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Waste to Energy Treatment for India Using CRITIC-WASPAS Method under Interval-Valued Pythagorean Neutrosophic Fuzzy Set

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Abstract. Municipal solid waste management (MSWM) has emerged as a major issue in India due to the massive amounts of waste generated on a daily basis. Governments are focusing on establishing a proper waste management system, including a timeline for the installation of waste processing and disposal facilities to reduce waste. For this problem, waste to energy (WtE) technologies have been identified because of their ability to convert waste into green energy while minimizing associated issues. This research investigates the different kinds of WtE treatments based on various factors, namely eco-friendly, budget friendly, technical, and social aspects. The findings of this study revealed which WtE treatments are best suited for waste management systems that convert green energy. In this paper, we propose the best WtE treatment for India using the interval-valued pythagorean neutrosophic fuzzy set (PNFS). We employ the WASPAS-CRITIC method in the interval-valued pythagorean neutrosophic fuzzy environment for this WtE treatment problem. Finally, a numerical example and a comparison are provided to illustrate the reliability and efficiency of the proposed technique.

Keywords: Neutrosophic Fuzzy Set, Pythagorean Neutrosophic Fuzzy Set, Interval-Valued Pythagorean Neutrosophic Fuzzy Set, WASPAS, CRITIC, WtE Treatments.

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1. **Introduction**

Municipal solid waste (MSW), hazardous wastes, industrial wastes, agricultural wastes, and bio-medical wastes are some of the most common types of solid waste. Growing waste generation and unscientific waste disposal methods are leading to the release of GHG (methane, CO_2, etc.) into the environment. MSW is a complex mix of food waste, metals, glass, yard trimmings, woody waste, non-recyclable paper and plastic, construction and demolition waste, rags, and wastewater treatment sludge. When used as a raw material for power production, MSW presents several challenges: it has a low power content, high moisture, a diverse composition, and is copious. Managing waste safely is critical for the environment and the long-term goals for both the public and private sectors. Harvest trash, livestock wastes, slaughter waste, forest wastes, and other agricultural recycle waste materials are examples. WtE routes helps to converted waste into useful power forms such as bio-hydrogen, biogas, bio-alcohols, and so on, allowing for the sustainable global development. Sum of solid waste is produced annually across country as a form of by-product of industrial, municipal, agricultural, mining, and other processes [1].

MSW management has originally involved in discharging waste in open dumps and burning it to decrease waste volumes. Dangerous Industrial waste was frequently disposed of alongside municipal garbage and refuse in open dumps or landfills. Contaminated Groundwater, toxic fume and greenhouse gas emissions, land contamination, and large pest and disease vector populations, such as rats, flies, and mosquitoes, all of them have been tied into these old landfills in the past. To reduce these environmental impacts when we dispose of MSW, the treatment of waste into energy is now done within the framework of waste management regulations [23]. Most countries are focusing on WtE projects for municipal solid waste.

In this study, we propose an appropriate WtE treatment for India using a fuzzy approach MCDM model. Reducing waste and finding new environmentally friendly forms of energy will help countries solve energy demand problems and develop a hygienic society in the near future. WtE treatments would be the best way to get renewable energy. These innovative technologies can generate huge amounts of heat and energy from waste, reducing the serious environmental problems associated with MSW and reducing the use of junk fuels that emit gas. Green houses cause climate change and global water consumption. These WtE treatments can also be useful to society due to their economic and environmental benefits.

In 1965, Zadeh introduced fuzzy logic concepts [2] to address the problems of human decision-making under unreliability. Fuzzy sets (FS) have some limitations when non membership concepts are involved. To tackle this issue, Atanassov [3] transformed a FS into an intuitionistic fuzzy set (IFS) by including a non-membership function. Yager [4–6] developed the Pythagorean fuzzy set (PFS), which has a larger solution space in ambiguous and imprecise environments. In addition, when compared to FS and IFS, the Pythagorean treatment for India Using CRITIC-WASPAS Method under IVPNFS fuzzy number provided a more comprehensive computational model. Smarandache [7] introduced the concepts of neutrosophic set and neutrosophic probability and their logic, which contains of three logics: truth, indeterminacy, and falsity-membership degree. Interval-valued fuzzy sets were introduced by Zadeh [2].

An interval-valued membership function defines an interval-valued fuzzy set (IVFS). IVFs are a subset of L-fuzzy sets [8] and type-2 fuzzy sets [9].

The interval-valued Pythagorean fuzzy set (IVPFS) is a PFS extension [10]. Due to a lack of easily available information, experts may find it difficult to explain their ideas accurately with a specific number for many real-world decision-related difficulties, but they can do so by using an interval number between [0, 1]. This entails the idea of IVPFS, which permits both the degrees of a set's membership and absence to have an interval value. It should be emphasized that IVPFS turns into PFS when the interval values' upper and lower limits are identical, proving that the latter is a special case of the former [11, 12]. In order to provide a more dependable solution to the WtE treatment problem, we apply the suggested model in this research to combine two sets, such as Pythagorean and Neutrosophic fuzzy sets, in interval form, namely as an interval-valued Pythagorean Neutrosophic fuzzy set.

Some new operations and properties for IVPFS are proposed by Peng and Yang [12]. Garg [13] discussed an accuracy function for IVPFS to solve the MCDM problem. Liang et al. [14] introduced the interval-valued Pythagorean fuzzy weighted aggregating operators. Garg [15] demonstrated an improved score function for a Pythagorean fuzzy set-based TOPSIS method with interval values. Chen [16] examined the IVPF outranking algorithm for the MCDM problem. Rahman et al. [17] proposed IVPF geometric aggregation operators for the MCGDM problem. Stephy Stephen and Helen [18] discussed the IVPN set and their application using TOPSIS. Narmada devi and Sowmiya [19, 20] introduced the Octagonal neutrosophic fuzzy number in game and sequencing problem. Jansi et al. [21] examined the basic operations and correlation measure of PNS set. Abdel-Basset et al. [22] used a hybrid MCDM approach in a neutrosophic environment. Khan et al. [23] explored the effects of renewable electricity generation from waste. Van Thanh et al. [24] proposed a fuzzy MCDM model to evaluate and select a location for a solid WtE plant in Vietnam. Kurbatova and Abu-Qdais [25] used AHP to evaluate the various waste-to-energy options and chose the best technology for Moscow. Hezam et al. [26] examined the optimal selection of recycling plant site. Sleem et al. [27] investigated te product's target demographic using CRITIC model under neutrosophic set. Gamal and Mohamed [28] proposed the industrial robots selection using hybrid MCDM approach. Narmada Devi et al. [29] proposed the suitable waste to energy technology for India using MULTIMOORA method. The majority of WtE options were identified under different MCDMs using various fuzzy sets in the studies reviewed above. In this study, we identify the appropriate WtE treatment for India based on the WASPAS model under an interval-valued Pythagorean Neutrosophic fuzzy set. The pictorial representation of the algorithm is shown in figure 1.

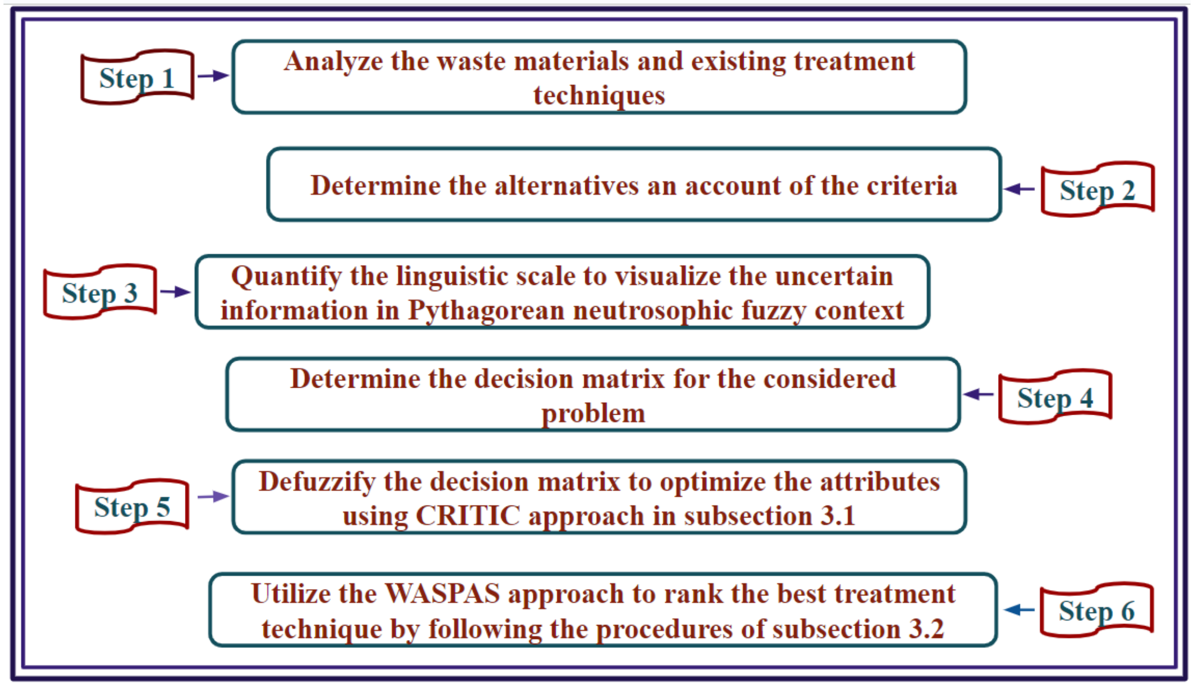

FIGURE 1. **Procedures of integrated fuzzy MCDM approach**

2. Preliminaries

Definition 2.1. [4–6] Consider Ω to be a non-empty set. Then a Pythagorean fuzzy set P over Ω, which is defined as follows:

$$P = \{(f, \alpha(f), \beta(f)) | f \in \Omega\}$$

where $\alpha_P(f) : \Omega \to [0,1]$ and $\beta_P(f) : \Omega \to [0,1]$ define the membership and non-membership, of the element $f \in \Omega$ to P.

$$0 \leq (\alpha_P(f))^2 + (\beta_P(f))^2 \leq 1$$

Suppose $(\alpha_P(f))^2 + (\beta_P(f))^2 \leq 1$ then there is a degree of indeterminacy of $f \in \Omega$ to P defined by $\alpha_P(f) : \sqrt{1 - [(\alpha_P(f))^2 + (\beta_P(f))^2]}$ and $\alpha_P(f) \in [0,1]$. In follows, $(\alpha_P(f))^2 + (\beta_P(f))^2 = 1$. Otherwise, $\alpha_P(f) = 0$ whenever $(\alpha_P(f))^2 + (\beta_P(f))^2 = 1$.

Definition 2.2. [7]

A Neutrosophic fuzzy set N on Ω is an object of the form:

$$N = \{(f, \alpha_N(f), \gamma_N(f), \beta_N(f)) : f \in \Omega\}$$

where $\alpha_N(f), \gamma_N(f), \beta_N(f) \in [0,1], 0 \leq \alpha_N(f) + \gamma_N(f) + \beta_N(f) \leq 3$ for all $f \in \Omega$, $\alpha_N(f)$, $\gamma_N(f)$, $\beta_N(f)$ are degrees of membership, indeterminacy and non-membership, respectively.

TABLE 1. Interval-Valued Pythagorean Neutrosophic fuzzy linguistic scale

Linguistic term	membership values	indeterminacy values	non-membership values
Extremely elevated (EE)	[0.1, 0.2]	[0.5, 0.6]	[0.8, 0.9]
Average elevated (AE)	[0.2, 0.4]	[0.4, 0.5]	[0.6, 0.8]
Average (A)	[0.4, 0.6]	[0.3, 0.4]	[0.4, 0.6]
Average dropped (AD)	[0.6, 0.8]	[0.2, 0.3]	[0.2, 0.4]
Extremely dropped (ED)	[0.8, 0.9]	[0.1, 0.2]	[0.1, 0.2]

Definition 2.3. [10] A Pythagorean Neutrosophic fuzzy set (PNFS) with T and F are dependent Neutrosophic components D on Ω is in the form

$$D = \{(f, \alpha_D(f), \gamma_D(f), \beta_D(f)) : f \in \Omega\}$$

where $\alpha_D(f), \gamma_D(f), \beta_D(f) \in [0,1]$, $0 \leq (\alpha_D(f))^2 + (\gamma_D(f))^2 + (\beta_D(f))^2 \leq 2$, for all $f \in \Omega$, $\alpha_D(f)$, $\gamma_D(f)$ and $\beta_D(f)$ are degrees of membership, indeterminacy, non-membership, respectively.

Definition 2.4. [12,13] A Interval-Valued Pythagorean Neutrosophic fuzzy set (PNFS) with T and F are dependent Neutrosophic components C on Ω is in the form

$$C = \{(f, [\alpha_C^L(f), \alpha_C^U(f)], [\gamma_C^L(f), \gamma_C^U(f)], [\beta_C^L(f), \beta_C^U(f)] : f \in \Omega\}$$

where $[\alpha_C^L(f), \alpha_C^U(f)], [\gamma_C^L(f), \gamma_C^U(f)], [\beta_C^L(f), \beta_C^U(z)] \in [0,1]$,

$$0 \leq [\frac{\alpha_C^L(f) + \alpha_C^U(f)}{2}]^2, [\frac{\gamma_C^L(f) + \gamma_C^U(f)}{2}]^2, [\frac{\beta_C^L(f) + \beta_C^U(f)}{2}]^2 \leq 2$$

, for all $f \in \Omega$, $[\alpha_C^L(f), \alpha_C^U(f)]$ is the degree of membership, $[\gamma_C^L(f), \gamma_C^U(f)]$ is the degree of indeterminacy and $[\beta_C^L(f), \beta_C^U(f)]$ is the degree of non-membership.

Definition 2.5. [13] The score function of the Pythagorean Neutrosophic fuzzy sets with dependent Pythogorean Neutrospohic components I and F are defined as:

$$S_C(x) = [T_C^L + (1 - I_C^U) + (1 - F_C^U), T_C^U + (1 - I_C^L) + (1 - F_C^L)]$$

with the condition $0 \leq [\frac{\alpha_C^L(x)+\alpha_C^U(x)}{2}]^2, [\frac{\gamma_C^L(x)+\gamma_C^U(x)}{2}]^2, [\frac{\beta_C^L(x)+\beta_C^U(x)}{2}]^2 \leq 2$.

Note:

The linguistic variables with Interval-Valued Pythgorean Neutrosophic fuzzy number to evaluate the WtE treatment based on selected criteria and the linguistic scale is presented in Table 1.

3. Mathematical methods

3.1. *The CRITIC method*

The CRITIC approach is one of the objective weighing methods suggested by Diakoulaki et al. [34]. It employs a decision matrix explicitly to compute criterion weights objectively. There is no requirement for decision-makers opinions or pairwise comparisons, as in other weighing procedures. Based on an analysis of the evaluation matrix, it collects all of the preference information contained in the evaluation criteria. Further, the objective weight is determined by quantifying the inherent information of each criterion. The procedure for obtaining objective weight includes not only the standard deviation of the criteria but also the correlation between the other criteria.

The steps of the CRITIC method are presented below [35].
Here, the problem has m alternatives $K_i(i = 1, 2, ..., m)$ and n criteria $V_j(j = 1, 2, ..., n)$.

Step 1: Here is the DM K as it is formed. It compares the performance of various alternatives based on selected criteria.

$$K = \begin{bmatrix} [k_{11}^L, k_{11}^U] & [k_{12}^L, k_{12}^U] & \dots & [k_{1n}^L, k_{1n}^U] \\ [k_{21}^L, k_{21}^U] & [k_{22}^L, k_{22}^U] & \dots & [k_{2n}^L, k_{2n}^U] \\ \dots & \dots & \dots & \dots \\ [k_{m1}^L, k_{m1}^U] & [k_{m2}^L, k_{m2}^U] & \dots & [k_{mn}^L, k_{mn}^U] \end{bmatrix} \quad (1)$$

Step 2: The DM is normalized by applying the below equation:

$$k_{ij}^* = \frac{k_{ij} - min(k_{ij})}{max(k_{ij}) - min(k_{ij})}, i = 1, 2, ..., m, j = 1, 2, ..., n \quad (2)$$

k_{ij} is the normalized value of i^{th} alternative on j^{th} criterion.

Step 3: Both the criterion's standard deviation (SD) and its correlation with other criteria are considered when determining the criteria's weights. The weight of the j^{th} criterion (w_j) is calculated as follows:

$$w_j = \frac{H_j}{\sum_{j=1}^{n} H_j} \quad (3)$$

where H_j is the quantity of information which obtained as:

$$H_j = \Gamma_j \sum_{j=1}^{n} (1 - t_{jj'}) \quad (4)$$

where j is SD of the j^{th} criterion and $t_{jj'}$ is the correlation coefficient between the two criteria. It is possible to conclude that this method gives more weight to the criterion with a high SD and a low correlation with other criteria [36]. A significantly higher value of H_j indicates that more detail is obtained from criterion, implying that the criterion's relative importance for the decision making problem is greater.

3.2. *The WASPAS method*

The WASPAS method was created by Chakraborty and Zavadskas [30]. The WSM method computes an alternative's entirety as a weighted sum of the criteria standards, whereas the WPM technique calculates an alternative's score as a product of the scaled grading of every criteria to a power equal to the weight of the specified criterion [31]. Furthermore to these approaches, WASPAS efforts to achieve the highest precision for estimation by optimising weighted aggregated functions [30]. The combined optimality on criteria values computed based on the results of these two models for rank the alternatives. The model is actually proposed as the best MCDM method in terms of accuracy or verification of accuracy when those two methods are used together.

The algorithm of the WASPAS model are as follows [32, 33]:

Step 1: Create the initial decision matrix (DM).

$$K = \begin{bmatrix} [k_{11}^L, k_{11}^U] & [k_{12}^L, k_{12}^U] & \dots & [k_{1n}^L, k_{1n}^U] \\ [k_{21}^L, k_{21}^U] & [k_{22}^L, k_{22}^U] & \dots & [k_{2n}^L, k_{2n}^U] \\ \dots & \dots & \dots & \dots \\ [k_{m1}^L, k_{m1}^U] & [k_{m2}^L, k_{m2}^U] & \dots & [k_{mn}^L, k_{mn}^U] \end{bmatrix} \tag{5}$$

where m represents the alternatives, n represents the criteria and k_{ij} is the performance value of i^{th} alternative with respect to j^{th} criteria.

Step 2: Calculate the linear normalized decision matrix using the following equations:

For benefit criteria:

$$\bar{k}_{ij} = \frac{k_{ij}}{\max_j k_{ij}} \tag{6}$$

For non-benefit criteria:

$$\bar{k}_{ij} = \frac{\min_j k_{ij}}{k_{ij}} \tag{7}$$

Where $\bar{k}_{ij}$ is the normalized value of k_{ij}.

Step 3: Compute the measures of WSM (L_j^1) and WPM (L_j^2) for each alternative by applying the below equation:

$$L_j^1 = \sum_{i=1}^{m} w_i \bar{k}_{ij} \tag{8}$$

$$L_j^2 = \prod_{i=1}^{m} (\bar{k}_{ij})^{w_i} \tag{9}$$

Step 4: To obtain the aggregate measure of the WASPAS model for every alternative using the below expression:

$$L_j = \delta L_j^1 + (1-\delta)L_j^2 \tag{10}$$

Where δ is the parameter of the model. It can take values in $[0-1]$. When $\delta = 1$, the WASPAS model is transformed to WSM, and $\delta = 0$ into WPM model.

Step 5: Finally, according to decreasing values of L_i, rank the alternatives.

4. Application

A considerable quantity of waste is produced in developing countries. The primary explanations for propelling waste generation and creating distinguished social and environmental concerns are accelerating urbanisation, economic expansion, population increase, and modern technology. Waste management is increasingly focused on sophisticated waste reduction strategies, but they are still looking for the optimum response to that issue with no adverse environmental or social impact. As a result, we have to figure out the optimal WtE treatment to create green energy from MSW wastes, thus contributing to environmental sustainability. In this work, we presented the WASPAS approach using an IVPNFS to discover the optimal WtE therapy for India. Based on the parameters we identified, we picked four types of WtE procedures.

5. Numerical example

In this section, we discuss the WtE treatment under the interval-valued pythagorean neutrosophic fuzzy set using the CRITIC-WASPAS method. Here, the experts evaluate this problem based on four criteria. The WtE treatment are: K_1- photo-biological process; K_2- dark fermentation; K_3- microbiological fuel cells; and K_4- microbial electrolysis cells. In this paper, experts evaluate the WtE treatment using the WASPAS method under IVPNFS. The linguistic scale is used to form a decision matrix. We are now analyzing the problem under proposed method.

5.1. *CRITIC method*

Step 1: Here is the decision matrix K as it is formed which is shown in Table 2. Using the IVPNFSs score function to create the DM shown in Table 3.

Step 2: The DM is normalized by applying the equation (8) and the normalized matrix is given in Table 4.

Step 3: Finally, the weight values of the criteria are computed by using the equation (9) and (10). The weight values of the criteria are 0.2772, 0.3938, 0.2735, 0.0555.

Table 2. Initial decision matrix

	V_1	V_2	V_3	V_4
K_1	([0.2,0.4], [0.3, 0.4], [0.4, 0.6])	([0.1, 0.2], [0.3, 0.4], [0.2, 0.4])	([0.4, 0.6], [0.1, 0.2], [0.2, 0.4])	([0.1, 0.2], [0.4, 0.5], [0.2, 0.4])
K_2	([0.6, 0.8], [0.3, 0.4], [0.1, 0.2])	([0.4, 0.6], [0.1, 0.2], [0.1, 0.2])	([0.2, 0.4], [0.3, 0.4], [0.2, 0.4])	([0.1, 0.2], [0.2, 0.3], [0.6, 0.8])
K_3	([0.6, 0.8], [0.4, 0.5], [0.4, 0.6])	([0.6, 0.8], [0.4, 0.5], [0.1, 0.2])	([0.6, 0.8], [0.1, 0.2], [0.2, 0.4])	([0.1, 0.2], [0.4, 0.5], [0.6, 0.8])
K_4	([0.1, 0.2], [0.4, 0.5], [0.4, 0.6])	([0.1, 0.2], [0.2, 0.3], [0.4, 0.6])	([0.1, 0.2], [0.5 0.6], [0.2, 0.4])	([0.2, 0.4], [0.3, 0.4], [0.1, 0.2])

Table 3. Decision matrix

	V_1	V_2	V_3	V_4
K_1	-0.4752	-0.3676	1.0154	-0.5015
K_2	0.4513	0.3781	-0.2236	-0.8551
K_3	0.5820	0.7627	0.5820	-0.1076
K_4	-0.7354	-0.5307	-0.6562	-0.1219

Table 4. Normalized decision matrix

	V_1	V_2	V_3	V_4
K_1	1.0000	1.0000	0.6700	-0.0384
K_2	0.9952	1.0000	0.6255	0.0442
K_3	0.6700	0.6255	1.0000	-0.7090
K_4	-0.0384	0.0442	-0.7090	1.0000

5.2. *WASPAS method:*

The WtE treatment and the criteria are given below:

K_1 – Photo - biological processes

K_2 – Dark fermentation

K_3 – Microbiological fuel cells

K_4 – Microbial electrolysis cells

$$\begin{aligned} &V_1 - \text{Ecosystem} \\ &V_2 - \text{Cost} \\ &V_3 - \text{Technical aspects} \\ &V_4 - \text{Social aspects} \end{aligned} \tag{11}$$

Step 1: The decision matrices are shown in Table 2 and 3.

Step 2: Calculate the linear normalized decision matrix using the equations (2) and (3).

Step 3: Calculated the measures of WSM (L_j^1) and WPM (L_j^2) for each alternative by using

Table 5. WSM and WPM values

WtE treatment	WSM (L_j^1)	WPM (L_j^2)
K_1	0.0482	0.0039
K_2	-0.1468	0.0110
K_3	0.9630	0.0012
K_4	-0.8402	-0.0014

Table 6. The final ranking results for proposed method

WtE	L_j	Rank
K_1	0.0299	2
K_2	-0.0569	4
K_3	0.4833	1
K_4	-0.4221	3

the equations (4) and (5). The WSM and WPM values are presented in Table 5.

Step 4: Finally, rank the alternatives according to decreasing values of L_j. The final ranking results is shown in Table 6.

From this Table 6, K_3- Microbiological fuel cells in WtE treatment is the most suitable and eco-friendly treatment, which make more green energy to keep environment clean and provide great employment to our society.

6. **Comparison and sensitivity analysis**

6.1. *Comparison Analysis*

To show the suggested approach's efficacy in comparison to other approaches from the literature, this section compares it against an assortment of those methods. The proposed approach was compared to two MCDM techniques: TOPSIS [33] and VIKOR [37]. These MCDM approaches employ the same weights. The results of the ranking order comparison are shown in table 7. The suggested ranking yields different outcomes from the compared models. As a result, when compared to existing MCDM approaches, the suggested methodology generates more dependable findings.

6.2. *Sensitivity analysis*

This model's sensitivity analysis compares the outcomes of four cases. Case 1 is the study's outcome, and Cases 2, 3, and 4 are the other outcomes discovered by varying the weights of the criteria, which are given in Table 8. Sensitivity analysis reveals that changing the weights

Table 7. Comparison analysis results

WtE	VIKOR	Rank	TOPSIS	Rank	Proposed method	Rank
K_1	0	1	0.6980	1	0.0299	2
K_2	0.4616	2	0.4419	3	-0.0569	4
K_3	1	4	0.3186	4	0.4833	1
K_4	0.4835	3	0.5196	2	-0.4221	3

Table 8. Weights in sensitivity analysis

WtE	Case 1	Case 2	Case 3	Case 4
V_1	0.2772	0.0555	0.2735	0.3938
V_2	0.3938	0.2772	0.0555	0.2735
V_3	0.2735	0.3938	0.2772	0.0555
V_4	0.0555	0.2735	0.3938	0.2772

Table 9. Sensitivity analysis results

WtE	Case 1	Rank	Case 2	Rank	Case 3	Rank	Case 4	Rank
K_1	0.247	3	0.286	2	0.178	4	0.289	1
K_2	0.286	2	0.178	4	0.289	1	0.247	3
K_3	0.178	4	0.289	1	0.247	3	0.286	2
K_4	0.289	1	0.247	3	0.286	2	0.178	4

of the criteria affects the ranking order. Those results of sensitivity analysis are presented in Table 9.

7. Conclusion

The normative waste disposal practices used in India, such as mass burning and dumps, have had detrimental effects on the environment and the general population. The nation, nonetheless, has identified the unexpected implications and harms of such approaches and has recommended ecologically friendly and cost-effective waste management options. Notwithstanding rising oil and other fossil fuel costs and the depletion of fossil fuels, demand for energy is increasing. If India prioritises economic and logistical planning, failures may be avoided. Furthermore, the entire country should seek to strengthen the regulatory framework, which may result in people, industry stakeholders, and shareholders fighting the process.We presented suggestions for the most effective and feasible treatment of WtE for waste management and energy generation in India, which eliminates huge quantities of greenhouse gases and carbon from the atmosphere and leads to global warming along with alterations in the climate, according to the research findings.

As a result, this research was conducted in order to present a broad, systematic framework that might aid policymakers in determining the most effective WtE treatment for constructing waste management systems in India. The IVPNFS score function and the IVPNF-WASPAS technique based on it are provided in this work. IVPNFNs are used to represent the characteristics of each WtE therapy. New trends in WtE have been recognised as the cleanest and most advantageous WtE technology in the present environment based on the suggested approach for determining the most suitable solution for the aforementioned issue. The suggested approach stated that the energy provided by microbiological fuel cells (K_3) is superior to other strategies in terms of releasing enough energy to partially cover the costs. This method contributes to waste reduction while also producing energy, which will help with future energy demand issues.

However, advancements in technical tools and techniques for updating WtE technologies are on the horizon. In addition, integrated outranking technologies with improved theoretical underpinnings will be pursued in the future.

References

[1] Narayanamoorthy, S., Anuja, A., Brainy, J. V., Manirathinam, T., Pragathi, S., Parthasarathy, T. N., & Kang, D. (2022). Assessment of the Solid Waste Disposal Method during COVID-19 Period Using the ELECTRE III Method in an Interval-Valued q-Rung Orthopair Fuzzy Approach. CMES-Computer Modeling in Engineering and Sciences, 1229-1261.

[2] Zadeh, L. A. (1975). The concept of a linguistic variable and its application to approximate reasoning-I. Information sciences, 8(3), 199-249.

[3] Atanassov, K.T. (1983). Intuitionistic Fuzzy Sets, VII ITKR's Session, Sofia, Deposed in Central Sci; 1697/84; Central Library of the Bulgarian Academy of Sciences: Sofia, Bulgaria.

[4] Yager, R.R. (2013). Pythagorean fuzzy subsets. In Proceedings of the Joint IFSAWorld Congress and NAFIPS Annual Meeting, Edmonton, AB, Canada, June 24-28, 257-61.

[5] Yager, R. R., Abbasov, A. M. (2013). Pythagorean membership grades, complex numbers, and decision making. International Journal of Intelligent Systems, 28(5), 436-452.

[6] Yager, R. R. (2013). Pythagorean membership grades in multi-criteria decision making. IEEE Transactions on Fuzzy Systems, 22(4), 958-965.

[7] Smarandache, F. (1998). Neutrosophy/neutrosophic probability, set and logic. American Research Press, Rehoboth.

[8] Goguen, J. A. (1967). L-fuzzy sets. Journal of mathematical analysis and applications, 18(1), 145-174.

[9] Dubois, D., & Prade, H. (2005, September). Interval-valued Fuzzy Sets, Possibility Theory and Imprecise Probability. In EUSFLAT Conf. (pp. 314-319).

[10] Peng, X. (2019). New operations for interval-valued Pythagorean fuzzy set. Scientia iranica, 26(2), 1049-1076.

[11] Zhang, X. (2016). Multi-criteria Pythagorean fuzzy decision analysis: A hierarchical QUALIFLEX approach with the closeness index-based ranking methods. Information Sciences, 330, 104-124.

[12] Peng, X., & Yang, Y. (2016). Fundamental properties of interval-valued Pythagorean fuzzy aggregation operators. International Journal of Intelligent Systems, 31(5), 444-487.

[13] Garg, H. (2017). A novel improved accuracy function for interval valued Pythagorean fuzzy sets and its applications in the decision-making process. International Journal of Intelligent Systems, 32(12), 1247-1260.

[14] Liang, W., Zhang, X., & Liu, M. (2015). The maximizing deviation method based on interval-valued Pythagorean fuzzy weighted aggregating operator for multiple criteria group decision analysis. Discrete Dynamics in Nature and Society, 2015.

[15] Garg, H. (2017). A new improved score function of an interval-valued Pythagorean fuzzy set based TOPSIS method. International Journal for Uncertainty Quantification, 7(5).

[16] Chen, T. Y. (2018). An interval-valued Pythagorean fuzzy outranking method with a closeness-based assignment model for multiple criteria decision making. International Journal of Intelligent Systems, 33(1), 126-168.

[17] Rahman, K., Abdullah, S., Shakeel, M., Ali Khan, M. S., & Ullah, M. (2017). Interval-valued pythagorean fuzzy geometric aggregation operators and their application to group decision making problem. Cogent Mathematics, 4(1), 1338638.

[18] Stephy Stephen., Helen.M. (2021). Interval-valued neutrosophic pythagorean sets and their application in decision making using IVNP-TOPSIS. International Journal of Innovative Research in Science, Engineering and Technology, 10(12), 14571-14578.

[19] Narmada Devi, R., & Sowmiya, S. (2022). On solving game problem using octagonal neutrosophic fuzzy number, International Journal of Operational Research. (Accepted)

[20] Narmada Devi, R., & Sowmiya, S. (2022). Solution of sequencing problem by using neutrosophic octagonal number, AIP Conference Proceedings 2516, 340004; https://doi.org/10.1063/5.0108810.

[21] Jansi, R., Mohana, K., & Smarandache, F. (2019). Correlation measure for pythagorean neutrosophic sets with t and f as dependent neutrosophic components. Infinite Study.

[22] Abdel-Basset, M., Gamal, A., ELkomy, O. M. (2021). Hybrid Multi-Criteria Decision Making approach for the evaluation of sustainable photovoltaic farms locations. Journal of Cleaner Production, 328, 129526.

[23] Khan, I., Kabir, Z. (2020). Waste-to-energy generation technologies and the developing economies: A multi-criteria analysis for sustainability assessment. Renewable Energy, 150, 320-333.

[24] Van Thanh, N. (2022). Optimal Waste-to-Energy Strategy Assisted by Fuzzy MCDM Model for Sustainable Solid Waste Management. Sustainability, 14(11), 6565.

[25] Kurbatova, A., & Abu-Qdais, H. A. (2020). Using multi-criteria decision analysis to select waste to energy technology for a mega city: The case of Moscow. Sustainability, 12(23), 9828.

[26] Hezam, I. M., Gamal, A., Abdel-Basset, M., Nabeeh, N. A., & Smarandache, F. (2023). Optimal selection of battery recycling plant location: strategies, challenges, perspectives, and sustainability. Soft Computing, 1-32.

[27] Sleem, A., Mostafa, N., & Elhenawy, I. (2023). Neutrosophic CRITIC MCDM methodology for ranking factors and needs of customers in product's target demographic in virtual reality metaverse. Neutrosophic Systems with Applications, 2, 55-65.

[28] Gamal, A., & Mohamed, M. (2023). A hybrid MCDM approach for industrial robots selection for the automotive industry. Neutrosophic Systems with Applications, 4, 1-11.

[29] Narmada Devi. R, Sowmiya. S, & Anuja. A (2022). Selecting the suitable waste to energy technology for India using MULTIMOORA method under pythagorean neutrosophic fuzzy logic, Neutrosophic Sets and Systems. (Accepted)

[30] Chakraborty, S., & Zavadskas, E. K. (2014). Applications of WASPAS method in manufacturing decision making. Informatica, 25(1), 1-20.

[31] Zavadskas, E. K., Turskis, Z., Antucheviciene, J., & Zakarevicius, A. (2012). Optimization of weighted aggregated sum product assessment. Elektronika ir elektrotechnika, 122(6), 3-6.

[32] Ghorabaee, M. K., Zavadskas, E. K., Amiri, M., & Esmaeili, A. (2016). Multi-criteria evaluation of green suppliers using an extended WASPAS method with interval type-2 fuzzy sets. Journal of Cleaner Production, 137, 213-229.

[33] Deveci, M., Canitez, F., & Gokasar, I. (2018). WASPAS and TOPSIS based interval type-2 fuzzy MCDM method for a selection of a car sharing station. Sustainable Cities and Society, 41, 777-791.

[34] Diakoulaki, D., Mavrotas, G., & Papayannakis, L. (1995). Determining objective weights in multiple criteria problems: The critic method. Computers & Operations Research, 22(7), 763-770.

[35] Madic, M., & Radovanovic, M. (2015). Ranking of some most commonly used nontraditional machining processes using ROV and CRITIC methods. UPB Sci. Bull., Series D, 77(2), 193-204.

[36] Aznar Bellver, J., Cervello Royo, R. E., & Garcia Garcia, F. (2011). Spanish savings banks and their future transformation into private capital banks. determining their value by a multicriteria valuation methodology. European Journal of Economics, Finance and Administrative Sciences, 35, 156-164.

[37] Radhika, S., Kumar, D. S., Swapna, D. (2013). VIKOR method for multi criteria decision making in academic staff selection. Journal of Production research and Management, 3(2), 30-35.

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