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Neutrosophic Z-Number and HyperSoft for Integrated Energy Supply System Performance Inference of Solar Energy and Cogenerations

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Abstract: The increasing global demand for sustainable energy solutions has led to the development of integrated energy supply systems that combine solar energy and cogeneration technologies. So, this study proposes a decision-making approach to evaluate The Energy Supply System Performance of Solar Energy and Cogenerations. Two methods are applied in this study, such as SIWEC to compute the criteria weights and EDAS method to rank the alternatives. These methods are used under the neutrosophic Z-number (NZN). We used the HyperSoft set to deal with various criteria and sub criteria. This study applied the NZN model with nine criteria and eight alternatives. Three experts can evaluate these criteria and alternatives. We applied the sensitivity analysis under nine different cases. The results showed that the ranks of the alternatives are stable in different cases.

Keywords: Neutrosophic Z-Number; HyperSoft; Solar Energy and Cogenerations; Energy Supply System.

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1. Introduction and Literature Review

The increasing global demand for sustainable energy solutions has led to the development of integrated energy supply systems that combine solar energy and cogeneration technologies. These hybrid systems aim to improve energy efficiency, reduce carbon emissions, and ensure a reliable and continuous power supply. Solar energy, as a clean and renewable resource, offers a sustainable alternative to fossil fuels, while cogeneration (or combined heat and power, CHP) maximizes energy utilization by simultaneously generating electricity and useful thermal energy. However, the performance of such integrated systems must be systematically evaluated to ensure optimal energy efficiency, economic feasibility, and environmental benefits[1], [2].

To assess the effectiveness of an integrated solar-cogeneration system, a comprehensive evaluation framework is required. Various factors, including energy efficiency, renewable energy utilization, carbon emissions reduction, system reliability, operational costs, scalability, and smart grid compatibility, must be considered. These criteria help determine the suitability and viability of different system configurations for various applications, such as residential, industrial, and commercial energy supply. Since different combinations of solar PV, solar thermal, and cogeneration technologies offer varying levels of performance, a structured multi-criteria decision-making (MCDM) approach is essential for effective evaluation[3], [4].

Several MCDM methods provide a systematic way to compare and rank alternative energy supply models based on multiple performance indicators. These methods facilitate data-driven decision-making by balancing technical, economic, and environmental aspects to identify the most efficient and sustainable system configuration. For instance, systems with high renewable energy utilization may have longer payback periods, while systems with lower operational costs might exhibit lower carbon emission reduction potential. By integrating MCDM techniques, policymakers and energy planners can optimize energy system designs that align with sustainability goals and economic constraints.

The future of integrated energy supply systems lies in continuous innovation and technological advancement. The incorporation of smart grid technologies, advanced energy storage solutions, and AI-driven energy management systems can further enhance the performance of solar-cogeneration systems. By conducting a comprehensive performance evaluation, stakeholders can ensure that integrated energy supply systems not only improve energy efficiency but also contribute to a more sustainable and resilient energy infrastructure. As the world transitions towards low-carbon energy solutions, the evaluation of such hybrid systems will play a crucial role in shaping the future of sustainable energy production[5], [6].

To represent a fuzzy value and a dependability metric in an uncertain and imprecise situation[7], Zadeh originally proposed a Z-number in 2011 as an extension of the fuzzy set notion[8]. An order pair of fuzzy numbers (N, M) with respect to an uncertain variable U make up the Z-number; component N is a fuzzy value of U, and component M is a reliability metric that is strongly associated with N[9]. The Z-number demonstrates the superiority of improving the fuzzy value's dependability in ambiguous and uncertain settings as compared to the conventional fuzzy set[10]. Consequently, Z-numbers have found utility in a variety of applications, including the study of stable strategies for evolutionary games, sensor data fusion, and decision making (DM)[11].

The Z-number loses the indeterminacy and falsity fuzzy values and reliability measures in the inconsistent, incomplete, and indeterminate environment, while being characterized by an order pair of fuzzy numbers (a fuzzy value and a reliability measure). While SNS (SVNS and INS) only include the truth, indeterminacy, and falsity membership degrees without considering their reliability measures, the Z-number is unable to express the hybrid information of the truth, indeterminacy, and falsity Z-numbers [12]. The truth, indeterminacy, and falsity Z-numbers may be used to convey the inconsistent and ambiguous knowledge and judgments of human cognitions if the Z-number is added to the neutrosophic idea. This is known as the neutrosophic Z-number (NZN) concept [13], [14].

In an uncertain context, Zadeh initially proposed a Z-number using a reliability measure and a fuzzy value. The fuzzy value's tight relationship to the dependability measure is its main feature. Nevertheless, the Z-number is devoid of reliability metrics and fuzzy values for indeterminacy and falsehood. The truth, indeterminacy, and falsity degrees define a single-valued neutrosophic set, however it does not have the reliability measures of these membership degrees. A neutrosophic Z-number (NZN) can be presented to convey the inconsistent, incomplete, and indeterminate knowledge and judgments of human cognitions in the actual world by using hybrid information of the truth, indeterminacy, and falsity Z-numbers.

There is no similarity measure of any NZN set in the body of extant research, even though it is a crucial mathematical tool for pattern identification and DM. Inspired by this notion, Jun Ye [15] offered cosine and cotangent similarity measures based on the weighted generalized distance of NZN sets after first proposing NZN sets and generalized distance and similarity measures between NZN sets. The suggested similarity metrics are then used to create an MCDM approach in the context of NZN sets.

The viability and logic of the suggested approach are illustrated with an example, and the comparative analysis then highlights the two main benefits: In addition to improving the reliability of DM problems, the established DM method based on the suggested similarity measures also demonstrates its superiority over current neutrosophic DM methods. (a) NZN enriches the neutrosophic information expression through the truth, indeterminacy, and falsity Z-numbers.

This paper's structure is built as follows: A NZN set, and its operational links with HyperSoft Sets are introduced in Sect. 2. In the context of NZN sets, an MCDM approach utilizing the suggested NZN is constructed in Sect. 3. The feasibility and effectiveness of the established DM method in the context of NZN sets are demonstrated in Sect. 4 using an illustrative example on the evaluation problem of MCDM. Conclusion is shown in Sect. 5

2. Neutrosophic Z-Number Sets (NZN)

With respect to an uncertain variable U, a Z-number is represented by an order pair of fuzzy numbers (N, M), where M is a reliability measure with respect to N and N is a fuzzy value of U. Consequently, it is devoid of both the falsehood and indeterminacy Z-number information. A NZN set is the extension of the Z-number that may be used to convey hybrid information of the truth, indeterminacy, and falsity Z-numbers [15].

Definition 1

The NZN can be defined as:

$$S_Z = \{(T(N,M)(u), I(N,M)(u), F(N,M)(u)) | u \in U\} \tag{1}$$

$$0 \leq T(N)(u) + I(N)(u) + F(N)(u) \leq 3 \tag{2}$$

$$0 \leq T(M)(u) + I(M)(u) + F(M)(u) \leq 3 \tag{3}$$

Definition 2

The component of NZN is presented as:

$$S_Z = \{(T(N,M), I(N,M), F(N,M))\} \tag{4}$$

$$S_Z = \{(TN, TM), (IN, IM), (FN, FM)\} \tag{5}$$

Definition 3

Let $S_{Z_1} = \begin{pmatrix} T_1(N,M), I_1(N,M), F_1(N,M) \\ ((TN_1, TM_1), (IN_1, IM_1), (FN_1, FM_1)) \end{pmatrix}$ and $S_{Z_2} = \begin{pmatrix} T_2(N,M), I_2(N,M), F_2(N,M) \\ ((TN_2, TM_2), (IN_2, IM_2), (FN_2, FM_2)) \end{pmatrix}$ be two NZNs and their operations can be defined as:

$$S_{Z_1} \sqsupseteq S_{Z_2} \Leftrightarrow TN_1 \geq TN_2, TM_1 \geq TM_2, IN_1 \leq IN_2, IM_1 \leq IM_2, FN_1 \leq FN_2, FM_1 \leq FM_2 \tag{6}$$

$$S_{Z_1} = S_{Z_2} \Leftrightarrow S_{Z_1} \sqsupseteq S_{Z_2} \; and \; S_{Z_2} \sqsupseteq S_{Z_1} \tag{7}$$

$$S_{Z_1} \cup S_{Z_2} = \begin{pmatrix} (TN_1 \vee TN_2, TM_1 \vee TM_2), \\ (IN_1 \wedge IN_2, IM_1 \wedge IM_2), \\ (FN_1 \wedge FN_2, FM_1 \wedge FM_2) \end{pmatrix} \tag{8}$$

$$S_{Z_1} \cap S_{Z_2} = \begin{pmatrix} (TN_1 \wedge TN_2, TM_1 \wedge TM_2), \\ (IN_1 \vee IN_2, IM_1 \vee IM_2), \\ (FN_1 \vee FN_2, FM_1 \vee FM_2) \end{pmatrix} \tag{9}$$

$$(S_{Z_1})^c = \begin{pmatrix} (FN_1, FM_1), \\ (1 - IN_1, 1 - IM_1), \\ (TN_1, TM_1) \end{pmatrix} \tag{10}$$

Definition 4

We can define the HyperSoft (HS) set as

Let X be the universal set and P(X) is the power set of X. Let $G^1, G^2, G^3, \dots G^n$ be a set of criteria for $n \geq 1$and the corresponding values are:

$S^1, S^2, S^3, \dots S^n$, $S^i \cap S^j = \emptyset \; for \; i \neq j$ and the relation $S^1 \times S^2 \times S^3 \dots . S^n = A$

A pair (F, A) is a NHS over X where $(F, S^1 \times S^2 \times S^3 \dots . S^n) = S^1 \times S^2 \times S^3 \dots . S^n \to P(X)$ with $F(S^1 \times S^2 \times S^3 \dots . S^n) = \{T(F(A)), I(F(A)), F(F(A))\}$ where T,I, and F refer to truth, indeterminacy, and falsity functions[16], [17].

3. NZN- SIWEC-EDAS Approach

This section shows the steps of the proposed approach. We used two methods, such as SIWEC method to compute the criteria weights and EDAS method to rank the alternatives. These methods are used under the NZN to deal with vague and uncertainty information.

Determine the importance of the criteria.

The rate of experts and decision makers are evaluated the criteria to determine their importance.

Build the decision matrix.

Experts build the decision matrix based on their opinions.

Normalize the decision matrix

$$u_{ij} = \frac{x_{ij}}{\max x_{ij}} \tag{11}$$

Computing the standard deviation

Multiply the standard deviation by the normalization values.

$$d_{ij} = u_{ij} \times \text{standard deviation} \tag{12}$$

Compute the sum of each row

$$r_j = \sum_{j=1}^{n} d_{ij} \tag{13}$$

Compute the criteria weights.

$$W_j = \frac{r_j}{\sum_{j=1}^{n} r_{ij}} \tag{14}$$

NZN-EDAS Method

We apply the steps of the EDAS method to rank the alternatives.

Determine the average solution of each criterion

$$V_j = \frac{\sum_{i=1}^{m} x_{ij}}{m} \tag{15}$$

Compute the positive distance from average and negative distance from average

$$PV_{ij} = \frac{\max\left(0, \left(x_{ij} - V_j\right)\right)}{V_j} \tag{16}$$

$$CV_{ij} = \frac{\max\left(0, \left(V_j - x_{ij}\right)\right)}{V_j} \tag{17}$$

And for cost criteria

$$PV_{ij} = \frac{\max\left(0,(V_j - x_{ij})\right)}{V_j} \tag{18}$$

$$CV_{ij} = \frac{\max\left(0,(x_{ij} - V_j)\right)}{V_j} \tag{19}$$

Compute the weighted PV_{ij} and CV_{ij}

$$SPV_{ij} = \sum_{j=1}^{n} PV_{ij}\, w_j \tag{20}$$

$$SCV_{ij} = \sum_{j=1}^{n} CV_{ij}\, w_j \tag{21}$$

Compute the weighted normalized PV_{ij} and CV_{ij}

$$NSPV_{ij} = \frac{SPV_{ij}}{\max(SPV_{ij})} \tag{22}$$

$$NSCV_{ij} = \frac{SCV_{ij}}{\max(SCV_{ij})} \tag{23}$$

Compute the appraisal score

$$F_i = \frac{NSCV_{ij} + NSPV_{ij}}{2} \tag{24}$$

4. An Illustrative Example

This section shows the results of the proposed approach to compute the criteria weights and ranking the alternatives. Three experts evaluated the criteria and alternatives. We gathered nine criteria and eight alternatives to be evaluated. The criteria of this study presented as: Smart Grid Compatibility (Limited, Moderate, High), Operational Cost (High, Moderate, Low), Payback Period (Long, Moderate, Short), Energy Efficiency (Low, Moderate, High), Scalability and Adaptability (Limited, Moderate, Flexible), System Reliability (Low, Moderate, High), Renewable Energy Utilization (Low, Moderate, High), Energy Storage Capability (Weak, Moderate, Strong), Carbon Emissions Reduction (Ineffective, Moderate, Effective). The alternatives of this study are presented as: Solar PV with Wind, Standalone Solar PV System, Solar PV with Biomass Cogeneration, Solar Thermal with Steam Turbine Cogeneration, Hybrid Solar PV, Solar PV with Gas-Based Cogeneration, Fully Integrated Multi-Source System, Solar PV with Geothermal Cogeneration

We build the decision matrix by using the NZN as shown in Table 1.

Eq. (11) is used to normalize the decision matrix as shown in Table 2.

We compute the standard deviation

We multiply the standard deviation by the normalization values using Eq. (12).

Then we compute the sum of each row using Eq. (13).

Then we compute the criteria weights using Eq. (14) as $C_1 = 0.088$, $C_2 = 0.111$, $C_3 = 0.091$, $C_4 = 0.144$, $C_5 = 0.103$, $C_6 = 0.115$, $C_7 = 0.138$, $C_8 = 0.092$, $C9_1 = 0.118$.

Table 1. The values of NZNs.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.76,0.75),(0.2,0.7),(0.1,0.8))
A_2	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))
A_3	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))
A_4	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))
A_5	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.8,0.8),(0.1,0.8),(0.2,0.8))
A_6	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.76,0.75),(0.2,0.7),(0.1,0.8))
A_7	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.8,0.8),(0.1,0.8),(0.2,0.8))
A_8	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.88,0.75),(0.2,0.8),(0.2,0.8))
A_2	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))
A_3	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))
A_4	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))
A_5	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.8,0.8),(0.1,0.8),(0.2,0.8))
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	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.76,0.75),(0.2,0.7),(0.1,0.8))
A_2	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))
A_3	((0.8,0.8),(0.1,0.8),(0.2,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.65,0.9),(0.2,0.7),(0.2,0.8))
A_4	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))
A_5	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))

A_6	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.85,0.75),(0.1,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.7,0.8),(0.2,0.7),(0.2,0.85))
A_7	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.65,0.9),(0.2,0.7),(0.2,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.76,0.75),(0.2,0.7),(0.1,0.8))	((0.7,0.8),(0.2,0.7),(0.2,0.85))
A_8	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.88,0.75),(0.2,0.8),(0.2,0.8))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.6,0.85),(0.1,0.8),(0.2,0.9))	((0.7,0.8),(0.2,0.7),(0.2,0.85))	((0.88,0.75),(0.2,0.8),(0.2,0.8))

Table 2. The normalization values.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	0.976584	0.922761	0.944215	1	0.973528	0.943384	0.904523	0.950413	0.943384
A_2	0.96832	0.975735	0.971074	0.904523	0.955068	1	1	0.977961	0.904523
A_3	0.950413	0.948052	0.944215	1	0.940439	0.929313	0.945729	0.983127	0.918593
A_4	1	0.950103	0.962466	0.943384	0.996169	0.929983	0.904523	1	1
A_5	0.972107	0.955571	1	0.956449	1	0.917923	0.942044	0.939394	0.944724
A_6	0.929752	1	0.955234	0.936013	0.957854	0.954439	0.904523	0.943526	0.931323
A_7	0.96832	0.932331	0.990014	0.924623	0.945315	0.941039	0.929983	0.976584	0.944724
A_8	0.971074	0.927546	0.950413	0.953099	0.990944	0.913903	0.909213	0.964187	0.943384

NZN-EDAS Method

Based on the neutrosophic HyperSoft set, three experts are using the values of the criteria. The values are used as: {High, Moderate, Long, High, Flexible, High, Moderate, Strong, Effective}

Eq. (15) is used to determine the average solution of each criterion

Eqs. (16-19) are used to compute the positive distance from average and negative distance from average as shown in Fig 1 and Fig 2.

Eqs. (20 and 21) are used to compute the weighted PV_{ij} and CV_{ij} as shown in Fig 3 and Fig 4.

Eqs. (22 and 23) are used to compute the weighted normalized PV_{ij} and CV_{ij} as shown in Fig 5.

Eq. (24) sis used to compute the appraisal score as shown in Fig 6. Then we ranked the alternatives as shown in Fig 7.

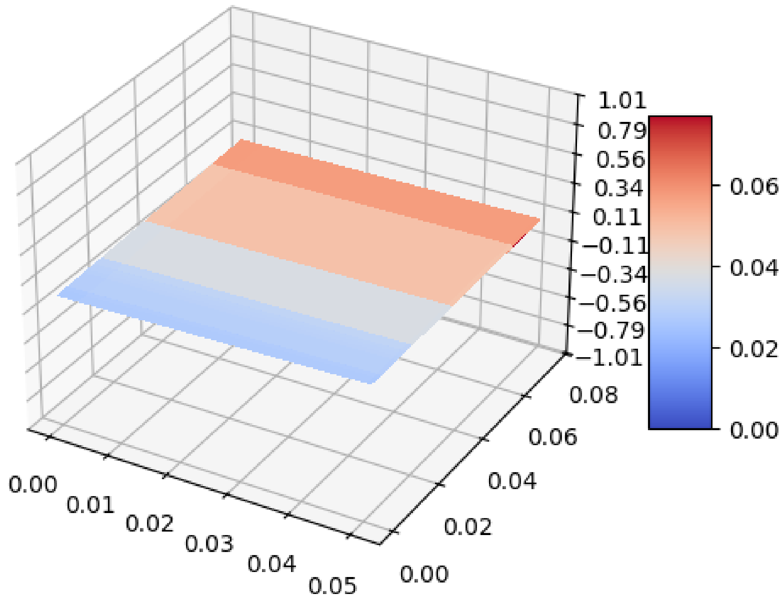

Fig 1. The values of PV_{ij}.

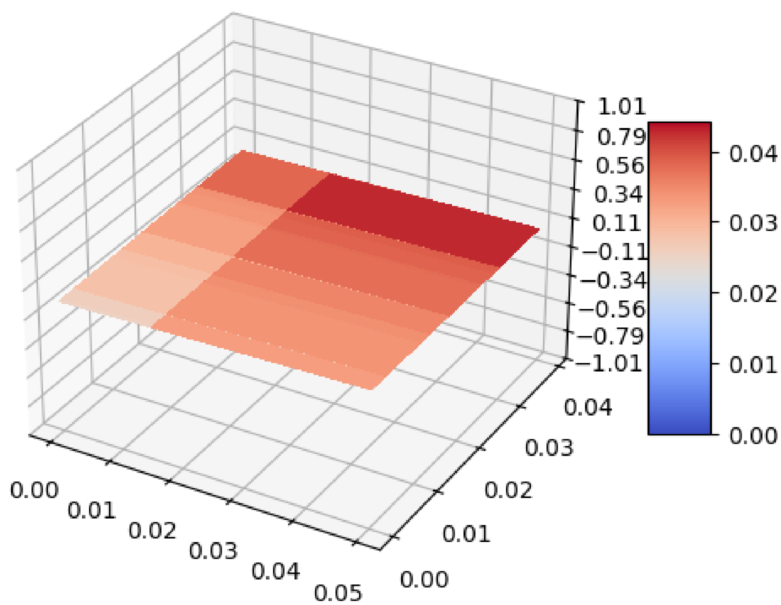

Fig 2. The values of CV_{ij}.

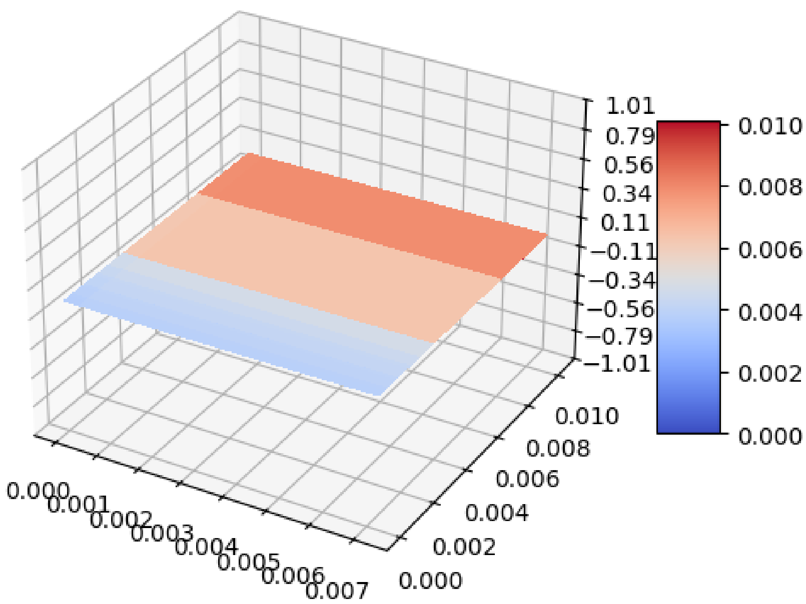

Fig 3. The weighted values of PV_{ij}.

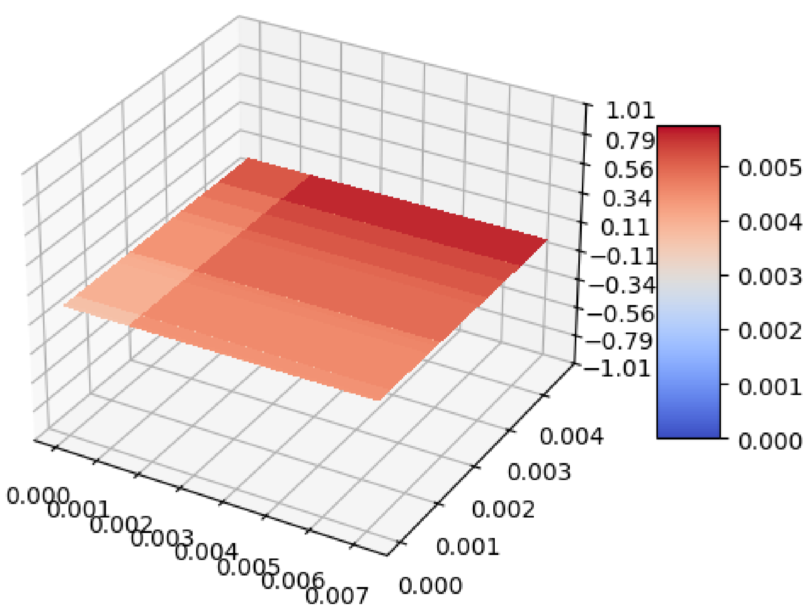

Fig 4. The weighted values of CV_{ij}.

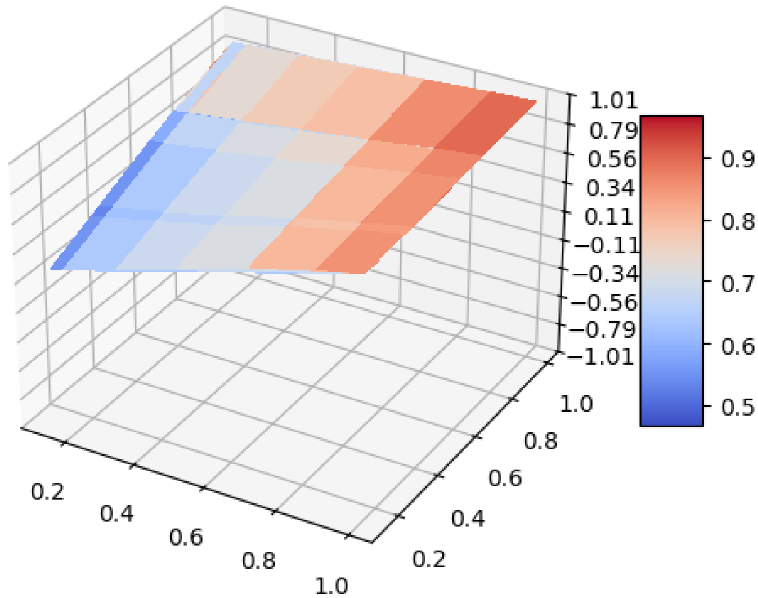

Fig 5. The weighted normalized PV_{ij} and CV_{ij}.

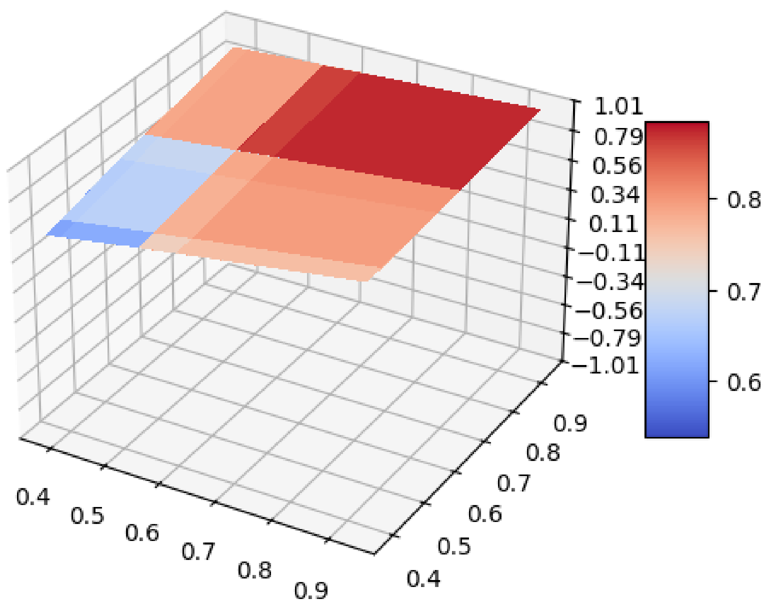

Fig 6. The appraisal values.

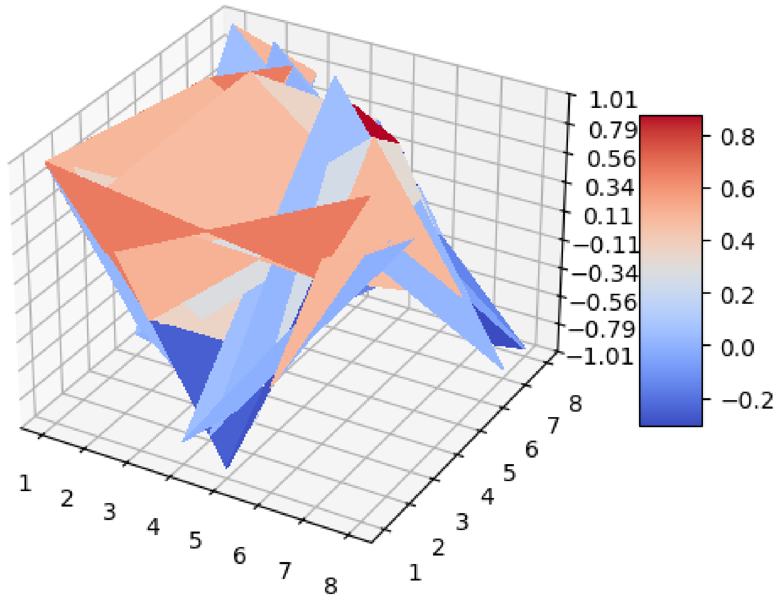

Fig 7. The rank of alternatives.

Sensitivity analysis

This part shows the aims of the sensitivity analysis. We applied the sensitivity analysis to show the stability of the ranks under different values. This study proposed nine cases in different criteria weights. We increase the criteria weights by 15%, then we decrease other criteria. These cases can influence the ranks of the alternatives. Fig 8 shows the nine cases in the criteria weights to show the ranks of alternatives.

Then we applied the EDAS method under these cases. The results show alternative 2 is the best and alternative 7 is the worst. The results of the sensitivity analysis show the proposed approach ranks are stable under different cases. Fig 9 shows the different ranks of the alternatives under different cases.

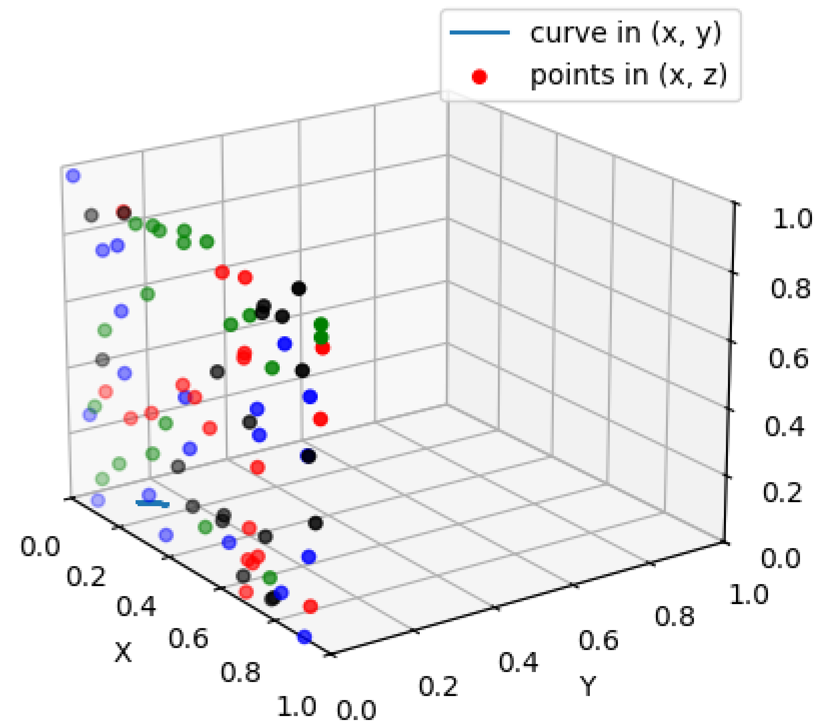

Fig 8. The different criteria weights.

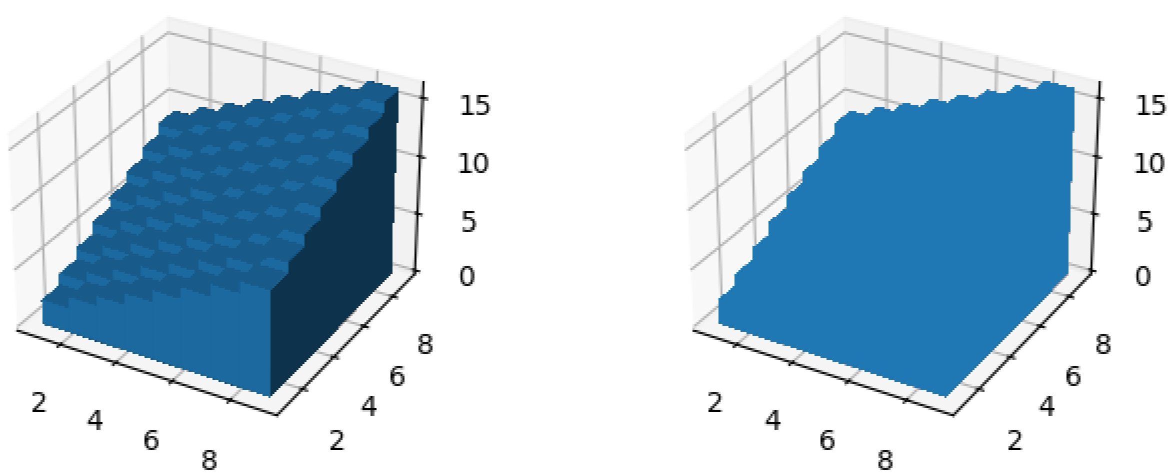

Fig 9. The different ranks of the alternatives.

5. Conclusions and Future Works

The suggested approaches were used to build an MCDM approach in the context of NZN sets. Lastly, to demonstrate the usefulness and rationale of the developed MCDM technique in the context of NZN sets, it was applied to an example evaluation MCDM problem. Two MCDM methods are used in this study, such as SIWEC to compute the criteria weights and the EDAS method to rank the alternatives. This study illustrated the primary benefits of the MCDM approach developed within the context of NZN sets, as well as the information expression and similarity metrics of NZN sets, through comparison analysis. MCDM approach and NZN are used with the HyperSoft set to deal with different criteria and sub criteria. Nonetheless, the developed MCDM approach based on the suggested NZN not only improves the DM issues' logic and dependability, but it also demonstrates its superiority over the current neutrosophic MCDM approaches. The sensitivity analysis results show that the proposed approach ranks are stable under nine cases.

In terms of future research, we will apply the NZN sets to further applications, including clustering analysis, pattern recognition, and medical diagnostics in the context of NZN sets. The MCDM problem can be solved by different MCDM methods to compute the criteria weights and rank the alternatives.

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