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Determining the Best Plastic Recycling Technology Using the MABAC Method in a Single-Valued Neutrosophic Fuzzy Approach

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Abstract. In recent years, waste management approaches have shifted to recycling and recovery, and waste is now viewed as a potentially new resource. Several research projects have developed extensive plans to observe the planning in these waste management systems. These plastic recycling methods contribute to the creation of environmentally friendly products from waste. In this study, we present a method of multi-attribute decision making (MADM) to provide an efficient way to choose the best plastic recycling method from the selected four recycling alternatives. The multi-attribute border approximation area comparison (MABAC) method is used to evaluate the alternatives under the single-valued neutrosophic fuzzy set (SVNFS). Additionally, we used SWARA in computing the weights of the attributes. Finally, a numerical illustration is given for this problem.

Keywords: Multi-attribute decision making; single-valued neutrosophic fuzzy set; plastic recycling; MABAC.

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1. Introduction

Plastics, once a rare commodity, are now our most serious threat. Plastic is widely used, durable, and cheap, so its use has become a part of all sectors. The use of plastic products in our daily lives has inevitably increased. Plastics are mainly used in daily life items, medical and industrial equipment, and electrical appliances. It plays an important role in the products that people mostly use in all fields. The reason for using this plastic is that it is very easy to carry and the price is cheap, so people are using it more and more.

A reference to plastic materials in the Earth's environment that affect organisms living on the Earth's surface is called "plastic pollution". When plastics are burned, they pollute land, water, the oceans, and the air. Many environmental problems are caused by pollution due to its use and improper management. Balancing the production of plastics and their recycling and reuse after use is a major challenge in today's environment. We can't stop using plastic right now and make it better, but we can certainly find and use alternatives to reduce the use and production of plastic in the world. This research paper explains how to control the effects of plastic waste and how to recycle it. Reusing plastic can help reduce overproduction. The process of converting waste materials into new products is called recycling. This study discusses recycling methods for plastic and thermoplastic polymers. Also, we discussed the plastic recycling methods (PRM) and their processes.

Sabino Armenise et al.[1] fully examined and reviewed in the area of plastic recycling with pyrolysis methods. Martinez [2] studied plastic pyrolysis methods in American countries. Anuar et al. [3] reviewed some literature about pyrolysis methodologies in plastic wastes. Harish Jeswani et al. [4] disguised about pyrolysis of mixed plastic waste. Sofie Huysman et al. [5] studied the pertinence of the recyclability benefit index concepts. Pakiya Pradeep and Gowthaman [6] explained waste plastic as potential alternative sources for fossil fuel. Goodship [7] provided a compendious of the quantities and the main effects of recycling on the plastic material. Adeleka et al. [8] explained the sustainable utilization of energy from waste in South Africa. Chen et al. [9] discussed the various recycling energy recovery technologies. Wilson et al. [10] summarized pyrolysis technology in plastic waste management; the experimental results on the pyrolysis of thermoplastic polymers are discussed on single and mixed waste plastics. Based on a real-world case study, Gu et al. [11] assessed mechanical plastic recycling practices. Pacheco et al. [12] overview and investigated of plastic recycling difficulties were in the Metropolitan area of Rio de Janeiro. Shanker et al. [13] proposed recycling technological options for India and reprocessing infrastructure for PWR in India. Plastics recycling worldwide overviewed by dAmbrires [14]. Challenges, and opportunities of recycling plastics in Western Australia reported by Cceres Ruiz and Zaman [15]. Many researchers examined various recycling technologies. All of these studies examined and aimed to identify the most viable plastic recycling method. As a result, the study's goal was to develop a general framework for selecting the most appropriate PRM based on environmental and social factors.

Real-life decision-making problems are made more difficult by ambiguity and fuzzy logic. Zadeh [16, 17] created the concept of fuzzy set theory, which describes and converts data that is imprecise rather than accurate. The theory of fuzzy logic demonstrates an empirical basis for gathering information about the risks and unpredictability associated with human cognitive abilities such as reasoning and comprehension [18]. Due to the intricate nature of data and the vagueness of the way humans think, the ability to identify members of the set of fuzzy numbers is not always adequate for determining the features of issues. To overcome this restriction, Atanassov [19] converted the fuzzy set into an intuitionistic fuzzy set (IFS) by introducing the not-being-a-member and unwillingness functions. An IFS may indicate situations in three ways: superiority, complex inferiority, and skepticism, with intuitionistic fuzzy numbers (IFNs) typically representing these [20]. Smarandache [21] recommended the neutrosophic set and neutrosophic possibility in 1998, in addition to the reasoning behind them, which includes three distinct sense ideas such as truthfulness, indeterminacy, and untruthfulness. This idea additionally encompasses the idea of trepidation, which contributes to the research having a significant impact in specific research areas. In a neutrosophic fuzzy set (NSS), truthfulness is expressed by T, indeterminacy by I, and falsehood by F. All of these are separate, adding up to $0 \leq T + I + F \leq 3$. Although the level of membership as well as non-membership determines the ambiguity of IFS, the indeterminacy associated with NFS is not dependent on truth and untruth values. NFNs can be used to define the ambiguity, falsity, and unwillingness of information in an everyday issue. Karaaslan and Hunu [22] used the TOPSIS approach to determine and explain single-valued neutrosophic sets (SVNS) and their applications in multiple attribute group decision making (MCGDM).

Balwada et al. [23] identify a better waste collection system using AHP for packaging plastic waste. Geetha et al. [24] proposed a suitable recycling method for plastics under hesitant pythagorean fuzzy ELECTRE III. Vinodh et al. [25] examined the best recycling method using integrated MCDM methods. Soni et al. [26] proposed a triangular fuzzy weighted bonferroni mean operator AHP-TOPSIS model for selecting an appropriate composition for developing floor tiles from recycled waste plastics. Chakraborty and Saha [27] presented a new GDM process that combines the AHP model and WASPAS under LR fuzzy numbers to convey and model expert linguistic judgments. Afzal and Aslam [28] introduced a novel methodology to establish the relationship between capacitance and resistance when dealing with imprecise data obtained from LCR meters. Using a neutrosophic set, Abdelhafeez et al. [29] proposed a mean weighting methodology for analysing and selecting the best criteria in smart farming. The AHP is combined with the SVNS to deal with uncertain data in the assessment process of underwater vehicles studied by Mohamed et al. [30]. Gamal and Mohamed [31] examined the integrated MCDM methods for the industrial robot selection problem. Abdel-Basset et al. [32] suggested a hybrid MCDM method for choosing the components of a sustainable RES in unpredictable circumstances, employing various triangular neutrosophic numbers for dealing with ambiguous data. Abdl-Basset et al. [33] described a novel hybrid MCDM framework for classifying and selecting third-party reverse logistics provider identification. Rani et al. [34] investigated a novel single-valued neutrosophic mixed compromise solution approach for selecting renewable energy resources. Ali Salamai [35] explored a neutrosophic SWARA and VIKOR integrated technique for ranking strategies in energy problems related to decision-making. Based on the SVNFS, Stanujkic et al. [36] suggested a multiple-criteria evaluation model. The MABAC model was used by Sahin and Altun [37] in a probabilistic single-valued neutrosophic hesitant scenario. Wang et al. [38] elevated the MABAC procedure for MCGDM in a fuzzy Q-rung environment.

Many studies have focused on the application of plastic recycling methods in the existing literature. The goal of this study is to develop a new MCDM model for the plastic recycling problem. There has been no research using the MABAC method with a single-valued neutrosophic fuzzy set. As a result, it is critical to address the lack of research in plastic recycling treatments. The MABAC model successfully adapts to the relevance needs for plastic recycling techniques, which motivated us to research and develop our proposed model for PRM, which may substantially minimise plastic waste while also protecting the environment and society. This is urgently needed. The contribution of the study is to use the proposed method to choose the best plastic recycling method in terms of minimal operating expenses, a small amount of contamination, additional social benefits, and fewer harms to the environment. In this research, we combined the MABAC model with the SWARA weight finding method and performed an analysis of comparison to validate the suggested method's suitability for PRM problems against existing methods such as EDAS and WASPAS. Furthermore, sustainability was examined and provided as a sensitivity analysis.

In this study, we use the SVNFS to present an improved and trustworthy solution to the plastic recycling challenge under MABAC and SWARA methods. Moreover, numerous studies investigated plastic recycling methods using a variety of fuzzy sets with different MCDM approaches. To fill this research gap for this problem, we use the proposed method under SVNFN.

This paper is organized as follows: Section 2 - preliminaries; Section 3 - mathematical methods; Section 4 - application; Section 5 - numerical example of the application; Section 6 - comparative and sensitivity analysis of the obtained solutions; Section 7-conclusions.

2. Preliminaries

Definition 2.1. [34, 36] Let U be a universal set. A fuzzy set F on U is a form

$$F = \{(a, \mu_F(a))|a \in U, 0 \leq \mu_F(a) \leq 1\}$$

Where $\mu_F(a)$ denoted the membership degree of $a \in U$ to F.

Definition 2.2. [34, 36] A neutrosophic fuzzy set N on U is a form:

$$N = \{(a, T_N(a), I_N(a), F_N(a)) : a \in U\}$$

where $T_N(a), I_N(a), F_N(a) \in [0, 1], 0 \leq T_N(a) + I_N(a) + F_N(u) \leq 3$ for all $a \in U$, $T_N(a)$ is membership, $I_N(a)$ is indeterminacy and $F_N(a)$ is non-membership degree. Here, $T_N(a)$ and $F_N(a)$ are dependent and $I_N(a)$ is an independent components.

Table 1. Linguistic scale

Linguistic term	Single-valued neutrosophic fuzzy number
Extremely High Preferred (EHP)	(0.85, 0.20, 0.15)
Very High Preferred (VHP)	(0.80, 0.25, 0.20)
High Preferred (HP)	(0.75, 0.25, 0.25)
Moderate (M)	(0.70, 0.30, 0.30)
Moderate Preferred (MP)	(0.65, 0.30, 0.35)
Low Moderate Preferred (LMP)	(0.60, 0.35, 0.40)
Extremely Moderate Preferred (EMP)	(0.55, 0.40, 0.45)

Definition 2.3. [36] A SVNF set S in U is a form:

$$S = < a, T_S(a), I_S(a), F_S(a) > | a \in U$$

Where $T_S : U \to [0,1]$ is called the truth-membership grade of $a \in U$ to S, $I_S : U \to [0,1]$ is indeterminacy-membership, $F_S : U \to [0,1]$ is called the falsity-membership grade. They satisfy $0 \leq T_S(a) + I_S(a) + F_S(a) \leq 3$ for $a \in U$.

Definition 2.4. [36, 37] Let $h =< T, I, F >$ be a SVNFN. The score function A_h of h is a follows:

$$A_h = (1 + T - 2I - F)/2$$

Where $A_h \in [-1, 1]$.

Definition 2.5 (31,39)**.** Let $m = (k_1, f_1)$ and $n = (k_2, f_2)$ be two SVNNs, then the single-valued neutrosophic fuzzy normalized hamming distance (SVNFNHD) is

$$D_{Ham}(m,n) = \frac{1}{3n} \sum_{i=1}^{n} (|T_m(a_i) - T_n(b_i)| + |I_m(a_i) - I_n(b_i)| + |F_m(a_i) - F_n(b_i)|)$$

Definition 2.6. Linguistic variables deal with many more complex and uncertain real-world decision-making problems [40]. Table 1 shows the linguistic variables with SVNFNs used to evaluate the PRM based on selected attributes and the linguistic scale.

3. Mathematical Methods

Pamucar and Cirovi [33] established the MABAC, which is an innovative distance-based approach. This strategy's policy is based on calculating criterion function parameters for alternatives and expressing the criterion function's distance from the border approximation area. As a result, all alternatives can be included into the approximation area's border (G), upper ($G+$), or lower ($G-$).

The procedure of the fuzzy MABAC method is discussed below.

4. The fuzzy MABAC method

Here, m alternatives $X_1, X_2, ..., X_m$, n attributes $Y_1, Y_2, ..., Y_n$ are given with weight W_j, and the decision-making procedures of the traditional MABAC method are explained below.

Step 1: Create the initial decision matrix $F = [X_{ij}], i = 1, 2, ..., m, j = 1, 2, ..., n$ as:

$$F = [X_{ij}] = \begin{bmatrix} x_{11} & x_{12} & ... & x_{1n} \\ x_{21} & x_{22} & ... & x_{2n} \\ \vdots & \vdots & ... & \vdots \\ x_{m1} & x_{m2} & ... & x_{mn} \end{bmatrix} \tag{1}$$

where x_{ij} represents the evaluation information of alternative X_i based on attributes Y_j by decision maker E.

Step 2: Normalize the initial decision matrix (NDM) $N = [X_{ij}]$ based on beneficial and non-beneficial attributes which are given below:
For beneficial attributes:

$$N_{ij} = X_{ij}, i = 1, 2, ..., m, j = 1, 2, ..., n \tag{2}$$

For non-beneficial attributes:

$$N_{ij} = 1 - X_{ij}, i = 1, 2, ..., m, j = 1, 2, ..., n \tag{3}$$

Step 3: In accordance with the NDM N_{ij} and attribute's weight values w_j; the weighted normalized matrix (WNDM) $V_{ij} = w_j N_{ij}$ can be calculated as:

$$V_{ij} = w_j N_{ij} \tag{4}$$

Step 4: Calculate the border approximation area (BAA) values and the BAA matrix $B = [b_j]_{1\times n}$ can be obtained as below:

$$b_j = (\prod_{i=1}^{m} V_{ij}) \tag{5}$$

Step 5: Obtain the distance $D = [d_{ij}]_{m\times n}$ between each alternative and the BAA is given below:

$$d_{ij} = \begin{cases} d(V_{ij}, b_j) & if \quad V_{ij} > b_j \\ Otherwise & if \quad V_{ij} = b_j \\ -d(V_{ij}, b_j) & if \quad V_{ij} < b_j \end{cases} \tag{6}$$

where $d(V_{ij}, b_j)$ denotes the distance from V_{ij} to b_j. Based on the values of d_{ij},

- if $d_{ij} > 0$, the alternatives are in the upper approximation area $G^+(UAA)$;
- if $d_{ij} = 0$, the alternatives are in the border approximation area $G(BAA)$;
- if $d_{ij} < 0$, the alternatives are in the lower approximation area $G^-(LAA)$;

Clearly, the best alternatives are in $G^{+}(UAA)$ and the worst alternatives are in $G^{-}(LAA)$.

Step 6: Sum the values of each alternatives d_{ij} is given below:

$$R_i = \sum_{j=1}^{n} d_{ij} \tag{7}$$

Here, the highest value of the alternative R_i is the best choice from the evaluation results.

4.1. *The Step-wise Weight Assessment Ratio Analysis weighting method*

The SWARA model developed by Kresuliene et al. [34] helps experts find criteria weights. The SWARA model procedure is as follows:

Step 1: Sort the criteria by priority.

Step 2: Obtain its relative importance δ_j.

Step 3: Compute γ_j, where $\gamma_j = \delta_j + 1$.

Step 4: Determine the starting weights $\eta_j, \eta_j = \frac{\delta_j}{\delta}$.

Step 5: Finally, in order to determine the final ranking of the criteria W_j, where $W_j = \frac{\eta_j}{\sum \eta_j}$.

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5. **Application**

Plastics are a type of chemical-based or partly synthetic substance that consists mainly of polymers. Because of their flexibility, plastics can be shaped, ejected, or transformed into solid things of various shapes. This versatility, along with additional features such as thinness, longevity, adaptability, and low manufacturing expenses, has contributed to its broad adoption. Plastics are usually manufactured using human industrial machinery. Most present-day plastics contain chemicals produced from fossil fuels such as natural gas or gasoline.

Plastic waste (PW) is a major source of solid waste pollution all over the world. PWs slow degradation rate kills billions of living organisms. People all over the world have tried different types of methods to degrade or convert PW into usable materials in order to dispose of it. Incineration involves the combustion of PW, which produces toxic gases. Recycling is another method for converting PW into new plastic products. Recycling is required because almost all plastic is non-biodegradable and thus accumulates in the environment, causing harm.

Modern landfill technology is already vastly superior to older landfills and open-air dumps. New landfills in the various countries are better designed and built in safer locations to reduce or prevent seepage of noxious water or gases into the environment. Especially by recycling plastic materials, the biggest impact can be avoided. The use of plastic waste to build roads can lead to quality roads. Learning basic knowledge about recycling processes will definitely help us fight plastic pollution and choose the most suitable recycling method. Modern policies are now in place to recycle plastics.

Mechanical recycling is the process of making secondary materials without significantly changing the chemical structure of the plastic. Thermoplastic is recycled in this manner [1, 4]. Pyrolysis is a chemical process that breaks down plastic by recycling it. When plastic waste is separated and extracted from pyrolysis, its raw materials reveal an excess of crude oil. Stabilization of plastic waste at different temperatures $(300 - 900^{o}C)$ in anoxic or low oxygen conditions is called "pyrolysis". In this case, their hydrocarbon composition is cracked instead of being heated. Pyrolysis is the process by which discarded plastic is converted into a valuable resource in the form of fuel and monomers. This recycling offers many advantages over conventional plastic waste management; another recycling method reduces the plasticity compared with pyrolysis. As the plastic is repeatedly recycled, its strength and flexibility decrease [1].

Cold plasma pyrolysis is the most advanced method of pyrolysis. In common, the method of pyrolysis is thermal decomposition with limited oxygen at temperatures between $400 and 650C$. From this process, one can generate electricity and fuels; in particular, when cold plasma is added to the pyrolysis process, waste plastics give off hydrogen, methane, and ethylene. Green energy can be generated from plastic waste. Hydrogen and methane are able to be employed as environmentally friendly energy sources due to their low emissions of CO_2, while ethylene is the basic component of most plastics. Rather than wasting plastics, cold plasma pyrolysis may preserve valuable substances that can be used to manufacture other kinds of plastic [35].

PRM is critical as a waste management method and as an essential part of the new circular economy and no-waste systems, all of which are designed to decrease waste and improve ecological sustainability. Only a small percentage of plastic waste is recycled. There are several reasons for this, and while our plastic waste is increasing, technological advancements and changes in how we recycle are assisting in making it more successful and efficient. In this paper, we propose the best plastic recycling method based on a single-valued neutrosophic fuzzy approach, using the fuzzy MABAC and SWARA methods.

6. **Numerical Illustration**

In this section, we discuss the PR treatment problem under the single-valued neutrosophic fuzzy set using the MABAC and SWARA model. Here, the decision maker evaluate this problem based on the four attributes which are Y_1 - Environment, Y_2 - Technology, Y_3 - Economic, and Y_4 - Social aspects. The PR technologies are X_1 - Cold Plasma Recycling, X_2 - Mechanical recycling, X_3 - Pyrolysis Recycling and X_4 - New trends in Landfill.

TABLE 2. Weight values of the criteria

Criteria	δ_j	$\gamma_j = \delta_j + 1$	$\eta_j = \frac{\delta_{j-1}}{\delta}$	$W_j = \frac{\eta_j}{\sum \eta_j}$
Y_1	0	1	1	0.4186
Y_4	0.32	1.32	0.7575	0.3171
Y_2	0.48	1.8	0.4208	0.1761
Y_3	0.20	2	0.2104	0.0880

To address this issue, experts use the proposed method to evaluate PRM. A decision matrix is constructed using the linguistic scale.

6.1. *SWARA method:*

Using the SWARA model procedure, we get the weight values of the attributes, which are shown in Table 2.

6.2. *The fuzzy MABAC method:*

The plastic recycling techniques and attributes are given below:

X_1 – Cold Plasma Recycling

X_2 – Mechanical recycling

X_3 – Pyrolysis Recycling

X_4 – New trends in Landfill

Attributes are as follows:

Y_1 – Environment

Y_2 – Technology

Y_3 – Economic (8)

Y_4 – Social aspects

Step 1: The evaluation attribute chosen by the decision maker is used to evaluate the plastic recycling techniques. Table 3 shows the initial decision matrix along with the assessments in the format of SVNFNs obtained from transforming the linguistic factors from Table 1.

Step 2: Table 4 shows the results of obtaining the NDM by using equations (2) and (3).

Step 3: The weighted NDM can be calculated using equation (4), which is given in Table 5.

Step 4: Using equation (5), calculate the BAA values shown in Table 6.

Step 5: Obtained the distance d_{ij} by applying the equation (6) which is shown in Table 7.

Table 3. Initial decision matrix

Alternatives / Attribute	Y_1	Y_2	Y_3	Y_4
X_1	(0.70, 0.35, 0.20)	(0.70, 0.30, 0.30)	(0.60, 0.30, 0.35)	(0.70, 0.25, 0.45)
X_2	(0.55, 0.30, 0.40)	(0.65, 0.35, 0.20)	(0.85, 0.25, 0.30)	(0.60, 0.25, 0.30)
X_3	(0.80, 0.25, 0.45)	(0.75, 0.30, 0.25)	(0.55, 0.25, 0.35)	(0.80, 0.35, 0.30)
X_4	(0.65, 0.40, 0.30)	(0.85, 0.35, 0.20)	(0.80, 0.25, 0.40)	(0.85, 0.30, 0.35)

Table 4. Normalized decision matrix

Alternatives / Attribute	Y_1	Y_2	Y_3	Y_4
X_1	(0.70, 0.35, 0.20)	(0.70, 0.30, 0.30)	(0.40, 0.70, 0.65)	(0.70, 0.25, 0.45)
X_2	(0.55, 0.30, 0.40)	(0.65, 0.35, 0.20)	(0.15, 0.75, 0.70)	(0.60, 0.25, 0.30)
X_3	(0.80, 0.25, 0.45)	(0.75, 0.30, 0.25)	(0.45, 0.75, 0.65)	(0.80, 0.35, 0.30)
X_4	(0.65, 0.40, 0.30)	(0.85, 0.35, 0.20)	(0.20, 0.75, 0.60)	(0.85, 0.30, 0.35)

Table 5. Weighted normalized decision matrix

Alternatives / Attribute	Y_1	Y_2	Y_3	Y_4
X_1	(0.2930, 0.1465, 0.0837)	(0.0792, 0.2219, 0.2219)	(0.0704, 0.1232, 0.1144)	(0.0264, 0.066, 0.0484)
X_2	(0.2302, 0.1255, 0.1674)	(0.1109, 0.2061, 0.2536)	(0.0264, 0.1320, 0.1232)	(0.0352, 0.066, 0.0616)
X_3	(0.3348, 0.1046, 0.1883)	(0.0792, 0.2219, 0.2378)	(0.0792, 0.1320, 0.1144)	(0.0176, 0.0572, 0.0616)
X_4	(0.2720, 0.1674, 0.1255)	(0.0475, 0.2061, 0.2536)	(0.0352, 0.1320, 0.1056)	(0.0132, 0.0616, 0.0572)

Table 6. BAA values

b_j	values
b_1	(0.2120, 0.1014, 0.1021)
b_2	(0.0657, 0.0285, 0.0205)
b_3	(0.1134, 0.3085, 0.2716)
b_4	(0.1286, 0.0500, 0.0607)

Step 6: Sum the values of each alternatives R_i is calculated by using equation (7). The final ranking results are shown in Table 8.

From this Table 8, X_1-Cold plasma recycling technology is the most suitable and environment friendly method for plastic recycling method.

TABLE 7. Distance d_{ij} values

	Y_1	Y_2	Y_3	Y_4
X_1	0.0917	0.0905	0.0586	0.0790
X_2	-0.1052	0.0824	-0.0566	0.0812
X_3	0.0970	0.0869	0.0685	-0.0902
X_4	-0.0972	-0.0886	-0.0560	-0.0871

TABLE 8. The final ranking results

Alternatives	R_i values	Ranking result
X_1	0.3198	1
X_2	0.0018	3
X_3	0.1622	2
X_4	-0.3289	4

7. Comparison and sensitivity analysis

In this section, we analyze the proficiency of this suggested method through the comparison of existing methods such as EDAS and WASPAS in the case of a SVNFN. For this study, sensitivity analysis was also established.

7.1. *Comparison Analysis*

Although contrasted to the EDAS and WASPAS shown in Figure 1, the MABAC is more readily compatible with our application. The analysis of comparison in this study generates more realistic and consistent outcomes if compared with different approaches. In short, instead of the EDAS and WASPAS techniques, the MABAC requires an alternative comparison. Furthermore, the selection results generated by the suggested approach provide more data in the form of a reliability index of outranking relationships among alternatives, which is more beneficial for the suggested approach. Table 9 indicates the order of importance provided for the two methods as well as the order of ranking results, and the graphic depictions are shown in Figure 1. We focused on just four criteria to determine alternatives in this paper; however, future research can employ the proposed approach to consider additional aspects such as expenses for operations and societal benefits. The proposed ranking produces results that more differ from the existing EDAS and WASPAS methods. As a result, the proposed approach produces more reliable results when compared to other MCDM model.

TABLE 9. Comparison analysis results

Alternatives	EDAS	Rank	VIKOR	Rank	Proposed method	Rank
X_1	0.2375	2	0.4216	1	0.3198	1
X_2	0.1818	3	0.4169	2	0.0018	3
X_3	0.3906	1	0.4033	4	0.1622	2
X_4	-0.1901	4	0.4137	3	-0.3289	4

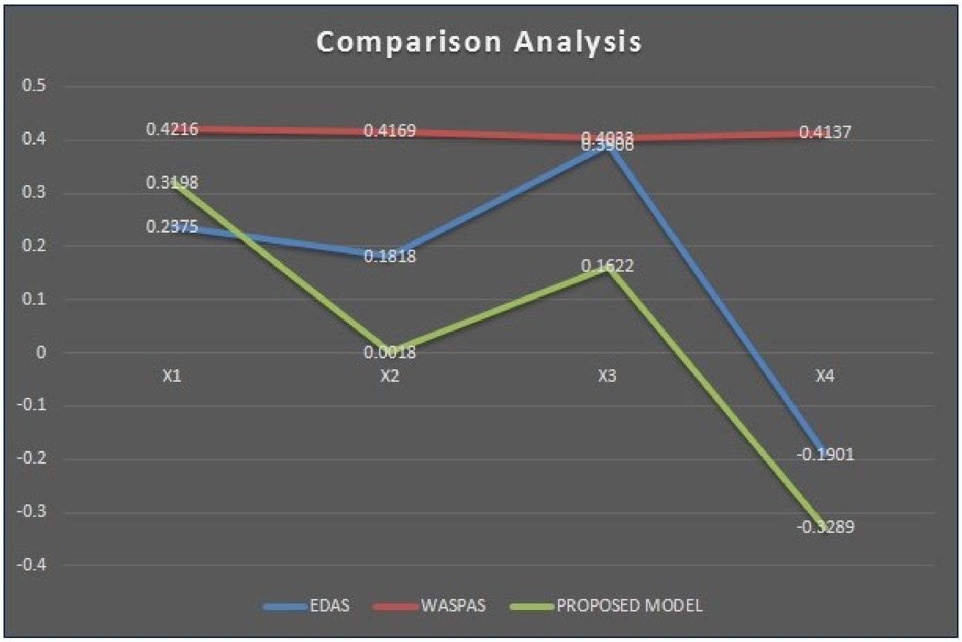

FIGURE 1. Graphical representation for comparison analysis

7.2. *Sensitivity analysis*

The sensitivity evaluation of this framework is contrasted with the outcomes of three cases, as shown in Table 10. These cases are discovered by varying the weights of the criteria. Case 1 is the study's outcome, and Cases 2 and 3 are each of the results obtained by applying various attribute weights. Sensitivity analysis reveals that changing the attribute weights has an impact on the overall order, as shown in Table 11, and Figure 2 depicts their graphical representation.

7.3. *Results and discussion*

There are numerous advantages to the cold plasma recycling of plastics. This results in a decrease in the utilization of novel goods and energy, lowering carbon dioxide emissions. As a

TABLE 10. Weights in sensitivity analysis

Attribute	Case 1	Case 2	Case 3
Y_1	0.4186	0.3171	0.1761
Y_2	0.3171	0.0880	0.4186
Y_3	0.1761	0.4186	0.0880
Y_4	0.0880	0.1761	0.3171

TABLE 11. Sensitivity analysis results

Alternatives	Case 1	Rank	Case 2	Rank	Case 3	Rank
M_1	0.3198	1	0.2185	2	0.1496	2
M_2	0.0018	3	-0.3793	4	0.0803	3
M_3	0.1622	2	0.3927	1	0.2427	1
M_4	-0.3289	4	-0.0592	3	0.0649	4

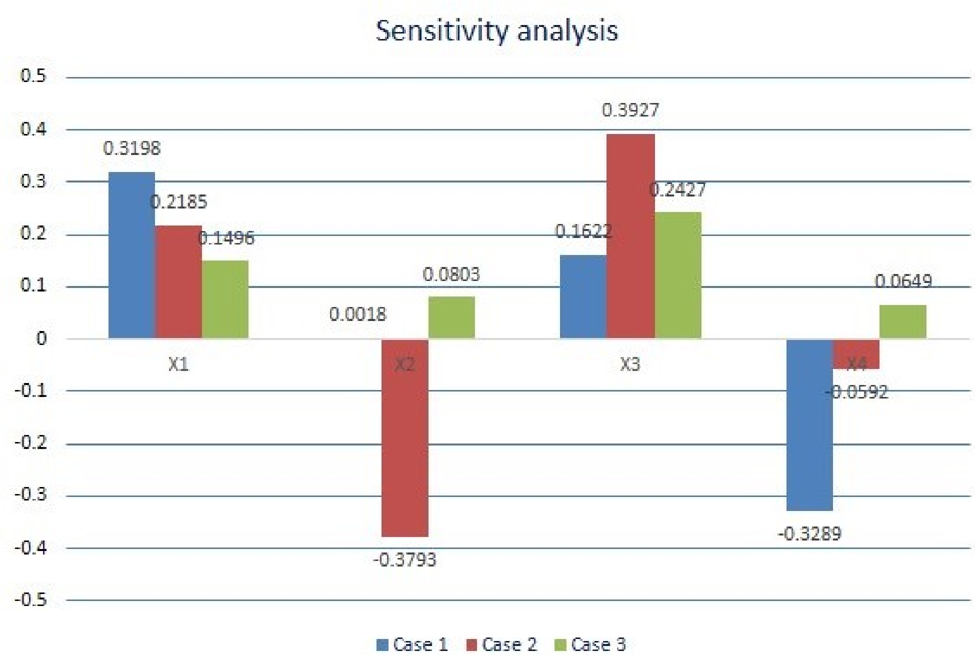

FIGURE 2. Graphical representation for sensitivity analysis

result, the cold plasma recycling method is a good plastic recycling method that contributes to lowering plastic waste [41]. Cold plasma recycling alternative X_1 is the best PRM technique. Furthermore, the overall ranking of the choices for this problem proposed a one-of-a-kind method. Because experts struggled to evaluate choices among the various levels of contentment and frustration in order to estimate unknowns, this research study used the SVNN to handle the data. Based on the end ranking results (Fig. 2), an enhanced MABAC model looks to be more precise and suitable to address a various of other issues in MADM. The contrast between suggested model and other ranking strategies reveals that proposed model provides a more realistic and suitable solution that is easier to implement. The obtained weight values of criteria show that this approach was combined with the advanced, rapid, and precisely calculated SWARA weight finding method. In this paper, we propose a cohesive MCDM model for the plastic recycling problem. The MABAC method is used to determine the order of the alternatives, and SWARA is used to calculate the weights of the criteria. These processes are particularly effective when contrasted with some MCDM methods. The MABAC model computes the distance between each alternative and the bore estimation area. This model has numerous benefits over other MCDM methods, including shorter processing times, greater ease and stability, and fewer numerical computations [42]. As a result, decision makers will be able to use fuzzy MABAC to select the best alternative with regard to processing time, reliability, and expenses. Compared to other criteria weight determination methods (such as AHP), the SWARA method has reduced computational challenges and greater consistency. As a result of these benefits, the SWARA method has been used to solve real-world issues in a variety of scenarios [43]. SWARA gives more plausible weight values than other weighting methods due to more consistent computations.

8. **Conclusion**

In this regard, the mathematical model is an important tool for the evaluation of plastic waste management systems and illustrates an efficient implementation of plastic recycling approach to the plastic recycling methods. The SVNFs decision techniques have distinguished similar rankings among the administrative choices when target weights are allocated to the criteria. An alternate ranking is obtained just with the weight set which vigorously needs technical/operation indicators. Consequently, attribute weighting is an important process in decision making. In this paper, we conclude cold plasma recycling method is the best alternative solution for the plastic recycling planning. This gives energy producing technique also and environmental friendly.

Plastic recycling methods, among others, have been recognised as a promising solution to the issue of intricately made and growing waste from plastics in advanced nations like the European Union and the US. The government and policymakers, on the other hand, continue to face major obstacles in determining appropriate plastic recycling techniques for establishing effective waste disposal systems. As a result, this research was conducted in order to suggest an overall organised structure that can assist policymakers in determining the most suitable technology. In this paper, MABAC and SWARA methods under single-valued neutrosophic fuzzy environment were presented. The characteristics of every option are represented by SVNFNs. According to the suggested strategy for determining a suitable solution for this problem, cold plasma recycling has been selected as the most secure and best-performing PRM technique in the present scenario. This method reduces waste while generating energy, which will aid in addressing future energy challenges. In the future, we are interested in extending the proposed method to other issues, such as microplastic disposal. Furthermore, applying the suggested methodology to the Pythagorean neutrosophic fuzzy approach is an intriguing avenue for future research.

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