Neutrosophic Sets and Systems, Vol. 82, 2025

University of New Mexico

Design Performance Measurement of Intelligent Garbage Sorting Cart using Neutrosophic Sets and SuperHyperSoft

Yiyue Zhang*

Zhejiang Guangsha Vocational and Technical University of Construction, Jinhua, 321000, Zhejiang, China

*Corresponding author, E-mail: 20223112@zjgsdx.edu.cn

Abstract: With the rapid increase in urban waste generation, efficient and automated waste sorting solutions have become essential for sustainable waste management. This study evaluates the gent Garbage Sorting Cart under the decision-making methodology. We use the Quadripartitioned Single-Valued Neutrosophic Z-Numbers (QSVNZN) with four membership functions to dela with the uncertainty information. Two methods are used in this study, such as the CRITIC method to compute the criteria weights and the ARAS method to rank the alternatives. The decision-making process is used with the SuperHyperSoft set to deal with different criteria and alternatives. We used eight criteria and six alternatives. We proposed six collections of SuperHyperSoft. In each collection, we applied the ARAS methodology and ranked the alternatives. The results show stability in the ranks.

Keywords: Quadripartitioned Single-Valued Neutrosophic Z-Numbers (QSVNZN); SuperHyperSoft Set; Intelligent Garbage Sorting Cart; Intelligent Garbage Sorting Cart.

1. Introduction

With the rapid increase in urban waste generation, efficient and automated waste sorting solutions have become essential for sustainable waste management. Traditional waste segregation methods are labor-intensive and prone to human error, leading to improper disposal and environmental hazards. The introduction of intelligent garbage sorting carts, integrated with advanced artificial intelligence (AI), sensors, and autonomous navigation, has revolutionized waste management by enhancing sorting accuracy and efficiency[1], [2]. However, to ensure optimal performance and practical implementation, a systematic evaluation of the design performance of these smart carts is necessary, considering multiple functional, technical, and economic criteria.

The design performance evaluation of intelligent garbage sorting carts requires a multi-criteria assessment that considers various aspects such as sorting accuracy, sensor efficiency, energy consumption, mobility, durability, and cost-effectiveness. These carts utilize AI-driven image recognition and sensor-based classification techniques to automatically identify and separate waste into categories like organic, recyclable, and hazardous waste[3], [4]. However, differences in design, technology integration, and operational efficiency necessitate a structured approach to compare and rank various models. A well-defined evaluation framework helps manufacturers, policymakers, and urban planners select the most effective designs for large-scale deployment.

To achieve an objective assessment, Multi-Criteria Decision-Making (MCDM) methodologies such as CRITIC, and ARAS can be applied to systematically evaluate and rank different intelligent garbage sorting cart models. These methods enable decision-makers to analyze multiple criteria simultaneously, balancing technical efficiency, cost, maintenance requirements, and user-friendliness. By leveraging MCDM techniques, stakeholders can ensure that the selected garbage sorting carts maximize waste segregation efficiency while maintaining affordability and sustainability in various operational settings, including residential areas, commercial spaces, and industrial waste management facilities.

The successful implementation of intelligent garbage sorting carts depends on a combination of technological advancements, design optimization, and real-world testing. A robust evaluation framework ensures that these smart carts meet the required performance standards while addressing practical concerns such as power consumption, maintenance costs, and ease of use. As cities move toward smart and sustainable waste management systems, evaluating the design performance of these carts is crucial to promoting efficient, eco-friendly, and automated waste sorting solutions[5]. Through continuous innovation and systematic evaluation, intelligent garbage sorting carts can significantly contribute to a cleaner and more sustainable urban environment.

This flaw in IFSs was fixed in 2005 when Smarandache proposed the idea of neutrosophic sets (NSs), which defined the indeterminacy degree as an independent component[6]. The study of neutralities, or "neutrosophy," is the field of philosophy that gave rise to Smarandache's NSs. All three components of NS theory derive their values from the non-standard unit interval, and each element is distinguished by a truth membership degree, an indeterminacy membership degree, and a falsity membership degree[7], [8]. However, NSs' actual technical, scientific, and practical uses were limited by their philosophical stance.

After that, Wang et al. [9] introduced the idea of SVNSs, which has no restrictions on the values that its constituent parts can adopt from the total of the truth, indeterminacy, and falsity degrees components falls between 0 and 3. There is still uncertainty even if the indeterminacy component in SVNSs is independent and more generic than the hesitation parameter in IFSs. It is uncertain exactly if the indeterminacy degree refers to an element's belongingness or non-belongingness. Due to this conflict of interest, Chatterjee et al. [10] developed the idea of QSVNSs, in which the indeterminacy component is further divided into "ignorance" (neither nor F) and "contradiction" (both I and F).

According to decision making theory, a model or framework that can handle the most ambiguous information effectively and ultimately provides the outcome is preferred. The descriptive power of QSVNSs can be further improved by assigning a reliability measure to each of the quadripartitioned single-valued neutrosophic components of truth, contradiction, ignorance, and falsity. QSVNSs are already an effective mathematical tool for handling imprecise or uncertain information. It may be possible to apply Zadeh's[11] Z-numbers notion in this context.

To put it simply, a Z-number is an ordered pair with fuzzy numbers as its constituents. While the second component provides an amount of assurance or dependability of information corresponding to the first component, the first component explains the limitations placed on the values that are assumed by an uncertain variable. In decision-making processes, accurate information is essential because those who rely on ambiguous or imprecise information risk financial losses, resource waste, lost time, and other consequences. Therefore, a strong instrument such as the Z-number may be used to both collect and convey the dependability of cognitive information.

According to Zadeh, the Z-number is an ordered pair of fuzzy numbers that may represent the certainty and dependability of any given piece of information. Similarly, Quadripartitioned Single-Valued Neutrosophic Sets (QSVNSs), which reflect ambiguous knowledge or facts at hand, are defined by four independent components of truth, contradiction, ignorance, and falsity degrees, based on Belnap's four-valued logic. QSVNSs are extensions of SVNSs, which SVNSs, with the indeterminacy component further divided into ignorance and contradiction. Nevertheless, QSVNSs by themselves are unable to capture the dependability metric of decision makers' allocations or preferences.

Therefore, Borah and Dutta [12] proposed a hybrid framework for the first time to improve uncertainty modeling and to integrate the knowledge of truth, contradiction, ignorance, and falsity degrees with their respective reliability qualities. Therefore, as a generalization of the Z-number and the QSVNSs, they suggested the idea of Quadripartitioned Single-Valued Neutrosophic Z-number (QSVNZN). To rank QSVNZNs, scoring functions and a few fundamental operations are also defined.

Three instances of MCDM, particularly in the context of COVID-19, are used to illustrate the applicability of our recently suggested operators and the score function. To illustrate the legitimacy, authenticity, and viability of our theoretical construction, careful comparison analysis, sensitivity analysis, runtime analysis, and the validity of our suggested methodologies are also conducted. The outcomes will be very helpful to decision-makers in handling uncertain and conflicting data effectively. Stated differently, the new framework must have adequate descriptive power from a human-cognition standpoint.

2. Basic Preliminaries

This section shows some basic preliminaries on quadripartitioned single-valued neutrosophic Z-numbers (QSVNZN)[12].

Definition 1

The QSVN can be defined by four components such as truth, $T_Q(x)$, contradiction $C_Q(x)$, ignorance $U_Q(x)$, and falsity functions $F_Q(x)$

$$0 \le T_Q(x) + C_Q(x) + U_Q(x) + F_Q(x) \le 4 \tag{1}$$

Definition 2

We can define the QSVNZN as:

$$Q_z = T_Q(R,C)(x), C_Q(R,C)(x), U_Q(R,C)(x), F_Q(R,C)(x) \tag{2}$$

each pair in the Q_z can be defined as:

$$T_Q(R,C)(x) = \left(T_Q^R(x), T_Q^C(x)\right) \tag{3}$$

$$C_Q(R,C)(x) = \left(C_Q^R(x), C_Q^C(x)\right) \tag{4}$$

$$U_Q(R,C)(x) = \left(U_Q^R(x), U_Q^C(x)\right) \tag{5}$$

$$F_Q(R,C)(x) = \left(F_Q^R(x), F_Q^C(x)\right) \tag{6}$$

$$0 \le T_Q^R(x) + C_Q^R(x) + U_Q^R(x) + F_Q^R(x) \le 4 \tag{7}$$

$$0 \le T_Q^C(x) + C_Q^C(x) + U_Q^C(x) + F_Q^C(x) \le 4 \tag{8}$$

Definition 3

Some operations of QSVNZN can be defined as:

$$Q_z^c = \left(F_Q(R,C)(x), U_Q(R,C)(x), C_Q(R,C)(x), T_Q(R,C)(x)\right) \tag{9}$$

$$Q_{Z_1} \cup Q_{Z_2} = \begin{pmatrix} \left(T_Q^{R1} \vee T_Q^{R2}, T_Q^{C1} \vee T_Q^{C2}\right), \\ \left(C_Q^{R1} \vee C_Q^{R2}, C_Q^{C1} \vee C_Q^{C2}\right), \\ \left(U_Q^{R1} \wedge U_Q^{R2}, U_Q^{C1} \wedge U_Q^{C2}\right), \\ \left(F_Q^{R1} \wedge F_Q^{R2}, F_Q^{C1} \wedge F_Q^{C2}\right) \end{pmatrix} \tag{10}$$

$$Q_{Z_1} \cap Q_{Z_2} = \begin{pmatrix} \left(T_Q^{R1} \wedge T_Q^{R2}, T_Q^{C1} \wedge T_Q^{C2}\right), \\ \left(C_Q^{R1} \wedge C_Q^{R2}, C_Q^{C1} \wedge C_Q^{C2}\right), \\ \left(U_Q^{R1} \vee U_Q^{R2}, U_Q^{C1} \vee U_Q^{C2}\right), \\ \left(F_Q^{R1} \vee F_Q^{R2}, F_Q^{C1} \vee F_Q^{C2}\right) \end{pmatrix} \tag{11}$$

$$Q_{Z_1} \oplus Q_{Z_2} = \begin{pmatrix} \left(T_Q^{R1} + T_Q^{R2} - T_Q^{R1}T_Q^{R2}, T_Q^{C1} + T_Q^{C2} - T_Q^{C1}T_Q^{C2}\right), \\ \left(C_Q^{R1} + C_Q^{R2} - C_Q^{R1}C_Q^{R2}, C_Q^{R1} + C_Q^{R2} - C_Q^{R1}C_Q^{R2}\right), \\ \left(U_Q^{R1}U_Q^{R2}, U_Q^{C1}U_Q^{C2}\right), \\ \left(F_Q^{R1}F_Q^{R2}, F_Q^{C1}F_Q^{C2}\right) \end{pmatrix} \tag{12}$$

$$Q_{Z_1} \otimes Q_{Z_2} = \begin{pmatrix} \left(T_Q^{R1}T_Q^{R2}, T_Q^{C1}T_Q^{C2}\right), \\ \left(C_Q^{R1}C_Q^{R2}, C_Q^{C1}C_Q^{C2}\right), \\ \left(U_Q^{R1} + U_Q^{R2} - U_Q^{R1}U_Q^{R2}, U_Q^{C1} + U_Q^{C2} - U_Q^{C1}U_Q^{C2}\right), \\ \left(F_Q^{R1} + F_Q^{R2} - F_Q^{R1}F_Q^{R2}, F_Q^{C1} + F_Q^{C2} - F_Q^{C1}F_Q^{C2}\right) \end{pmatrix} \tag{13}$$

3. QSVNZN-CRITIC-ARAS Method

This section presents the steps of the proposed approach. We used the CRITIC method to compute the criteria weights and the ARAS method to rank the alternatives. These methods are used under the QSVNZN environment to deal with uncertainty information.

QSVNZN-CRITIC

We compute the criteria weights by the CRITIC method.

Build the decision matrix.

We used the QSVNZN to evaluate the criteria and alternative and build the decision matrix such as:

$$Q = \begin{bmatrix} q_{11} & \cdots & q_{1n} \\ \vdots & \ddots & \vdots \\ q_{m1} & \cdots & q_{mn} \end{bmatrix}_{m \times n} ; i = 1, \ldots, m; j = 1, \ldots, n \tag{14}$$

Normalize the decision matrix

The decision matrix is normalized for positive and cost criterion

$$u_{ij} = \frac{q_{ij} - \min q_{ij}}{\max q_{ij} - \min q_{ij}} \tag{15}$$

$$u_{ij} = \frac{q_{ij} - \max q_{ij}}{\min q_{ij} - \max q_{ij}} \tag{16}$$

Obtain the correlation matrix between the criteria O_{jk}

Compute the C index

$$C_j = f_j \sum_{k=1}^{n} \left(1 - O_{jk}\right) \tag{17}$$

Where f_j refers to the standard deviation

Compute the criteria weights

$$W_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \tag{18}$$

QSVNZN-ARAS

We use the ARAS method to rank the alternatives.

Normalize the decision matrix

$$y_{ij} = \frac{q_{ij}}{\sum_{i=0}^{m} q_{ij}} \tag{19}$$

Compute the weighted normalized decision matrix

$$T_{ij} = W_j y_{ij} \tag{20}$$

Compute the optimality function

$$L_i = \sum_{j=1}^{n} T_{ij} \tag{21}$$

Compute the utility degree

$$E_i = \frac{L_i}{\max L_i} \tag{22}$$

SuperHyperSoft (SHS)

SHS is used to deal with the standards and sub standards with different values. It is defined based on the HyperSoft set[13], [14]. Let the universe set $U = \{K_1, K_2, \dots . K_n\}$. The power set of U is a $P(U)$ and V_1, V_2, V_3 are select as a criteria. $P(V_1) \times P(V_2)\ and\ P(V_3)\ are\ powersets\ of\ V_1, V_2, V_3$

Let $F: P(V_1) \times P(V_2) \to P(V)$ this called SHS over V.

$$P(V_1) \times P(V_2) \times P(V_3) = \left\{ \begin{matrix} \{V_{11}\}, \{V_{12}\}, \{V_{11}, V_{12}\} \times \\ \{V_{21}\}, \{V_{22}\}, \{V_{21}, V_{22}\} \times \\ \{V_{31}\}, \{V_{32}\}, \{V_{33}\}, \{V_{31}, V_{32}\}, \{V_{31}, V_{33}\}, \\ \{V_{32}, V_{33}\}, \{V_{31}, V_{32}, V_{33}\} \end{matrix} \right\} \tag{23}$$

4. An application

This section shows the results of the proposed approach. Three experts are invited to evaluate the criteria and alternatives. Eight criteria and six alternatives are used in this study to select the best one based on a set of criteria.

The criteria and sub values are:

- ✓ User-Friendliness {Complex, Moderate, Simple}
- ✓ Maintenance Requirements {Frequent, Moderate, Minimal}
- ✓ Energy Consumption {High, Moderate, Low}
- ✓ Mobility & Navigation {Limited, Advanced}
- ✓ Sensor Efficiency {Inefficient, Moderate, Efficient}
- ✓ Cost-Effectiveness {Expensive, Moderate, Affordable}
- ✓ Durability & Build Quality {Weak, Moderate, Strong}
- ✓ Sorting Accuracy {Low, Moderate, High}

The alternatives of this study are:

- ✓ Basic AI-Sensor Cart
- ✓ Solar-Powered Smart Cart
- ✓ Autonomous Navigation Cart
- ✓ Heavy-Duty Industrial Cart
- ✓ Compact Household Cart
- ✓ AI-Enhanced Precision Cart

We used the QSVNZN to build the decision matrix as shown in Tables 1-4.

Then we normalize the decision matrix using Eq. (15) as shown in Table 5

Then we obtain the correlation matrix between the criteria O_{jk}.

Then we compute the C index using Eq. (17)

Then we compute the criteria weights using Eq. (18). The criteria weights can be represented as: C1= 0.114925131, C2= 0.102561851, C3= 0.13194509, C4= 0.108780779, C5= 0.165034631, C6= 0.089873444, C7= 0.120758257, C8= 0.166120817

Table 1. The first values of QSVNZN.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))
A2	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))
A3	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))
A4	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))
A5	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))
A6	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))

Table 2. The second values of QSVNZN.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))
A2	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))
A3	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))
A4	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))
A5	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))
A6	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))

Table 3. The third values of QSVNZN.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))
A2	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))
A3	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))

A4	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))
A5	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))
A6	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))

Table 4. The fourth values of QSVNZN.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A1	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))
A2	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))
A3	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))
A4	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))
A5	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.5,0.6),(0.6,0.7),(0.4,0.5),(0.2,0.1))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.7,0.7),(0.6,0.7),(0.4,0.5),(0.3,0.2))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.3,0.2),(0.2,0.3),(0.6,0.5),(0.7,0.9))
A6	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.8,0.9),(0.8,0.8),(0.2,0.3),(0.3,0.4))	((0.1,0.2),(0.2,0.3),(0.5,0.7),(0.6,0.8))	((0.1,0.1),(0.2,0.2),(0.7,0.9),(0.8,0.9))	((0.5,0.5),(0.6,0.4),(0.3,0.4),(0.3,0.2))

Table 5. The normalized values of QSVNZN by CRITIC.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	1	0.664615	0.853293	0	0	0.445367	0	1
A_2	0.336449	0.146154	0.847305	0.30491	0.052061	0.697095	1	0
A_3	0.623832	1	0	0.397933	0.78308	0.780083	0.713392	0.284211
A_4	0.614486	0.618462	1	0.742894	0.893709	1	0.732165	0.64386
A_5	0.158879	0.563077	0.663174	1	0.958785	0.387275	0.684606	0.231579
A_6	0	0	0.158683	0.102067	1	0	0.440551	0.9

QSVNZN-ARAS

This study uses the SuperHyperSoft set to treat various criteria and values. This study divided the values of criteria into several HyperSoft sets. Then we ranked the alternatives based on these divisions. The values of criteria are selected as: {Simple}, {Moderate}, {High}, {Limited, Advanced}, Inefficient, Moderate, Efficient}, {Affordable}, {Strong}, {High}

- **Collection 1:** {Simple}, {Moderate}, {High}, {Limited}, {Inefficient}, {Affordable}, {Strong}, {High}
- **Collection 2:** {Simple}, {Moderate}, {High}, {Limited}, {Moderate}, {Affordable}, {Strong}, {High}
- **Collection 3:** {Simple}, {Moderate}, {High}, {Limited}, {Efficient}, {Affordable}, {Strong}, {High}
- **Collection 4:** {Simple}, {Moderate}, {High}, {Advanced}, {Inefficient}, {Affordable}, {Strong}, {High}
- **Collection 5:** {Simple}, {Moderate}, {High}, {Advanced}, {Moderate}, {Affordable}, {Strong}, {High}

- **Collection 6:** {Simple}, {Moderate}, {High}, {Advanced}, {Efficient}, {Affordable}, {Strong}, {High}

Ranking the alternatives based on collection 1

Eq. (19) is used to normalize the decision matrix as shown in Fig 1.

Eq. (20) is used to compute the weighted normalized decision matrix as shown in Fig 2.

Eq. (21) is used to compute the optimality function.

Eq. (22) is used to compute the utility degree.

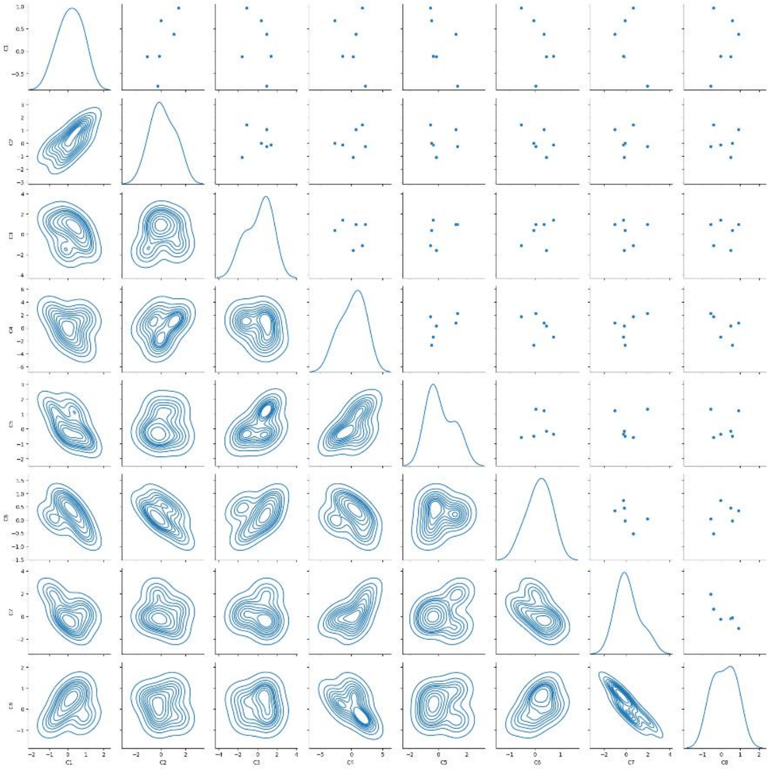

Fig 1. The normalization values.

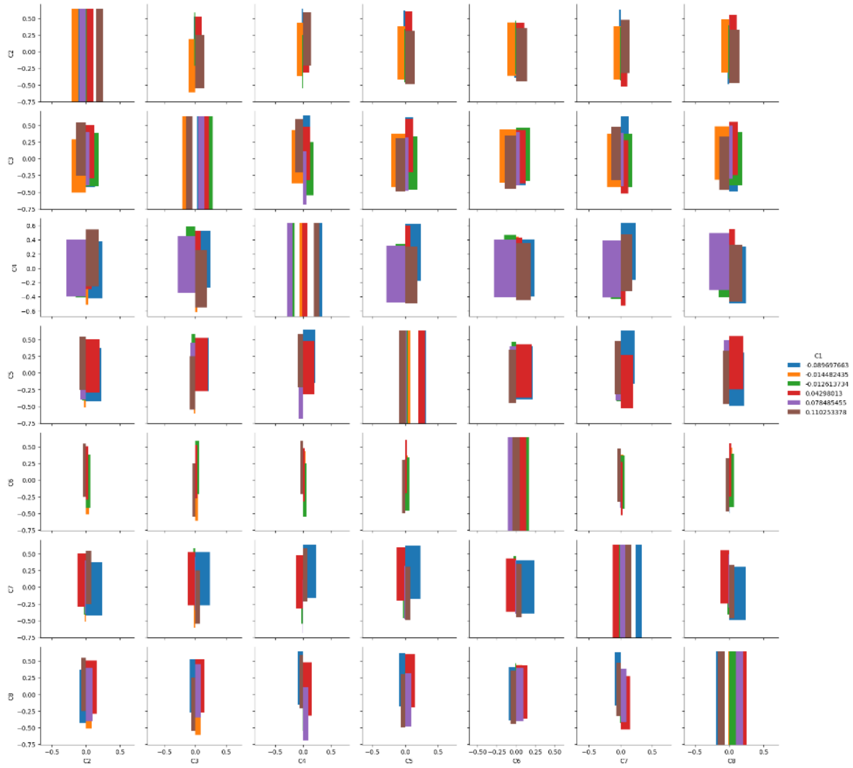

Fig 2. The weighted normalization values.

Ranking the alternatives based on collection 2

We normalize the decision matrix as shown in Fig 3.

We compute the weighted normalized decision matrix as shown in Fig 4.

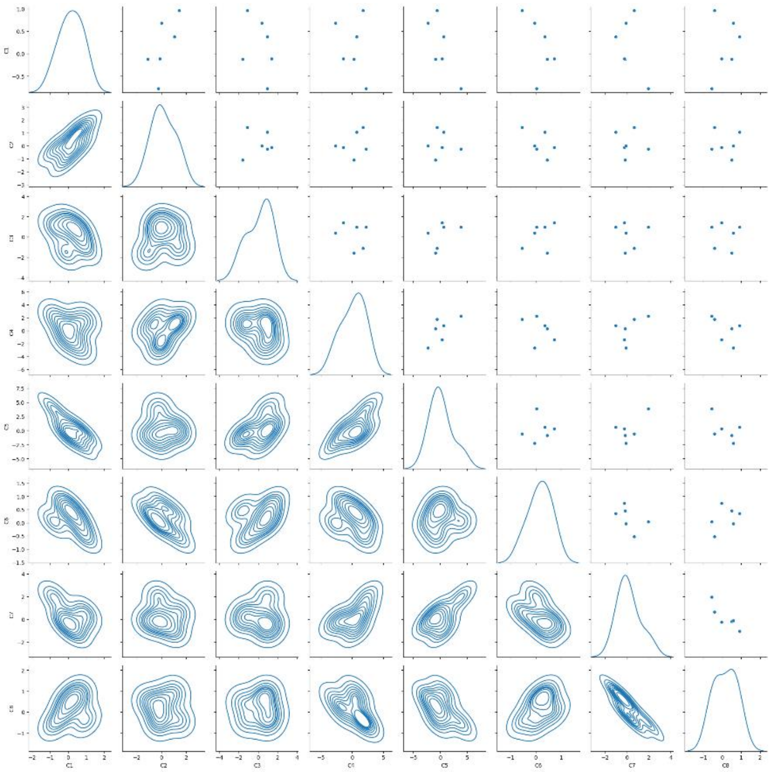

Fig 3. The normalization values.

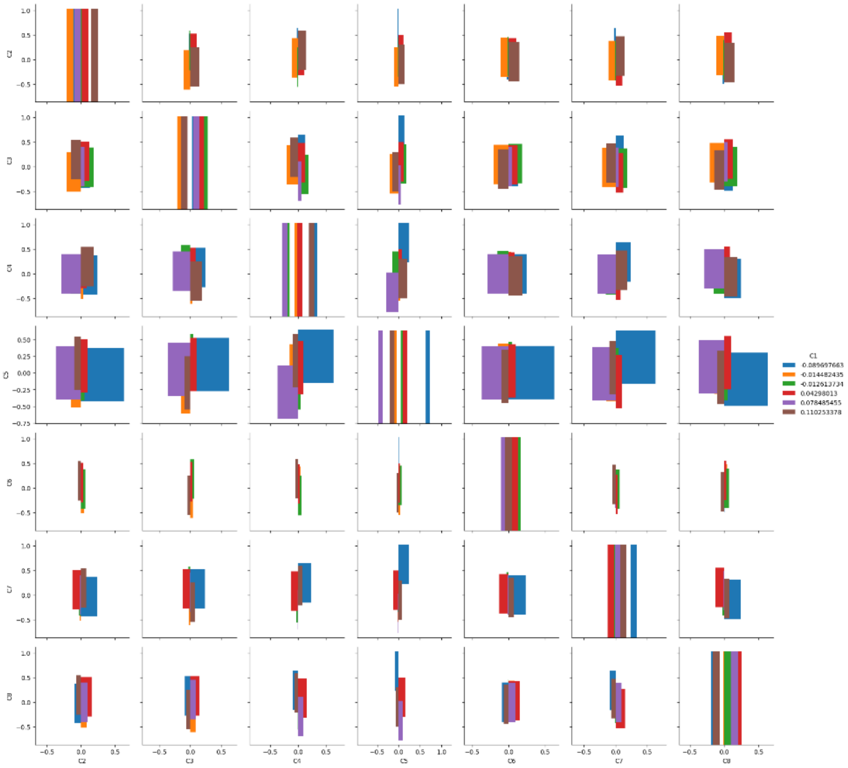

Fig 4. The weighted normalization values.

Ranking the alternatives based on collection 3

We normalize the decision matrix as shown in Fig 5.

We compute the weighted normalized decision matrix as shown in Fig 6.

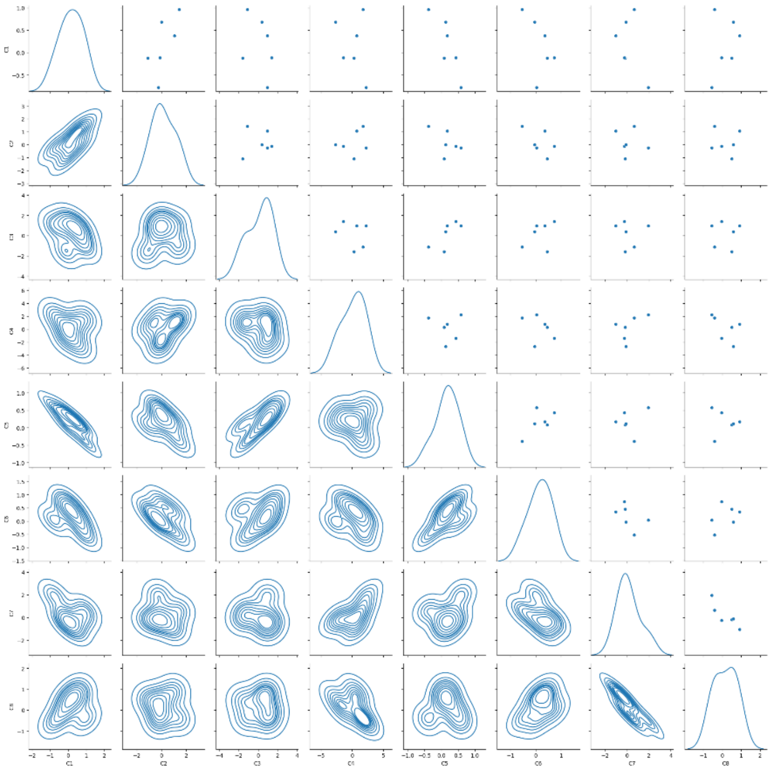

Fig 5. The normalization values.

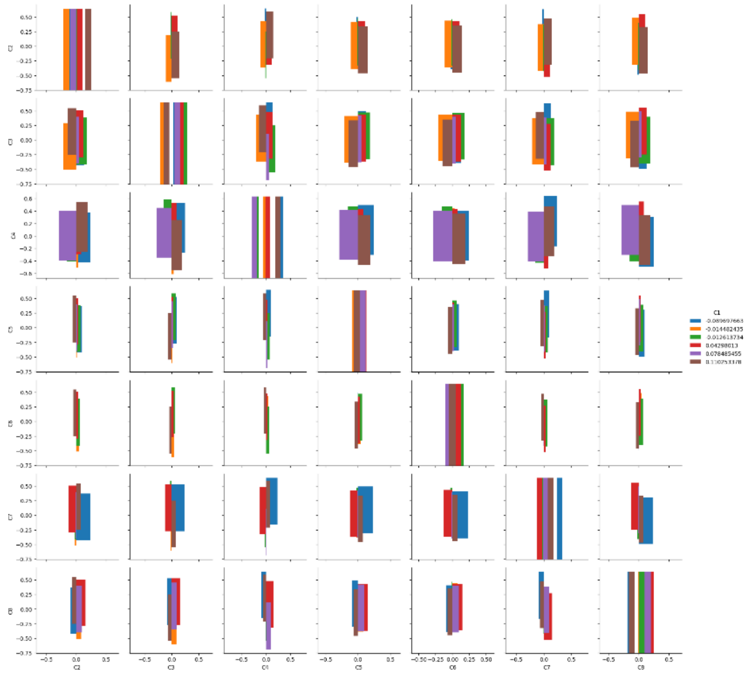

Fig 6. The weighted normalization values.

Ranking the alternatives based on collection 4

We normalize the decision matrix as shown in Fig 7.

We compute the weighted normalized decision matrix as shown in Fig 8.

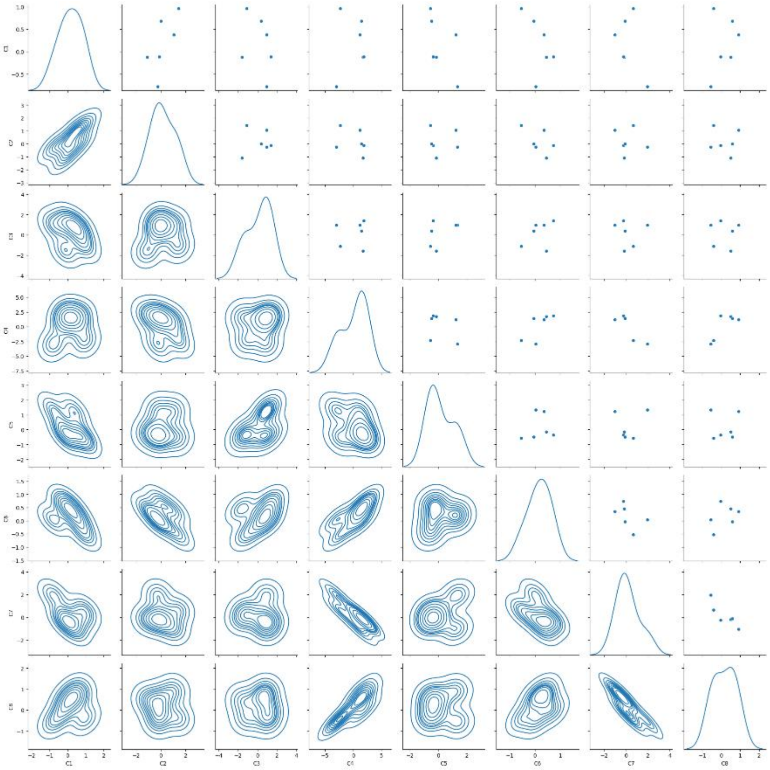

Fig 7 The normalization values.

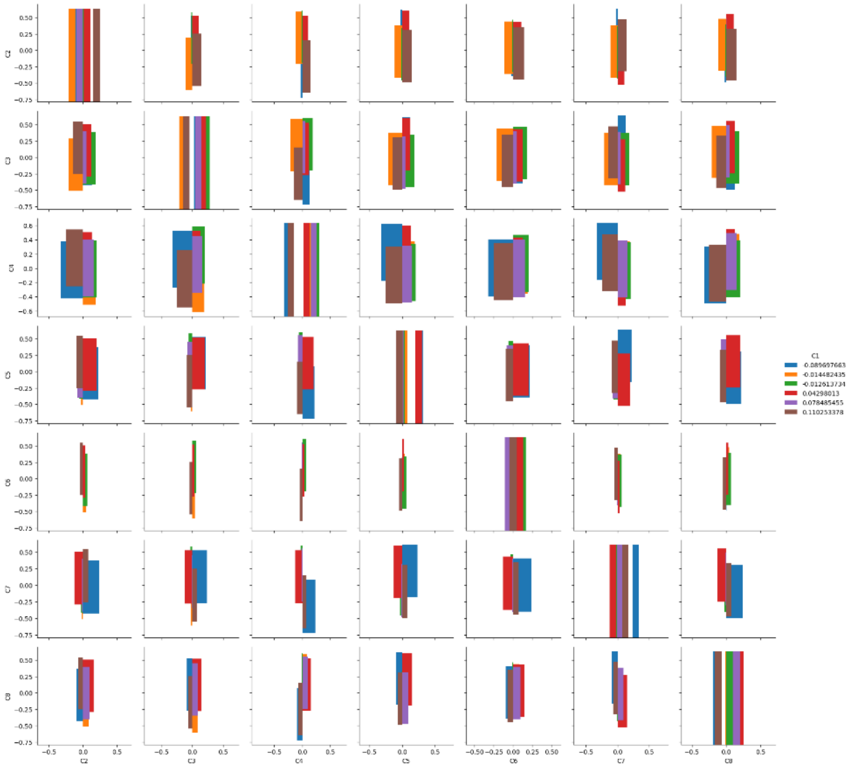

Fig 8. The weighted normalization values.

Ranking the alternatives based on collection 5

We normalize the decision matrix as shown in Fig 9.

We compute the weighted normalized decision matrix as shown in Fig 10.

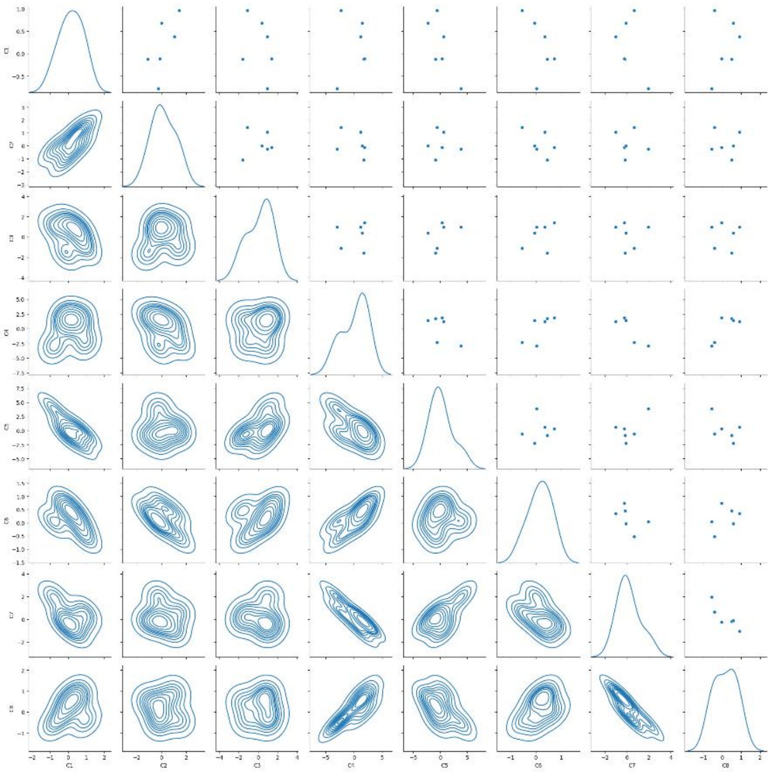

Fig 9. The normalization values.

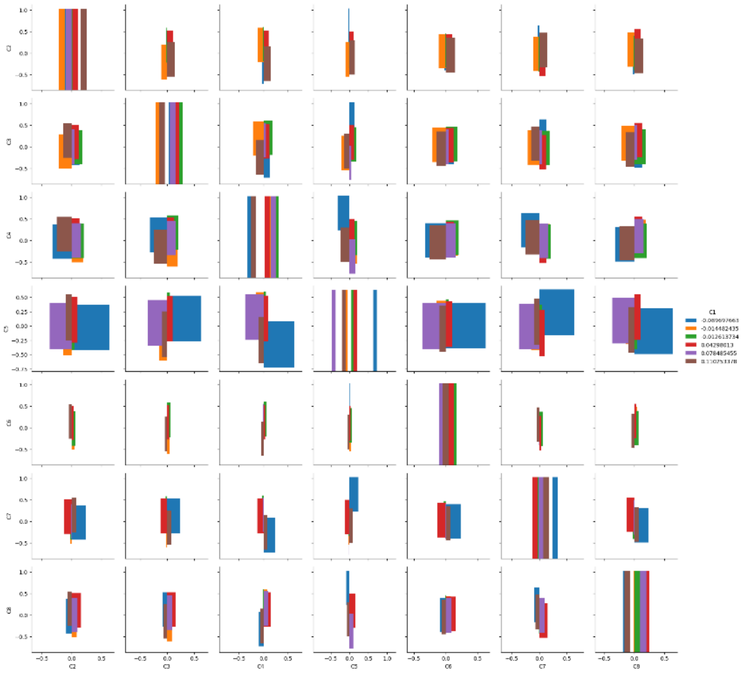

Fig 10. The weighted normalization values.

Ranking the alternatives based on collection 6

We normalize the decision matrix as shown in Fig 11.

We compute the weighted normalized decision matrix as shown in Fig 12.

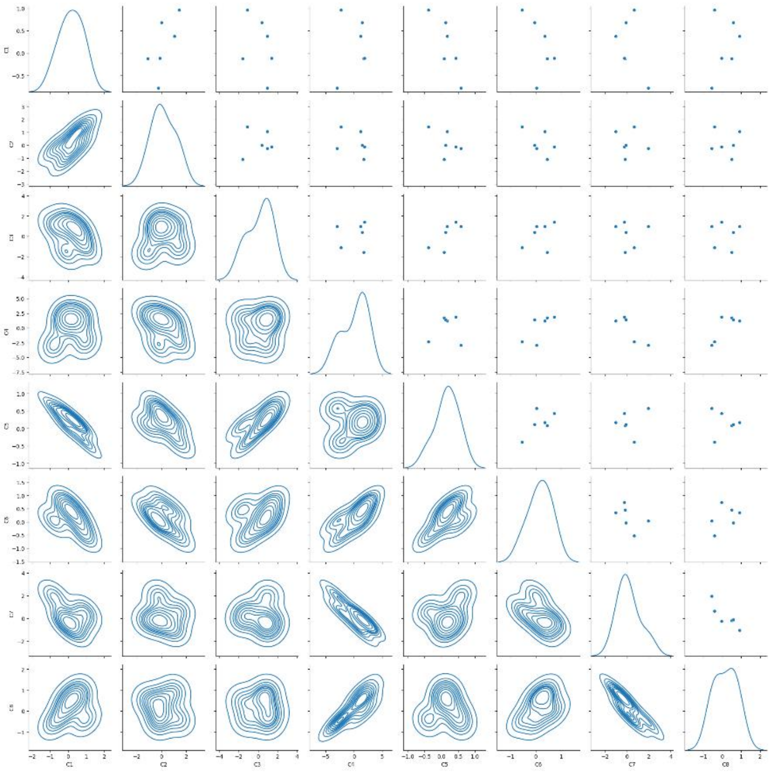

Fig 11. The normalization values.

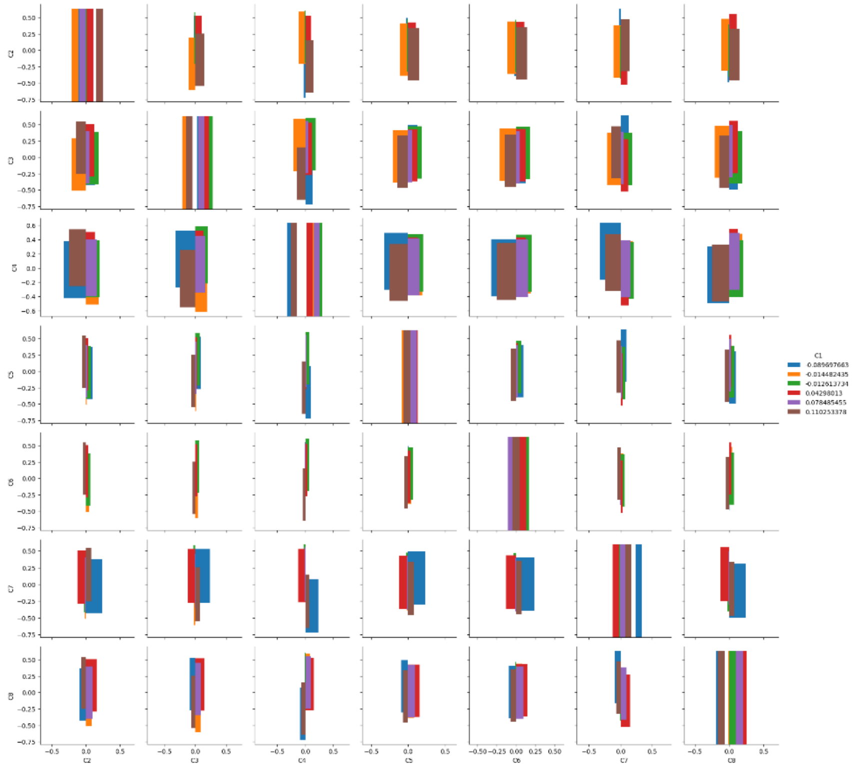

Fig 12. The weighted normalization values.

Finally, we compute the utility degree of each collection as shown in Fig 13. Then we ranked the alternatives in each collection as shown in Fig 14.

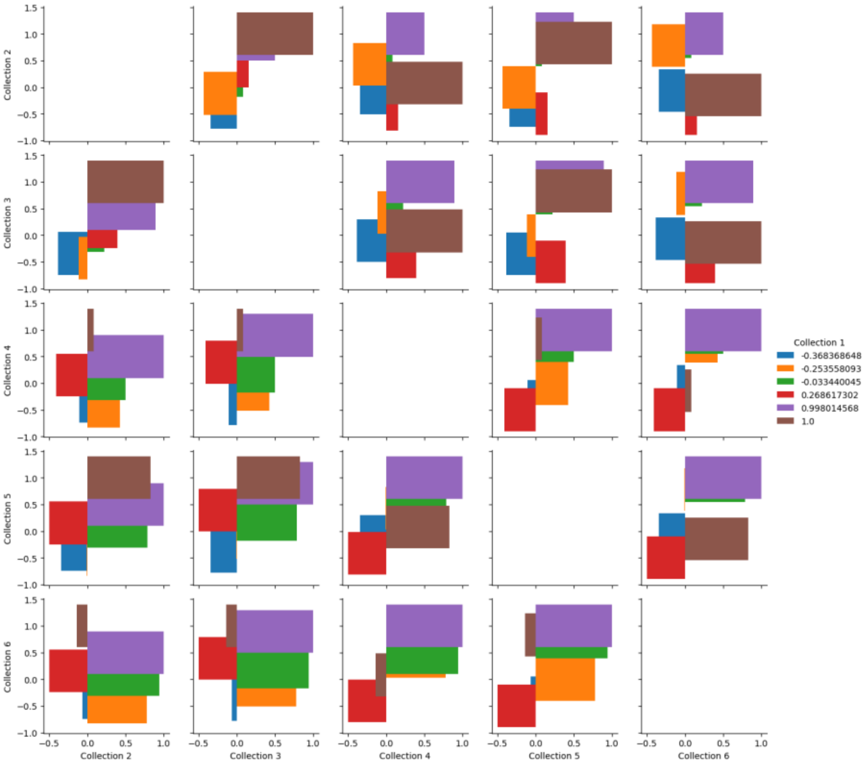

Fig 13. The utility degree of each collection.

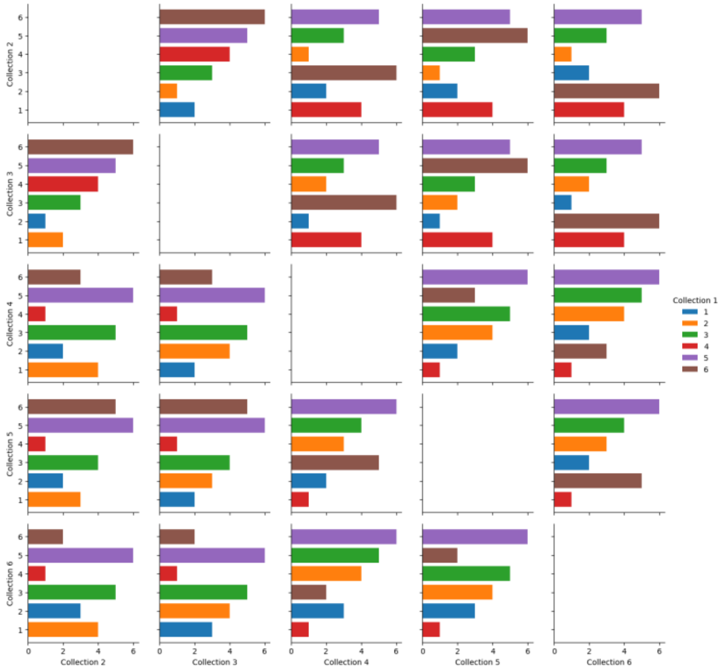

Fig 14. The ranks of each collection.

5. Conclusions

There is uncertainty everywhere. Most real-world issues that are often articulated in natural language are predicated on information that is vague, ambiguous, and/or only partially trustworthy. People naturally make judgments in a variety of settings, from straightforward to intricate. However, the effectiveness of people's decisions may be impacted if the information is unreliable. This paper addresses the current flaws of missing reliability measurements in quadripartitioned neutrosophic information by proposing a hybrid idea of QSVNZN set that conveys cognitive information with its appropriate reliability measures. A more manageable and efficient method of modeling the system and assisting with human decision-making is to use QSVNZNs, which indicate the selection-makers' level of confidence. We integrated the SuperHyperSoft set with the neutrosophic sets to dela with the different criteria and alternatives. we proposed six collections in the SuperHyperSoft set. Then we applied the ARAS method on these collections and then ranked the alternatives. The results show stability in the ranks of the alternatives under the SuperHyperSoft set and neutrosophic sets.

Acknowledgment

This work was supported by Domestic Visiting Scholar Program for Universities in Zhejiang Province.

References

[1] Z. Zhao *et al.*, "Evaluation of a data-driven intelligent waste classification system for scientific management of garbage recycling in a Chinese community," *Environ. Sci. Pollut. Res.*, vol. 30, no. 37,

pp. 87913–87924, 2023.

[2] T. Zhu, "A smart recycle sort network for garbage sorting," *Intell. Decis. Technol.*, vol. 18, no. 3, pp. 1981–1992, 2024.

[3] I. M. Hezam, A. Gamal, M. Abdel-Basset, and K. Sallam, "Facile and optimal evaluation model of intelligent waste collection systems based on the Internet of Things: a new approach toward sustainability," *Environ. Dev. Sustain.*, vol. 26, no. 5, pp. 12639–12677, 2024.

[4] Y. Zhao, Q. Wang, Y. Zang, and J. Wan, "Design of intelligent garbage collection system," in *International Conference on Applications and Techniques in Cyber Intelligence ATCI 2019: Applications and Techniques in Cyber Intelligence 7*, Springer, 2020, pp. 542–547.

[5] C. Sirawattananon, N. Muangnak, and W. Pukdee, "Designing of IoT-based smart waste sorting system with image-based deep learning applications," in *2021 18th international conference on electrical engineering/electronics, computer, telecommunications and information technology (ECTI-CON)*, IEEE, 2021, pp. 383–387.

[6] F. Smarandache, "Neutrosophic set-a generalization of the intuitionistic fuzzy set.," *Int. J. pure Appl. Math.*, vol. 24, no. 3, p. 287, 2005.

[7] K. Muniba, M. N. Jafar, A. Riffat, J. Mukhtar, and A. Saleem, "Climate Change Prediction Model using MCDM Technique based on Neutrosophic Soft Functions with Aggregate Operators," *Neutrosophic Syst. with Appl.*, vol. 21, pp. 25–35, 2024.

[8] A. Elsayed and M. Mohamed, "Comparative Analysis of Multi-Criteria Techniques in Neutrosophic Environment and their Applications to Economic Condition Assessment," *Neutrosophic Syst. with Appl.*, vol. 24, pp. 63–83, 2024.

[9] H. Wang, F. Smarandache, Y. Zhang, and R. Sunderraman, "Single valued neutrosophic sets," *Infin. study*, vol. 12, 2010.

[10] R. Chatterjee, P. Majumdar, and S. K. Samanta, "On some similarity measures and entropy on quadripartitioned single valued neutrosophic sets," *J. Intell. Fuzzy Syst.*, vol. 30, no. 4, pp. 2475–2485, 2016.

[11] L. A. Zadeh, "A note on Z-numbers," *Inf. Sci. (Ny).*, vol. 181, no. 14, pp. 2923–2932, 2011.

[12] G. Borah and P. Dutta, "Aggregation operators of quadripartitioned single-valued neutrosophic Z-numbers with applications to diverse COVID-19 scenarios," *Eng. Appl. Artif. Intell.*, vol. 119, p. 105748, 2023.

[13] T. Fujita and F. Smarandache, "A short note for hypersoft rough graphs," *HyperSoft Set Methods Eng.*, vol. 3, pp. 1–25, 2025.

[14] S. Rana, M. Saeed, M. Qayyum, and F. Smarandache, *Plithogenic subjective hyper-super-soft matrices with new definitions & local, global, universal subjective ranking model*. Infinite Study, 2020.

Received: Oct 1, 2024. Accepted: March 4, 2025