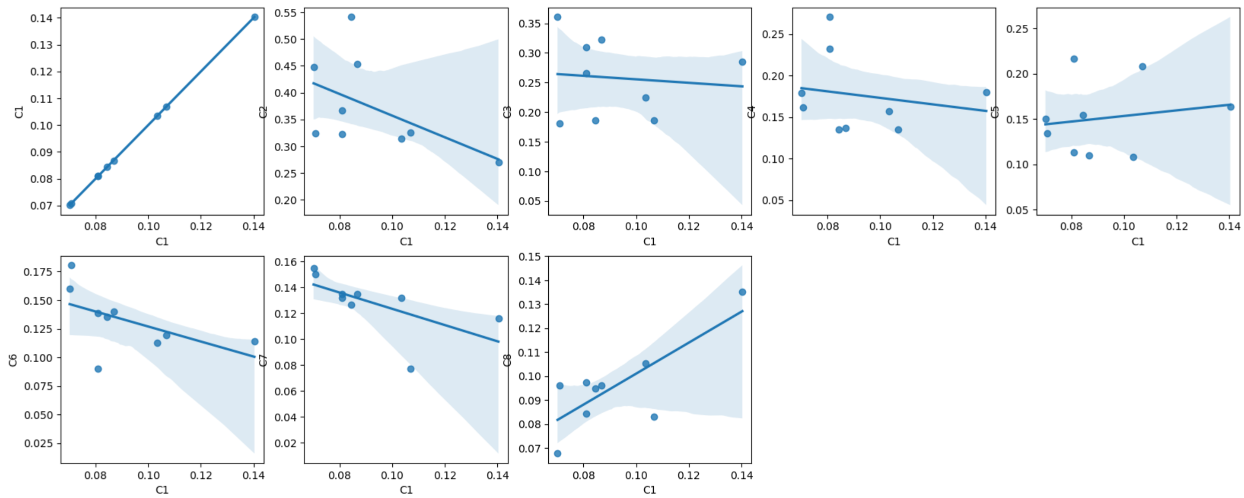

Fig 7. The weighted normalized matrix.

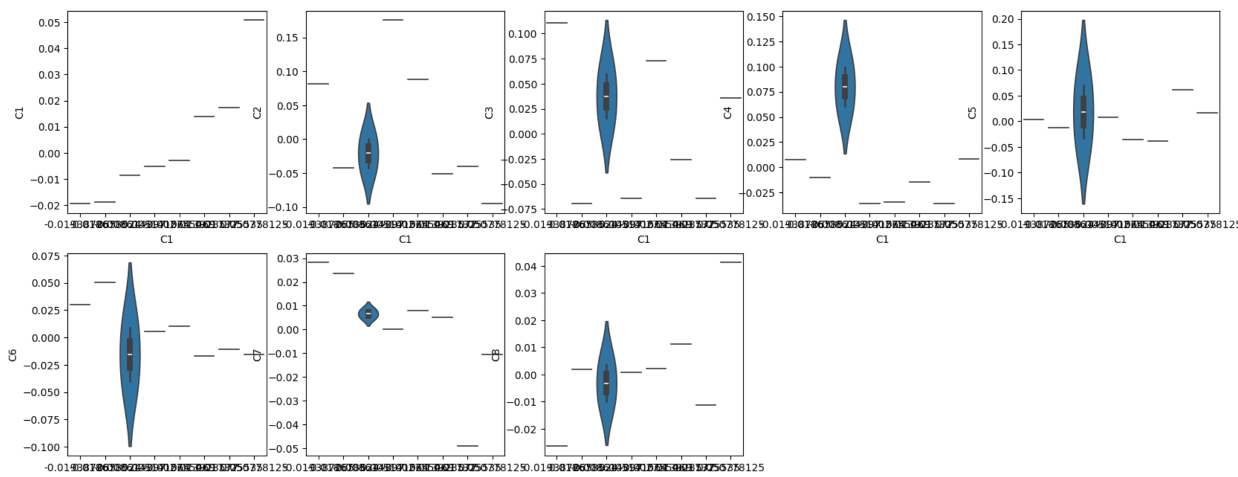

Fig 8. The total distances.

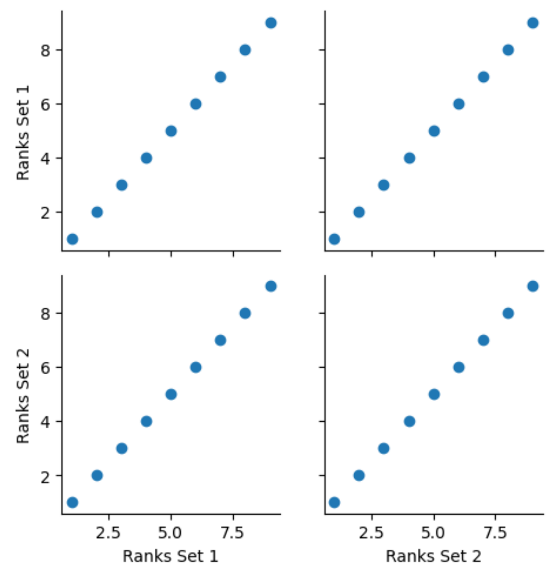

Fig 9. The final ranks of alternatives.

4.2. Sensitivity analysis

This part shows the sensitivity analysis to show the ranks of alternatives under different cases. We change the criteria weights by 9 cases to show different values of each alternative. We increase the weights of the criteria by 28% and other criteria have the same weights.

We applied the MABAC method under these cases, to show the ranks of the criteria. In the first case, we work on the same weights of all criteria. Then we increase the criteria weights by 28%. We obtain the total distance of each alternative with each case as shown in Fig 10. Then we rank the alternatives under different cases as shown in Fig 11. We show the rank of alternatives is stable under different cases. So, the MABAC method obtains stability in the ranks.

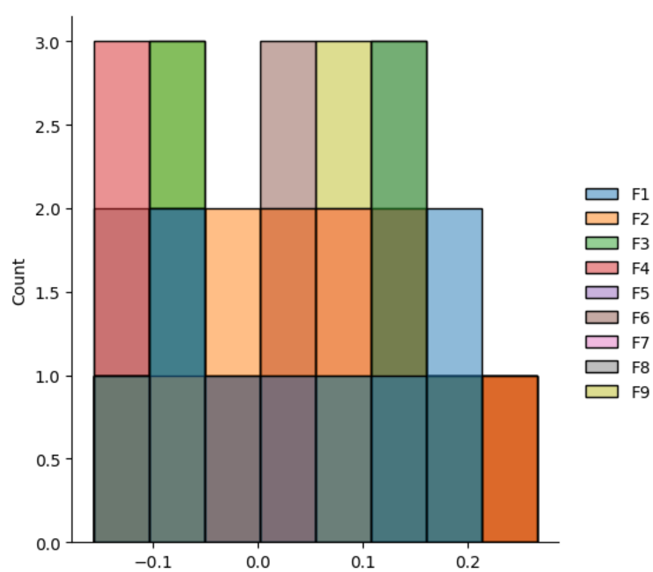

Fig 10. The total distance in sensitivity analysis.

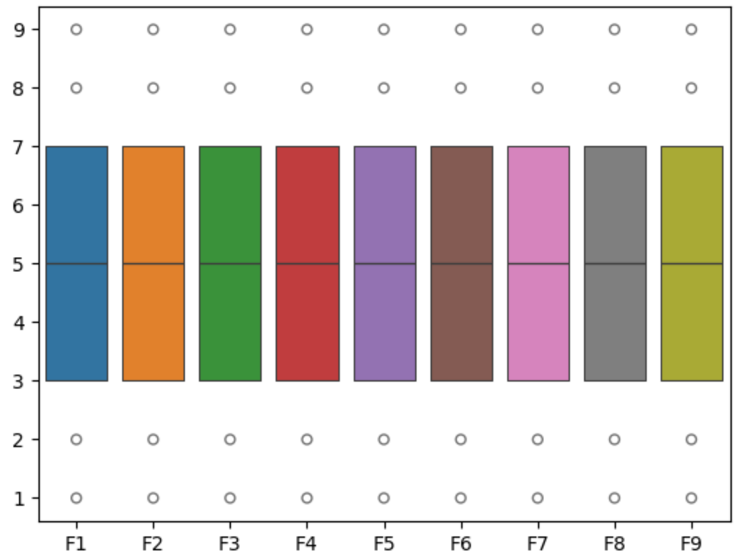

Fig 11. The ranks in sensitivity analysis.

4.3. Comparative analysis

This part shows the comparative analysis between the proposed approach and other methods to show the effectiveness of the proposed approach. We compared the proposed approach with the Proposed Model, TODIM Method, COPRAS Method, ELECTRE Method as shown in Fig 12. The proposed approach has the alternative 4 is the best and alternative 9 is the worst. The results show the proposed approach is effective compared to other methods.

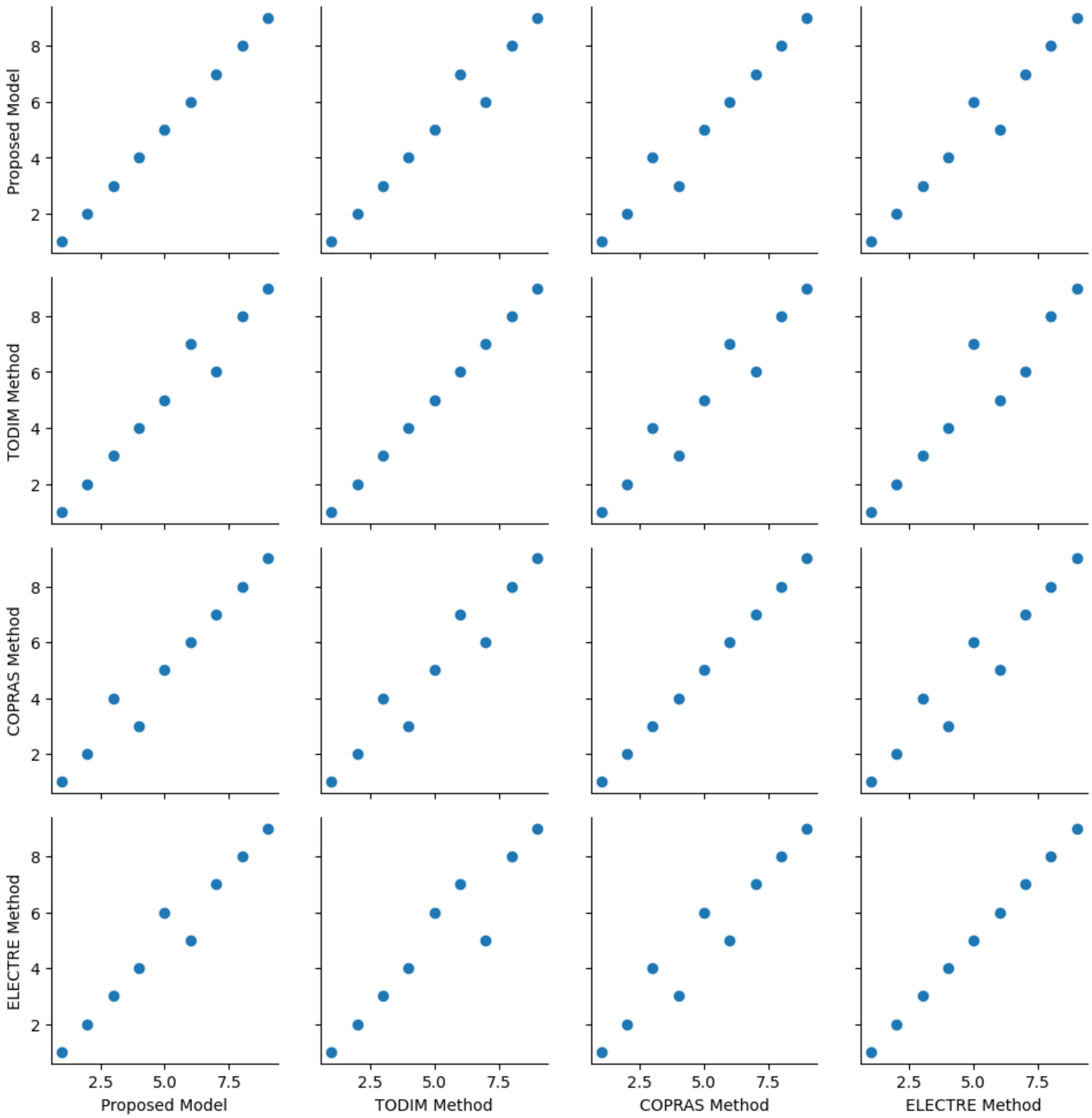

Fig 12. The comparative results

5. Conclusions

This study evaluated transportation efficiency by conducting a set of criteria and alternatives. Two methods are used in this study, such as BWM to compute the criteria weights and the MABAC method to rank the alternatives. These methods are used under the Interval Valued Intuitionistic Neutrosophic number (IVINN) to deal with vague information. SuperHyperSoft set is used with this model to treat various criteria and sub criteria. The results show alternative 4 is the best and alternative 9 is the worst. The sensitivity analysis is conducted by using nine cases.

The ranks of alternatives under these cases are stable. We compared the proposed approach with four methods. The results show the proposed approach is effective.

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