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Abstract. Conservation of natural resources like water, soil, and biodiversity is necessary for ecological balance and human survival. This article aims to identify potential ways to conserve natural resources while maintaining a balance between ecology and human survival. An integrated neutrosophic CRiteria Importance Through Intercriteria (CRITIC)-Multi-Atributive Ideal-Real Comparative Analysis (MAIRCA) approach is developed to handle uncertain and inconsistent information. The linguistic assessments of the criteria are quantified through single-valued neutrosophic sets (SVNSs). The CRITIC method evaluates the criteria weights to avoid subjective and biased assessments. The MAIRCA approach is improved in a neutrosophic context to identify the ranking of the alternatives. The combined neutrosophic CRITIC-MAIRCA approach determines the best way to preserve natural resources. The proposed method reveals that the most favourable ways to conserve natural resources are through research and monitoring, while the last option is sustainable practices. Comparison and sensitivity discussions of the proposed approach are conducted to check its consistency and robustness.

Keywords: Single-valued neutrosophic set; MAIRCA; CRITIC; MCDM; Objective weights; Natural resource conservation

1. Introduction

Managing and preserving water, soil, forests, and wildlife to guarantee their continued availability for future generations is known as natural resource conservation [1]. Protecting areas, restoring damaged ecosystems, and implementing sustainable practices are all part of it. Protecting natural resources aims to satisfy present-day human needs while preserving ecological balance by adopting laws and increasing public awareness [1]. Over-exploitation can result in species extinction, environmental damage, and resource depletion without conservation. Pollination, clean air, and water filtration are examples of ecosystem services maintained when these resources are protected [2]. Rich nations consume six times more resources and cause ten times more climate damage than lower-income countries. According to the survey, worldwide use of natural resources is expected to increase by 60 percent by 2060 compared to 2020 levels [3]. Therefore, it is necessary to address this issue with the utmost priority of conserving the elements of natural resources.

A multifaceted strategy is needed to address these issues, including increasing public awareness, creating sustainable practices, enforcing laws, and encouraging international cooperation. In this situation, decisions are influenced by various factors that cannot be easily quantified or compared directly. Various Multi-criteria decision-making (MCDM) methods, including outranking approaches, reference point approaches, and utility and value theory, are implemented to promote the conservation and management of natural resources [4, 5]. However, these crisp MCDM approaches need to deal with a qualitative assessment of the associated factors in natural resource conservation. In this regard, it becomes necessary to formulate an improved MCDM methodology to deal with vague and indeterminate descriptions of the criteria [6, 7]. Therefore, this article aims to introduce a completely flexible MCDM method for analyzing the available strategies for natural resource conservation and, if necessary, generating a new strategy. In conclusion, the objectives of this article include:

- ☐ To formulate an integrated MCDM method that can deal with indeterminate and incomplete information.
- ☐ To determine the objective criteria weight for avoiding subjective and biased assessment.
- ☐ To formulate an MCDM framework on natural resource conservation by identifying strategies and their related goals.
- ☐ To identify the executive strategy through the implementation of proposed MCDM methods

To reach the mentioned objectives, this article contributes as follows:

- Proposed an integrated neutrosophic Multi-Atributive Ideal-Real Comparative Analysis (MAIRCA) approach to address uncertain and indeterminate MCDM issues.
- Implemented the CRiteria Importance Through Intercriteria (CRITIC) approach to determine the objective criteria weights.
- Formulate an MCDM framework with six strategies and eleven criteria on natural resource conservation.
- Illustrate the proposed method numerically to select the best strategy for natural resource conservation.
- Established the proposed neutrosophic CRITIC-MAIRCA approach through comparison and sensitivity analysis.

To track the remaining article, the following section provides a brief literature study on the fuzzy MAIRCA approach and MCDM application on natural resource conservation. The proposed methodology with preliminary discussion on single valued neutrosophic sets (SVNSs) is demonstrated in Section 3. A framework on strategy selection to conserve natural resources is formulated in Section 4. Section 5 contains a comparison and sensitivity analysis-based numerical demonstration of the proposed approach. Section 6 accomplishes the article with some insights and findings.

2. **Literature review**

MAIRCA [8] simultaneously analyzes several competing criteria to provide an organized and methodical approach to decision-making. MAIRCA offers a fair evaluation of different options and their associated trade-offs by quantifying the criteria and lowering subjective biases through objective assessment. Though MAIRCA is helpful in handling multi-criteria, it cannot quantify qualitative assessment. Therefore, introducing fuzzy sets into the MCDM problem is a significant development to counter the uncertain decision-making process. It improves the capacity to handle ambiguity, imprecision, and qualitative aspects of decision criteria, resulting in decision-making processes that are more adaptable, practical, and focused on people. Chatterjee et al. [9] study the MAIRCA approach to assess the efficiency of environmentally friendly suppliers in the electronics sector. Trung et al. [10] and Nguyen et al. [11] compare the effectiveness of the MAIRCA approach with other MCDM methods. Hadian et al. [12] conducted a study that specifically examined flood susceptibility assessment using the MAIRCA approach. Maruf and Özdemir [13] work on tourism websites ranking by the MAIRCA method.

2.1. *Fuzzy MAIRCA approach*

The introduction of two membership degrees of intuitionistic fuzzy sets (IFSs) [14], Pythagorean fuzzy sets (PFSs) [15], and fermatean fuzzy sets (FFSs) [16] are the primary extensions of fuzzy sets that represent the acceptance and rejection of ambiguous information. However, these extensions fail to represent the indeterminacy of DM in quantifying inconsistent and hesitant data. The neutrosophic sets [17] are defined by membership, non-membership, and indeterminacy, which independently lies in (0, 1) and can represent the indeterminacy in decision-making. The significance of neutrosophic fuzzy logic in decision-making has led to considerable advancements in SVNSs [18, 19]. Researchers developed their idea of neutrosophic fuzzy to analyze more conveniently to handle fuzziness [20, 21]. The fuzzy MAIRCA approach is utilized in several applications like defense system strategy selection [22], analysis of sustainable methods for treating wastewater [23], choosing a COVID-19 vaccination during the coronavirus pandemic [24], occupational health and environmental risk assessment [25], assessment of occupational risks [26]. Haq et al. [27] use the MAIRCA technique throughout an interval neutrosophic framework to determine the most suitable sustainable material for Human-Powered Aircraft.

The CRITIC [28] method establishes the objective weights of the criteria through the inter-criteria relationship established by statistical measures. The objectivity and certainty of selecting the best alternatives can be organized by combining MAIRCA and CRITIC approaches.

2.2. *MCDM in natural resource conservation*

The effective management and protection of natural resources have emerged as significant problems in biodiversity and ecological systems. Academic researchers are demonstrating commendable achievement in the domain of natural resource conservation. The literature has a large number of works about the same. The research by Regan et al. [29] examines the complete criteria for assessing biodiversity in forest conservation planning. Mendoza and Martins [30] examine the application of MCDM for natural resource management, with a specific focus on forest ecosystems. Hassangavyar et al. [31] investigate the methods used to mitigate soil erosion using a comparison of Vise Kriterijumska Optimizajica (VIKOR) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) models. Yang et al. [32] examine the connection between environmental preservation and managing natural assets through the VIKOR approach. Fuzzy MCDM techniques make a significant contribution to the preservation of natural resources. Researchers used several different applications of fuzzy MCDM for various reasons relating to the conservation of resources. Chen et al. [33] use the fuzzy Analytic Hierarchy Process (AHP) methodology to determine the optimal environment-watershed design. Narayanamoorthy et al. [34] conduct a thorough analysis of the selection of appropriate biomass conservation strategies using the fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. Table 1 summarizes the case studies conducted on natural resource conservation.

TABLE 1. Natural resource conservation: Fuzzy decision-making.

Benchmark	Fuzziness	Application	Contributor
AHP, WASPAS		Energy, deforestation, biodiversity	[35]
WASPAS	TFN	Climate change mitigation	[36]
AHP	TFN	Watersheds for conservation measures	[37]
AHP	TFN	Soil erosion conservation	[38]
VIKOR	TFN	Coastal areas conservation	[39]
TOPSIS	TFN	Forest conservation	[40]
TOPSIS	Trapezoidal fuzzy	Water resources	[41]
CoCoSo	Fermatean Fuzzy	Water save	[42]
MARCOS		Solar cite location	[43]
TOPSIS	Hesitant fuzzy set	Energy policy	[44]

It is evident from Table 1 that the researchers primarily used TFN for uncertainty representation while AHP, WASPAS, and TOPSIS dominate in the MCDM approaches. The applications of these fuzzy approaches mainly cover specific conservation, such as energy, deforestation, watersheds, soil, and forests.

2.3. *Research gap*

Through the pertinent literature review on the MAIRCA approach in fuzzy environments and MCDM application for natural resource conservation, we have identified the following as the progressive research area:

- ◇ To conserve natural resources, it is more meaningful to consider all aspects rather than a specific goal. Specific conservation may not be affected due to the interlinked properties of the elements related to natural resources.
- ◇ There needs to be more fuzzy decision-making approaches in natural resource conservation. The existing approaches only consider basic fuzzy sets for representing uncertainty, which may miss the hesitancy component of a decision expert.

- ◇ The researchers often need to pay more attention to the criteria weight determination procedure and deploy subjective assessment in this case. Hence, employing an objective assessment of the criteria is necessary to avoid subjective assessments and biases.
- ◇ The neutrosophic extension of the MAIRCA approach is available in the literature, but the neutrosophic MAIRCA was not combined with the CRITIC approach to produce a combined MCDM method.

3. Material and method

This section provides preliminary information on SVNSs and the proposed methodology.

3.1. *Preliminaries*

Definition 3.1. [17] An SVNS is represented by $A = (x,\ \varphi_A(x),\ \varpi_A(x),\ \varrho_A(x)|x \in X)$ on a fixed set X, where $\varphi_A(x),\ \varpi_A(x),\ \varrho_A(x) \in [0,\ 1]$ are degrees of membership, non-membership, and indeterminacy of the element $x \in X$ to the set A, respectively. For simplicity, $A = (\varphi_A,\ \varpi_A,\ \varrho_A)$ is used as single-valued neutrosophic number (SVNE).

Definition 3.2. [45] Let $A_1 = (x,\ \varphi_1,\ \varpi_1,\ \varrho_1)$ and $A_2 = (x,\ \varphi_2,\ \varpi_2,\ \varrho_2)$ be two SVNEs and $\lambda \geq 0$, the arithmetic operations are defined as follows:

$$A_1 \bigoplus A_2 = (\varphi_1 + \varphi_2 - \varphi_1.\varphi_2, \varpi_1\varpi_2, \varrho_1\varrho_1)$$
$$A_1 \bigotimes A_2 = (\varphi_1.\varphi_2,\ \varpi_1 + \varpi_2 - \varpi_1\varpi_2,\ \varpi_1 + \varpi_2 - \varpi_1\varpi_2,\ \varrho_1\varrho_1)$$
$$\lambda A_1 = (1 - (1 - \varphi_1)^\lambda,\ \varpi_1^\lambda,\ \varrho_1^\lambda)$$

Definition 3.3. [46] **Score function of SVNS:** Let $A = (x,\ \varphi_A(x),\ \varpi_A(x),\ \varrho_A(x)|x \in X)$ be a SVNS, then the score function of A is

$$\mathcal{SC}(A) = \frac{3 + \varphi_A(x) - 2.\varpi_A(x) - \varrho_A(x)}{4} \tag{1}$$

Let $\mathcal{SC}(A_1)$ and $\mathcal{SC}(A_2)$ be the score functions of two SVNEs A_1 and A_2 respectively, then

(i) If $\mathcal{SC}(A_1) \geq \mathcal{SC}(A_2)$ then $A_1 \geq A_2$
(ii) If $\mathcal{SC}(A_1) \leq \mathcal{SC}(A_2)$ then $A_1 \leq A_2$

3.2. *Proposed methodology*

In a neutrosophic context, this section develops a decision-making technique that employs the CRITIC and MAIRCA approaches to address imprecise MCDM problems. The suggested technique includes the following steps:

Step 1:: Formulate an MCDM issue with 'm' options $\mathcal{N} = \{\mathcal{N}_1,\ \mathcal{N}_2,\ ...,\ \mathcal{N}_m\}$ and 'n' criteria $\mathcal{R} = \{\mathcal{R}_1,\ \mathcal{R}_2,\ ...,\ \mathcal{R}_n\}$, where beneficiary and non-beneficiary criteria are denoted by $\mathcal{R}_{\mathcal{B}}$ and $\mathcal{R}_{\mathcal{NB}}$, respectively such that $\mathcal{R}_{\mathcal{B}} \cup \mathcal{R}_{\mathcal{NB}} = \mathcal{R}$ and $\mathcal{R}_{\mathcal{B}} \cap \mathcal{R}_{\mathcal{NB}} = \emptyset$.

Step 2:: Gather opinions of the DM using the seven-point linguistic scale provided in Table 2 to formulate a neutrosophic decision matrix $\mathrm{D} = (\S_{ij})_{m\times n}$, where $\S_{ij} = (\Upsilon_{ij}, \aleph_{ij}, \daleth_{ij})$ such that Υ_{ij} is membership degree, $\aleph_{ij}$ is non-membership degree, and $\daleth_{ij}$ is indeterminacy degree.

Table 2. Scale for criteria assessment.

Linguistic terms	SVNS (Υ, $\aleph$, $\daleth$)
Highly Oppose (HO)	(0.01, 0.75, 0.35)
Oppose (O)	(0.25, 0.55, 0.30)
Slightly Oppose (SO)	(0.30, 0.45, 0.25)
Neutral (N)	(0.50, 0.35, 0.20)
Slightly Favour (SF)	(0.75, 0.25, 0.15)
Favour (F)	(0.90, 0.15, 0.10)
Highly Favour (HF)	(0.99, 0.01, 0.01)

Step 3:: Determine the preference degree ($\mathcal{P}_{A_i}$) of the alternatives according to DM. Since the primary presumption of DM is unbiased about the alternatives, hence

$$\mathcal{P}_{A_i} = \frac{1}{m},\ \sum_{i=1}^{m} \mathcal{P}_{A_i} = 1$$

Step 4:: Criteria weight determination using the CRITIC method.

Step 4.1:: Evaluate crisp decision matrix from neutrosophic decision matrix D using equation (1).

Step 4.2:: Compute the criteria' respective standard deviations as follows: $\sigma_j = \sqrt{\frac{1}{m}\sum_{i=1}^{m}\left(\S_{ij} - \overline{\S_i}\right)^2},\ j = 1(1)n.$

Step 4.3:: Calculate the linear correlation coefficient of every element of crisp decision matrix as $\rho_{ij} = \frac{\sum_{j=1}^{n}(\S_{ij}-\overline{\S_i})((\S_{kj}-\overline{\S_k})}{\sqrt{\sum_{j=1}^{n}(\S_{ij}-\overline{\S_i})^2((\S_{kj}-\overline{\S_k})^2}}$

Step 4.4:: Determine key indicators of each criterion as:

$$\text{II}_j = \sigma_j . \sum_{i=1}^{m}(1 - \rho_{ik}) \tag{2}$$

and weights as

$$\omega_j = \frac{\text{II}_j}{\sum_{j=1}^{n} \text{II}_j}. \tag{3}$$

Step 5:: Compute the theoretical evaluation matrix $\mathcal{T}_P = (\text{t}_{p_{ij}})_{m\times n}$ such that $\text{t}_{p_{ij}} = \omega_j \mathcal{P}_{A_i}$.

Step 6:: Determination of real evaluation matrix $\mathcal{T}_r = (\text{t}_{r_{ij}})_{m\times n}$ from equations (4) and (5).

(i) For beneficiary criteria

$$\text{t}_{r_{ij}} = \text{t}_{p_{ij}} \times (\frac{\S_{ij} - \S_i^-}{\S_i^+ - \S_i^-}) \tag{4}$$

(ii) For non-beneficiary criteria

$$\text{t}_{r_{ij}} = \text{t}_{p_{ij}} \times (\frac{\S_{ij} - \S_i^+}{\S_i^- - \S_i^+}) \tag{5}$$

where $\S_i^+ = \max_i(\S_{ij})$ and $\S_i^- = \min_i(\S_{ij}),\ i = 1(1)m$.

Step 7:: Compute the overall gap matrix $\mathcal{G} = (\text{g}_{ij})_{m\times n}$, where $\text{g}_{ij} = \text{t}_{p_{ij}} - \text{t}_{r_{ij}}$.

Step 8:: Determine the total of the criterion function $(mathcalQ_i)$ for every option derived from equation (6).

$$\mathcal{Q}_i = \sum_{j=1}^{n} \text{g}_{ij},\ i = 1(1)n. \tag{6}$$

Step 9:: Determine alternate ranking based on the decreasing order of the criterion function sum $(\mathcal{Q}_i)$.

4. Natural resource conservation via MCDM problem

The criteria of natural resource conservation and the strategies to conserve are identified in this section.

4.1. *Identification of strategies alternatives*

In order to maintain sustainable use for present and future generations, it is necessary to put strategies in place to protect ecosystems, biodiversity, and natural processes. The following are some crucial tactics that are frequently used to protect natural resources:

Protected areas and conservation reserves [47, 48] ($\mathcal{N}_1$):: Establishing designated areas where human activities are limited to protect biodiversity, habitats, and ecosystem functions includes biosphere reserves, marine protected areas, national parks, and wildlife sanctuaries.

Sustainable resource management [49] ($\mathcal{N}_2$):: Preserving natural resources while satisfying present demands without jeopardizing the capability of upcoming generations to satisfy their own. Sustainable practices in agriculture, fisheries management, and forestry, such as organic farming and agroforestry, are exemplified by measures like protected breeding areas, quotas, and selective logging and reforestation.

Biodiversity conservation [50] ($\mathcal{N}_3$):: Safeguarding an ecosystem's species diversity and genetic diversity, among other aspects of its diversity and variability. A few instances include conservation breeding initiatives for endangered species, species reintroduction initiatives, and habitat restoration and protection initiatives.

Ecosystem restoration [51] ($\mathcal{N}_4$):: Revitalization is the process of restoring the biodiversity and ecological functionality of harmed or destroyed ecosystems. Reforestation of degraded land, rehabilitation of coral reefs, and restoration of rivers, as well as wetland habitats, are a few examples.

Climate change adaptation and mitigation [52] ($\mathcal{N}_5$):: Employing adaptation of climate change mitigation techniques on ecosystems and natural resources while lowering greenhouse gas emissions. A few examples are implementing carbon sequestration projects (e.g., afforestation and mangrove restoration) and creating climate-resilient ecosystems.

Research and monitoring [53] ($\mathcal{N}_6$):: Assessing the condition of natural resources, identifying threats, and assessing the efficacy of conservation strategies through scientific research and monitoring programs. Studies on the ecological impacts caused by people, biodiversity surveys, and ecological monitoring programs are a few examples.

4.2. *Defining criteria*

Several variables influence the conservation and preservation of resources. These features above are considered to be essential factors for the conservation of natural resources. However, further study focuses on the specific criteria used to assess the rehabilitation and preservation of natural resources. The present study has effectively identified an array of eleven significant elements that are described in Table 3.

Table 3. Criteria description.

Criteria	Description	Symbol
Ecological Impact [54]	Consider biodiversity, ecosystem services, habitat quality, and climate change resilience when evaluating each strategy	$\mathcal{R}_1$
Economic Costs [55, 56]	Examine the financial effects of every approach, taking into account startup costs, ongoing expenses, and possible sources of income (such as eco-tourism or the sale of timber)	$\mathcal{R}_2$
Social Acceptance [57]	Various stakeholder groups, such as local communities, indigenous peoples, and future generations, should have their benefits and burdens distributed accordingly	$\mathcal{R}_3$
Regulatory Compliance	Ensure adherence to local, national, and international laws and regulations governing natural resource management	$\mathcal{R}_4$
Regulatory Effectiveness [58]	Think about the method's effectiveness in utilizing energy, land, and water as natural resources	$\mathcal{R}_5$
Technological Feasibility [59, 60]	Examine whether the technologies needed to implement the strategy are dependable and readily available	$\mathcal{R}_6$
Public Health and Safety	Determine the possible effects on people's health and safety, taking into account any exposure to risks or pollutants	$\mathcal{R}_7$
Long-Term Sustainability [61]	Evaluate the strategy's capacity to sustain social justice, economic feasibility, and ecological balance over time	$\mathcal{R}_8$
Risk and Uncertainty [62]	Analyze the strategy's degree of risk while taking the economy, society, and environment into consideration	$\mathcal{R}_9$
Scalability and Replicability	Examine the possibility of scaling up or replicating the strategy in different settings or areas.	$\mathcal{R}_{10}$
Stakeholder Acceptance [63]	Assess the degree of acceptance and support from important parties such as businesses, governmental organizations, environmental non-governmental organizations, and communities	$\mathcal{R}_{11}$

Among these criteria $\mathcal{R}_2$ and $\mathcal{R}_9$ are cost-base whereas remaining are benefit-base criteria.

5. Numerical analysis of proposed method on natural resource conservation

Step 1::

Create an MCDM problem with six alternatives $\mathcal{N} = \{\mathcal{N}_1,\ \mathcal{N}_2,\ \mathcal{N}_3,\ \mathcal{N}_4,\ \mathcal{N}_5,\ \mathcal{N}_6\}$ and eleven criteria $\mathcal{R} = \{\mathcal{R}_1,\ \mathcal{R}_2,\ \mathcal{R}_3,\ \mathcal{R}_4,\ \mathcal{R}_5, \mathcal{R}_6,\ \mathcal{R}_7,\ \mathcal{R}_8,\ \mathcal{R}_9,\ \mathcal{R}_{10},\ \mathcal{R}_{11}\}$.

Step 2:: The neutrosophic decision matrix D is formulated in Table 4, using criteria rating from Table 2.

Table 4. Linguistic neutrosophic decision matrix.

Alt./Cr.	$\mathcal{R}_1$	$\mathcal{R}_2$	$\mathcal{R}_3$	$\mathcal{R}_4$	$\mathcal{R}_5$	$\mathcal{R}_6$	$\mathcal{R}_7$	$\mathcal{R}_8$	$\mathcal{R}_9$	$\mathcal{R}_{10}$	$\mathcal{R}_{11}$
$\mathcal{N}_1$	SF	F	O	HF	HF	HF	SF	HF	HF	F	HF
$\mathcal{N}_2$	F	F	O	HF	HF	HF	F	HF	HF	HF	F
$\mathcal{N}_3$	F	HF	SO	HF	HF	HF	SF	HF	HF	F	F
$\mathcal{N}_4$	HF	HF	SO	HF	HF	HF	SO	F	F	F	F
$\mathcal{N}_5$	HF	N	HO	N	SF	O	SO	F	HF	F	F
$\mathcal{N}_6$	HF	N	HO	F	HF	HF	F	F	HF	HF	HF

Step 3:: Since the problem regarding natural resource conservation contains six alternatives, the preference degree ($\mathcal{P}_{A_i}$) of each alternative is $\mathcal{P}_{A_i} = \frac{1}{6};\ i = 1,\ 2,\ 3,\ 4,\ 5,\ 6.$

Step 4:: Application of the CRITIC approach:

Step 4.1:: Crisp decision-matrix is determined from the linguistic neutrosophic decision matrix of Table 4 using equation (1).

Step 4.2: The standard deviations $\sigma_j,\ j = 1(1)11$ are computed for each criteria. The outcomes of these two steps are demonstrated in Table 5.

Table 5. Crisp decision matrix and standard deviations.

Alt./Cr.	$\mathcal{R}_1$	$\mathcal{R}_2$	$\mathcal{R}_3$	$\mathcal{R}_4$	$\mathcal{R}_5$	$\mathcal{R}_6$	$\mathcal{R}_7$	$\mathcal{R}_8$	$\mathcal{R}_9$	$\mathcal{R}_{10}$	$\mathcal{R}_{11}$
$\mathcal{N}_1$	0.85	0.925	0.612	0.995	0.995	0.995	0.85	0.995	0.995	0.9	0.995
$\mathcal{N}_2$	0.925	0.925	0.612	0.995	0.995	0.995	0.925	0.995	0.995	0.992	0.925
$\mathcal{N}_3$	0.925	0.995	0.662	0.995	0.995	0.995	0.85	0.995	0.995	0.9	0.925
$\mathcal{N}_4$	0.995	0.995	0.662	0.995	0.995	0.995	0.6625	0.925	0.925	0.9	0.925
$\mathcal{N}_5$	0.995	0.75	0.465	0.75	0.85	0.662	0.662	0.925	0.995	0.9	0.925
$\mathcal{N}_6$	0.995	0.75	0.465	0.925	0.995	0.995	0.925	0.925	0.995	0.992	0.995
σ_j	0.059	0.113	0.092	0.098	0.059	0.136	0.121	0.038	0.029	0.048	0.036

Step 4.3:: Derive the linear correlation relationship of every element of the crisp decision matrix

TABLE 6. Correlation coefficient of each criterion.

Criteria	$\mathcal{R}_1$	$\mathcal{R}_2$	$\mathcal{R}_3$	$\mathcal{R}_4$	$\mathcal{R}_5$	$\mathcal{R}_6$	$\mathcal{R}_7$	$\mathcal{R}_8$	$\mathcal{R}_9$	$\mathcal{R}_{10}$	$\mathcal{R}_{11}$
$\mathcal{R}_1$	1.000	-0.448	-0.473	-0.517	-0.396	-0.396	-0.448	-0.885	-0.396	0.165	-0.329
$\mathcal{R}_2$	-0.448	1.000	0.999	0.794	0.608	0.608	-0.019	0.566	-0.456	-0.360	-0.360
$\mathcal{R}_3$	-0.473	0.999	1.000	0.561	0.613	0.613	-0.002	0.586	-0.440	-0.348	-0.348
$\mathcal{R}_4$	-0.517	0.794	0.794	1.000	0.959	0.959	0.485	0.585	-0.261	0.138	0.138
$\mathcal{R}_5$	-0.396	0.608	0.613	0.959	1.000	1.000	0.608	0.447	0.447	-0.200	0.316
$\mathcal{R}_6$	-0.396	0.608	-0.002	0.959	1.000	1.000	0.608	0.447	-0.200	0.316	0.316
$\mathcal{R}_7$	-0.448	-0.019	-0.002	0.485	0.608	0.608	1.000	0.566	0.608	0.721	0.480
$\mathcal{R}_8$	-0.885	0.566	0.586	0.585	0.447	0.447	0.566	1.000	0.447	0.000	0.000
$\mathcal{R}_9$	-0.396	-0.456	-0.440	-0.261	0.447	-0.200	0.608	0.447	1.000	0.316	0.316
$\mathcal{R}_{10}$	0.165	-0.360	-0.348	0.138	-0.200	0.316	0.721	0.000	0.316	1.000	0.250
$\mathcal{R}_{11}$	-0.329	-0.360	-0.348	0.138	0.316	0.316	0.480	0.000	0.316	0.250	1.000

Step 4.4:: Determine key indicators of the criteria using equation 2 and corresponding weights using equation 3. Table 7 demonstrates the computational outcomes of criteria weight determination.

TABLE 7. Key indicator and criteria weight by CRITIC approach.

Criteria	$\mathcal{R}_1$	$\mathcal{R}_2$	$\mathcal{R}_3$	$\mathcal{R}_4$	$\mathcal{R}_5$	$\mathcal{R}_6$	$\mathcal{R}_7$	$\mathcal{R}_8$	$\mathcal{R}_9$	$\mathcal{R}_{10}$	$\mathcal{R}_{11}$
$\mathcal{R}_1$	0.000	1.448	1.473	1.517	1.396	1.396	1.448	1.885	1.396	0.835	1.329
$\mathcal{R}_2$	1.448	0.000	0.001	0.206	0.392	0.392	1.019	0.434	1.456	1.360	1.360
$\mathcal{R}_3$	1.473	0.001	0.000	0.439	0.387	0.387	1.002	0.414	1.440	1.348	1.348
$\mathcal{R}_4$	1.517	0.206	0.206	0.000	0.041	0.041	0.515	0.415	1.261	0.862	0.862
$\mathcal{R}_5$	1.396	0.392	0.387	0.041	0.000	0.000	0.392	0.553	0.553	1.200	0.684
$\mathcal{R}_6$	1.396	0.392	1.002	0.041	0.000	0.000	0.392	0.553	1.200	0.684	0.684
$\mathcal{R}_7$	1.448	1.019	1.002	0.515	0.392	0.392	0.000	0.434	0.392	0.279	0.520
$\mathcal{R}_8$	1.885	0.434	0.414	0.415	0.553	0.553	0.434	0.000	0.553	1.000	1.000
$\mathcal{R}_9$	1.396	1.456	1.440	1.261	0.553	1.200	0.392	0.553	0.000	0.684	0.684
$\mathcal{R}_{10}$	0.835	1.360	1.348	0.862	1.200	0.684	0.279	1.000	0.684	0.000	0.750
$\mathcal{R}_{11}$	1.329	1.360	1.348	0.862	0.684	0.684	0.520	1.000	0.684	0.750	0.000
Sum	11.834	8.047	8.066	8.204	8.216	8.216	10.376	9.701	12.106	11.606	11.584
σ_j	0.059	0.113	0.092	0.098	0.059	0.136	0.121	0.038	0.029	0.048	0.036
II_j	0.696	0.908	0.741	0.807	0.486	1.115	1.255	0.372	0.346	0.554	0.419
ω_j	0.090	0.118	0.096	0.105	0.063	0.145	0.163	0.048	0.045	0.072	0.054

Step 5:: Calculate the theoretical evaluation matrix $\mathcal{T}_P$ and we get

TABLE 8. Theoretical evaluation matrix.

Criteria	$\mathcal{R}_1$	$\mathcal{R}_2$	$\mathcal{R}_3$	$\mathcal{R}_4$	$\mathcal{R}_5$	$\mathcal{R}_6$	$\mathcal{R}_7$	$\mathcal{R}_8$	$\mathcal{R}_9$	$\mathcal{R}_{10}$	$\mathcal{R}_{11}$
$\mathcal{N}_1$	0.020	0.009	0.009	0.010	0.010	0.010	0.017	0.015	0.023	0.021	0.126
$\mathcal{N}_2$	0.020	0.009	0.009	0.010	0.010	0.010	0.017	0.015	0.023	0.021	0.126
$\mathcal{N}_3$	0.020	0.009	0.009	0.010	0.010	0.010	0.017	0.015	0.023	0.021	0.126
$\mathcal{N}_4$	0.020	0.009	0.009	0.010	0.010	0.010	0.017	0.015	0.023	0.021	0.126
$\mathcal{N}_5$	0.020	0.009	0.009	0.010	0.010	0.010	0.017	0.015	0.023	0.021	0.126
$\mathcal{N}_6$	0.020	0.009	0.009	0.010	0.010	0.010	0.017	0.015	0.023	0.021	0.126

Step 6:: Determination of real evaluation Equation $\mathcal{T}_r$ and we get

TABLE 9. Real evaluation matrix.

Cr./Alt.	$\mathcal{N}_1$	$\mathcal{N}_2$	$\mathcal{N}_3$	$\mathcal{N}_4$	$\mathcal{N}_5$	$\mathcal{N}_6$
$\mathcal{R}_1$	0.000	0.011	0.011	0.020	0.020	0.000
$\mathcal{R}_2$	0.004	0.004	0.000	0.000	0.016	0.016
$\mathcal{R}_3$	-0.015	-0.015	-0.012	-0.012	-0.025	-0.025
$\mathcal{R}_4$	0.010	0.010	0.010	0.010	-0.007	-0.007
$\mathcal{R}_5$	0.010	0.010	0.010	0.010	0.000	0.000
$\mathcal{R}_6$	0.010	0.010	0.010	0.010	-0.017	-0.017
$\mathcal{R}_7$	0.000	0.009	0.000	-0.022	-0.022	-0.022
$\mathcal{R}_8$	0.015	0.015	0.015	0.008	0.008	0.008
$\mathcal{R}_9$	0.000	0.000	0.000	0.011	0.000	0.011
$\mathcal{R}_{10}$	0.011	0.021	0.011	0.011	0.011	0.011
$\mathcal{R}_{11}$	0.000	0.061	0.061	0.061	0.061	0.061

Step 7:: Obtain the gap matrix $\mathcal{G}$ shown in table 10

Step 8:: Calculate values of criteria-function $\mathcal{Q}_i$ shown in table 10

Step 9:: The ranking order of the alternatives are evaluated and listed Table 10.

Table 10. Gap matrix and ranking order of the alternatives.

Cr./Alt.	$\mathcal{N}_1$	$\mathcal{N}_2$	$\mathcal{N}_3$	$\mathcal{N}_4$	$\mathcal{N}_5$	$\mathcal{N}_6$
$\mathcal{R}_1$	0.015	0.007	0.007	0.000	0.000	0.015
$\mathcal{R}_2$	0.010	0.010	0.020	0.020	-0.014	-0.014
$\mathcal{R}_3$	0.042	0.042	0.037	0.037	0.059	0.059
$\mathcal{R}_4$	0.000	0.000	0.000	0.000	0.030	0.030
$\mathcal{R}_5$	0.000	0.000	0.000	0.000	0.011	0.011
$\mathcal{R}_6$	0.000	0.000	0.000	0.000	0.064	0.064
$\mathcal{R}_7$	0.027	0.013	0.027	0.062	0.062	0.062
$\mathcal{R}_8$	0.000	0.000	0.000	0.004	0.004	0.004
$\mathcal{R}_9$	0.007	0.007	0.007	0.004	0.007	0.004
$\mathcal{R}_{10}$	0.006	0.000	0.006	0.006	0.006	0.006
$\mathcal{R}_{11}$	0.126	0.065	0.065	0.065	0.065	0.065
$\sum_{i=1}^{m} \mathcal{Q}_i$	0.234	0.146	0.169	0.197	0.293	0.305
Rank	3	6	5	4	2	1

5.1. *Sensitivity analysis*

A critical factor in determining the classification order of the alternatives is the influence of criteria weight variations. It is imperative to evaluate the effect on the robustness of the proposed neutrosophic MAIRCA approach. We employ the MEREC [64], Rank-Sum [65], Entropy [66], and FUCOM [67] methods to determine the weight, as illustrated in Table 11. To ensure that the proposed approach remains logically equivalent, the remaining procedures are maintained identically.

Table 11. Criteria preferences determined by various methods.

Methods	$\mathcal{R}_1$	$\mathcal{R}_2$	$\mathcal{R}_3$	$\mathcal{R}_4$	$\mathcal{R}_5$	$\mathcal{R}_6$	$\mathcal{R}_7$	$\mathcal{R}_8$	$\mathcal{R}_9$	$\mathcal{R}_{10}$	$\mathcal{R}_{11}$
CRITIC	0.090	0.118	0.096	0.105	0.063	0.145	0.163	0.048	0.045	0.072	0.054
MEREC	0.166	0.025	0.061	0.027	0.198	0.026	0.095	0.026	0.200	0.024	0.151
RANK-SUM	0.167	0.076	0.061	0.030	0.045	0.152	0.106	0.136	0.121	0.091	0.015
ENTROPY	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
FUCOM	0.0001	0.0002	0.0007	0.0001	0.003	0.007	0.018	0.034	0.088	0.245	0.596

The CRITIC approach assigns higher preference to $\mathcal{R}_2$, $\mathcal{R}_6$, and $\mathcal{R}_7$ while sets lower preferences to $\mathcal{R}_8$ and $\mathcal{R}_9$. The MEREC method allocates comparatively higher weights to the criteria $\mathcal{R}_1$, $\mathcal{R}_5$, and $\mathcal{R}_9$ while sets lower wights to the criteria $\mathcal{R}_2$, $\mathcal{R}_4$, $\mathcal{R}_8$, and $\mathcal{R}_{10}$. Surprisingly, the entropy approach assigns identical preferences to the criteria, which results in equal treatment. The FUCOM approach assigns significantly higher preferences to the criteria $\mathcal{R}_{10}$ and $\mathcal{R}_{11}$ compared to the remaining criteria. In conclusion, the cost-based criteria $\mathcal{R}_2$ and

$\mathcal{R}_9$ received higher preference than the remaining criteria except in the FUCOM approach. Figure 1 is drawn to understand the allocation of criteria weights in these approaches.

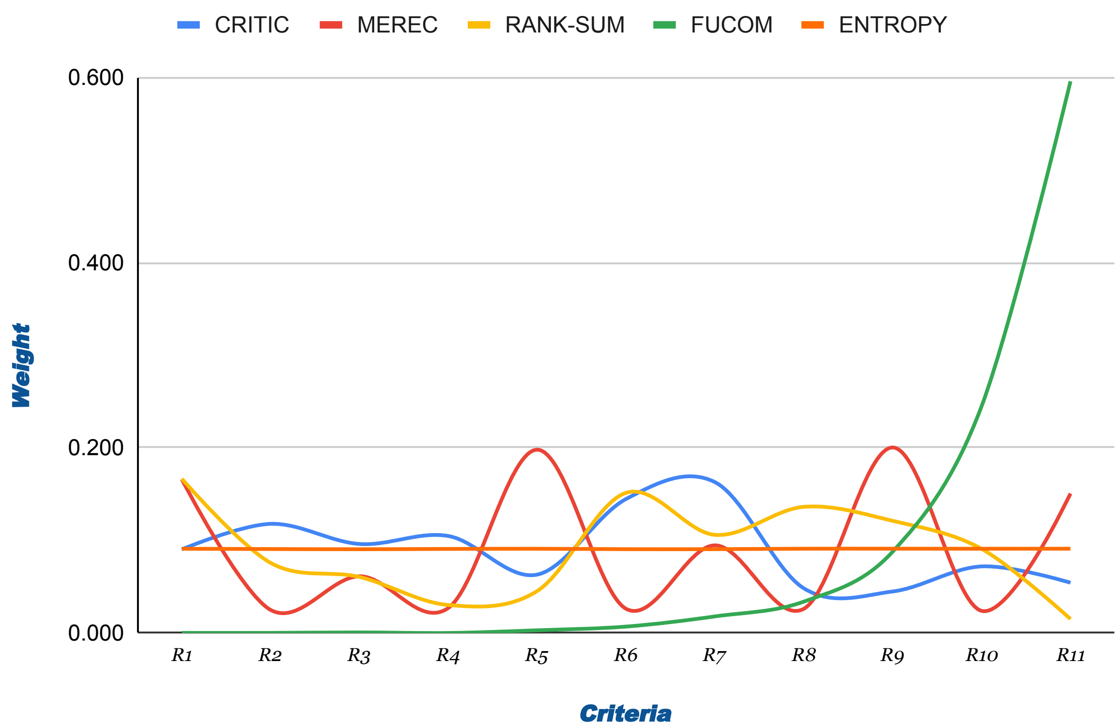

FIGURE 1. Criteria weight allocation in different approaches.

Figure 1 shows that the criteria weights of $\mathcal{R}_1$, $\mathcal{R}_2$, $\mathcal{R}_3$, and $\mathcal{R}_4$ have low variation, $\mathcal{R}_5$, $\mathcal{R}_6$, $\mathcal{R}_7$, $\mathcal{R}_8$ and $\mathcal{R}_9$ have moderate variation, and $\mathcal{R}_{10}$ and $\mathcal{R}_{11}$ have high variation. The FUCOM approach has the highest degree of variation in assigning criteria weights as it gradually increases from the $\mathcal{R}_1$ criterion weight to $\mathcal{R}_8$ criterion weight. However, the curve instantly grows high for the criteria weights from $\mathcal{R}_9$ to $\mathcal{R}_{11}$. The impact of the criteria weights on the ranking sequence of the options is depicted in Table 12.

TABLE 12. Ranking of alternatives based on various methods.

Methods	Performance score						Rank
——	$\mathcal{N}_1$	$\mathcal{N}_2$	$\mathcal{N}_3$	$\mathcal{N}_4$	$\mathcal{N}_5$	$\mathcal{N}_6$	
CRITIC	0.234	0.146	0.169	0.197	0.293	0.305	$\mathcal{N}_6 \succ \mathcal{N}_5 \succ \mathcal{N}_1 \succ \mathcal{N}_4 \succ \mathcal{N}_3 \succ \mathcal{N}_2$
MEREC	0.234	0.149	0.157	0.150	0.226	0.237	$\mathcal{N}_6 \succ \mathcal{N}_1 \succ \mathcal{N}_5 \succ \mathcal{N}_3 \succ \mathcal{N}_4 \succ \mathcal{N}_2$
RANK-SUM	0.232	0.141	0.160	0.170	0.255	0.273	$\mathcal{N}_6 \succ \mathcal{N}_5 \succ \mathcal{N}_1 \succ \mathcal{N}_4 \succ \mathcal{N}_3 \succ \mathcal{N}_2$
ENTROPY	0.226	0.143	0.160	0.172	0.255	0.263	$\mathcal{N}_6 \succ \mathcal{N}_5 \succ \mathcal{N}_1 \succ \mathcal{N}_4 \succ \mathcal{N}_3 \succ \mathcal{N}_2$
FUCOM	0.164	0.082	0.103	0.102	0.113	0.106	$\mathcal{N}_1 \succ \mathcal{N}_5 \succ \mathcal{N}_6 \succ \mathcal{N}_3 \succ \mathcal{N}_4 \succ \mathcal{N}_2$

The alternative $\mathcal{N}_6$ ranks first in all weight determination techniques except FUCOM. In contrast, each technique allocates the alternative $\mathcal{N}_2$ to the last position. The alternative $\mathcal{N}_5$ always occupies the second position, except for the MEREC approach. In all methods, the fourth and fifth places are consistently occupied by either $\mathcal{N}_3$ or $\mathcal{N}_4$. Hence, the alternative $\mathcal{N}_6$ suppresses the remaining alternatives in terms of their performance through almost all weight determination procedures while $\mathcal{N}_2$'s performance is the weakest. This phenomenon can be conveniently viewed from figure 2.

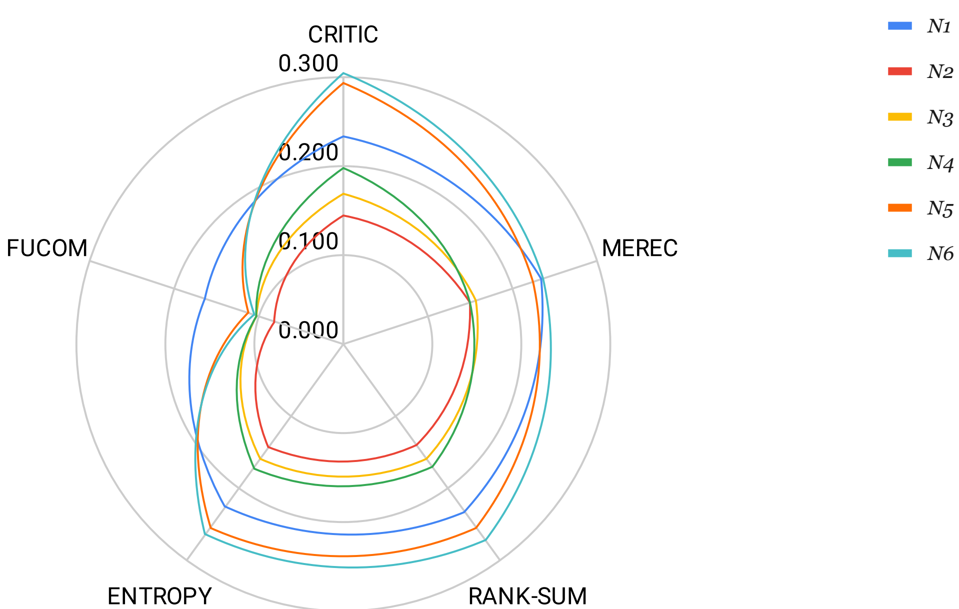

FIGURE 2. Performance score of each alternative by using various methods of weight calculation.

Figure 2 shows the performance score variation of alternatives for several weight methods. A marginal influence on the performance scores of the alternatives for the FUCOM approach is seen in figure 2. Based on the CRITIC approach, a significant disparity in performance scores is seen by which one can easily rank the options, with $\mathcal{N}_6$ occupying the top position and $\mathcal{N}_2$ ranking last. In the context of performance scores for the CRITIC, RANK-SUM, and ENTROPY methods, the figure illustrates how to rank the options easily. The MEREC technique offers an alternative approach that assigns greater performance priority to $\mathcal{N}_6$, $\mathcal{N}_5$, and $\mathcal{N}_1$ while assigning lesser preference to $\mathcal{N}_2$, $\mathcal{N}_3$, and $\mathcal{N}_4$.

5.2. *Comparison analysis*

To establish it, it is imperative to compare the outcomes of the suggested SVN-MAIRCA with those of the current MCDM techniques. We have considered popular MCDM approaches like TOPSIS, MARCOS, and MABAC to compare the outcome of the proposed SVN-MAIRCA approach. Evaluating alternative rankings using the CRITIC criterion weight maintains logical similarity in computation. The crisp MCDM approaches are applied to the crisp decision matrix from Table 7. Table 13 compares the proposed and existing techniques' ranking orders.

TABLE 13. Alternatives' ranking in suggested and existing methods.

Approach	SVN-MAIRCA		TOPSIS		MARCOS		MABAC	
Alternatives	Score	Rank	Score	Rank	Score	Rank	Score	Rank
$\mathcal{N}_1$	0.226	3	0.632	3	0.011	3	1.637	3
$\mathcal{N}_2$	0.136	6	0.634	1	0.011	1	1.748	2
$\mathcal{N}_3$	0.156	5	0.633	2	0.011	2	1.620	4
$\mathcal{N}_4$	0.164	4	0.630	5	0.011	4	1.544	5
$\mathcal{N}_5$	0.227	2	0.617	6	0.009	6	1.208	6
$\mathcal{N}_6$	0.236	1	0.631	4	0.010	5	1.780	1

Table 13 demonstrates that the ranking order derived from the SVN-MAIRCA method exhibits a substantial disparity compared to the rankings generated from other MCDM techniques. The first ranked alternative $\mathcal{N}_6$ in the SVN-MAIRCA model is only equivalent to MABAC. The alternative $\mathcal{N}_5$ obtained the lowest score in all crisp approaches, except for SVN-MAIRCA, which achieved the second highest ranking. The alternative $\mathcal{N}_2$ exhibits significant rank fluctuations when comparing the neutrosophic and crisp MCDM techniques. The remaining options exhibit a moderate degree of difference in ranking between the proposed and current techniques. Figure 3 compares the alternatives' ranking among SVN-MAIRCA and existing approaches.

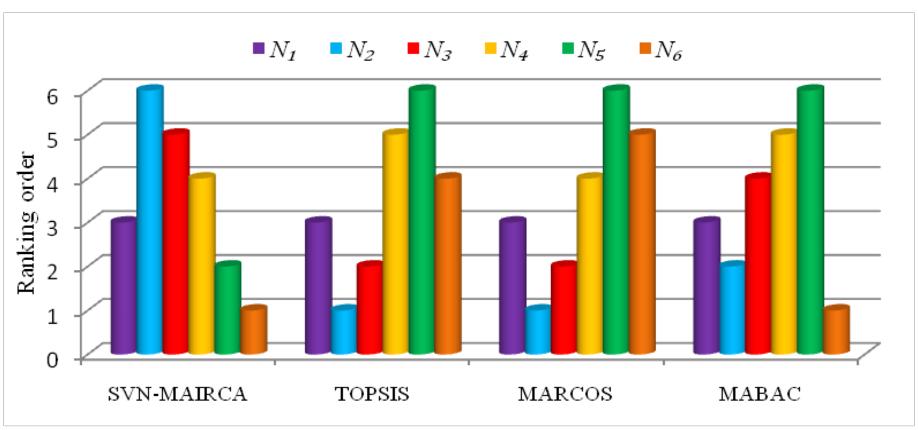

FIGURE 3. Ranking comparison of natural resource conservation strategy

The diagram 3 makes clear that the option $\mathcal{N}_1$ is consistently assigned third place by both the suggested SVN-MAIRCA technique and other approaches. This phenomenon indicates that the suggested technique is consistent. Every approach assigns $\mathcal{N}_4$ to either the third or fourth position. Figure 3 also shows that, in contrast to the suggested SVN-MAIRCA technique, which allocates $\mathcal{N}_5$ at the second place, all considered methods allocate it at the last position.

Conclusion

This paper presented an integrated neutrosophic MCDM methodology, that successfully determined the criteria weight and the ranking of the alternatives. The suggested method incorporates hesitation in decision-making through SVNS-rating of the criteria. The criteria weight variation shows that the proposed method is robust in decision-making. The comparison analysis reveals that the proposed neutrosophic methodology is inconsistent with the outcome of crisp MCDM approaches. The reason behind this inconsistency is the incorporation of uncertainty and hesitation in the computation procedures of the recommended approach. Based on the presented methodology, the alternative “research and monitoring” is the most optimal strategy, while “sustainable resource management” is deemed the least desirable. The critical criteria for ranking preference are ecological impact, economic costs, and stakeholder acceptance. Since the preference of the criterion is high, the financial cost is much higher than the remaining critical criteria; hence, it significantly impacts strategy selection for natural resource conservation.

Although the suggested method has several benefits, it has some constraints, as follows: (i) single DM may be subjective to some particular criterion, so producing a skewed assessment; (ii) the inclusion of uncertainty and hesitation in computation procedures is unavailable in criteria weight determination; and (iii) the availability of hesitant information about the criteria descriptions.

Recently developed fuzzy sets such as the Z-number, D-number, type-2 fuzzy set, and hesitant bi-fuzzy set may be used to update or enhance the criterion rating. The CRITIC approach may be expanded to include uncertainty in the criterion weight calculation in a Pythagorean, fermatean fuzzy environment. Introducing a panel of available DMs, a group decision-making methodology can be developed using the proposed N-MAIRCA approach for a more compact assessment of the criteria.

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