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Selection of Sustainable Material for the Construction of Drone Aerodynamic Wing using Neutrosophic RAWEC

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Abstract

In light of the expansion of the use of drones in many fields, the development of the drone industry has gained the attention of many researchers. The process of selecting the materials used in developing and constructing the wing of the drone has become a very important and complex matter due to its reliance on multiple and sometimes conflicting criteria. Therefore, it must have an informed approach to the selection and decision-making process thoughtfully. The goal of this research is to introduce a new approach in a neutrosophic environment for the first time, to select the most suitable material for constructing a drone wing. The material must meet several criteria, including low weight, high rigidity, resistance to deformation, durability, and excellent stability. Neutrosophic is one of the most effective tools for dealing with ambiguity since it addresses the problem of uncertainty in the decision-making process. We have presented the SVTNSs - LMAW (single value triangular neutrosophic sets-logarithm methodology of additive weights) approach for calculating the weights of criteria and the new SVTNSs - RAWEC (single value triangular neutrosophic sets-ranking alternatives with weights of criterion) approach for ranking available alternatives involves straightforward computation steps, eliminating the need for pairwise comparisons in contrast to other MCDM approaches and saving time. Also, we examined the impact of changing the normalization method on the rank of the alternatives. We have conducted a sensitivity analysis to ensure the strength and stability of our proposed approach, and the results have proven that the proposed approach for selecting the appropriate material in light of ambiguity and lack of certainty that occurs in real life is very effective. By using the SVTNSs-LMAW-RAWEC approach the companies and factories will choose the most effective and efficient materials to develop and create a drone wing.

Keywords: Soft Computing, MCDM, SVTNS, RAWEC, LMAW, Drone Aerodynamic Wing, Triangular Neutrosophic Numbers.

1 | Introduction

In recent years, the artificial intelligence and robotics industries have led to significant scientific and technological advancements. Drones are one example of artificial intelligence applications, contributing to various fields such as agriculture, industry, medicine, military, engineering, and rescue operations [1-4]. Thus, the design and development of drones are crucial, with careful consideration given to the materials used in their manufacture [5]. The selection of appropriate sustainable materials for drones is a crucial design requirement based on their intended use.

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The wing of a drone is a crucial component because it affects its functions, performance, and durability. Selecting materials for the drone wing is a major challenge where researchers are interested in using lighter materials to reduce aircraft weight while maintaining durability and rigidity therefore there is optimization of design parameters, assistance for design configurations, and optimization of performance parameters that can be applied in many applications [6]. A new design was implemented to enable the materials to withstand pressure and force, composite materials and additional layers to the material were utilized to enhance the material's hardness [7]. One of the most prevalent composite materials in the drone industry is reinforced polymer because of its characteristics and high quality [8]. It has been found that Kevlar, polymer reinforced with carbon fibers, titanium alloys, and aluminum are among the most important materials for designing and developing drone wings [5, 9]. When choosing, there are evaluation criteria that must be taken into consideration, such as hardness, strength, resistance to vibration, resistance to deformation, and cost. Technical and economic needs must be balanced when selecting materials for drones. Meeting these requirements is complex and challenging. If choosing the right materials for drones is important, then selecting the ideal material from among these options becomes extremely crucial and poses a challenge for decision-makers where choosing an unsuitable material can lead to structural failure, resulting in wasted time and money. Therefore, there is a need for a powerful tool that assists decision-makers in making informed decisions based on scientific expertise. As a result, the issue has been categorized as a decision-making problem.

The MCDM technique is commonly used to select the best material for various applications [10, 11]. It provides the benefit of making intricate decisions based on multiple criteria at the same time. It allows for the consideration of both qualitative and quantitative factors, while also reducing risks and maximizing decision performance. This enhances the fairness and transparency of the decision-making process. The most popular approach for selecting the material for a drone's wing is TOPSIS [12, 13]. Senan, M.H., et al. [14] utilized the TOPSIS method to select the best natural fiber composite yarn material for building the drone structure, they used seven evaluation criteria (tensile power, modulus of tensile, flexibility or strength, Modulus of flexure, deformation, von misses tension, strain) and five alternatives, demonstrating that the top material among the available options is r-WoPPC NaOH Silane. AL-Taie, A.I. and Q.M. Doos [15] utilized the grey relational approach and the Entropy Method to select the best material for manufacturing rotary helicopters. They concluded that the CFRP material is the most suitable choice. All of the previously mentioned literary works explained the importance of using MCDM technology for selecting the material used in drone construction. The RAWEC (ranking alternatives with weights of criterion) method is one of the new MCDM methods presented in 2024 [16], characterized by its simple calculations that contain a small number of steps and do not require pairwise comparisons. In addition, it is easy to understand but it has a limitation where the rank of alternatives depends on the deviations from ideal values. Petrovic, N., et al [17] utilized the RAWEC and entropy methods to assess several environmentally friendly forms of transportation in the European Union. In [18] authors used RAWEC, RAM, PIV, and SRP methods to assess and choose Vietnam's top colleges. However, until now, the RAWEC method has not been used to choose the appropriate sustainable material for manufacturing a drone wing. The RAWEC method [16] does not account for uncertainty and vagueness in decision-making processes that are common in real-life situations. By using the neutrosophic set in MCDM, ambiguity and uncertainty can be effectively managed, in addition the neutrosophic sets differentiate between relative and absolute truth. Also, LMAW method which presented by Pamucar, D., et al. [19] is one of the MCDM methods for calculating the criteria's weight coefficients which handles the rank reversal problem that occurs in the TOPSIS method and shows stability in a dynamic environment. In [20-23], the researchers utilized the LMAW method with a fuzzy environment for the decision-making process. However, the fuzzy set cannot deal with the indeterminacy and inconsistency that occur in reality since it deals only with truth and falsehood. Thus, we are the first to apply the LMAW and RAWEC approaches within the context of the neutrosophic environment (SVTNSs – LMAW- RAWEC) to select suitable material for drone construction. We evaluated six criteria and four alternatives with the help of experts.

Contributions of this research:

- Developed a new version of the LMAW approach in a neutrosophic environment for the first time for calculating the weight of criteria.
- Developed a new version of the RAWEC approach in the context of a neutrosophic environment to select the appropriate material for drone construction.
- Study the effect of changing the normalization method in REWAC on the final rank.
- Our approach addresses the ambiguity in the decision-making process that happens in reality, aiding in the construction of a precise decision matrix.
- A sensitivity analysis was performed to assess the proposed approach and determine its stability under various sets of criteria weights.

2 | Techniques

This section proposes a novel MCDM structure based on the LMAW technique, SVTrN set, and the RAWEC technique and called single value triangular neutrosophic sets LMAW-RAWEC (SVTNSs – LMAW-RAWEC). In this structure, the weights of evaluation criteria are evaluated through a novel SVTNSs -LMAW approach, and a novel SVTNS -RAWEC approach used for ranking the alternative. The procedure of the developed structure is depicted in Figure 1 and is given by:

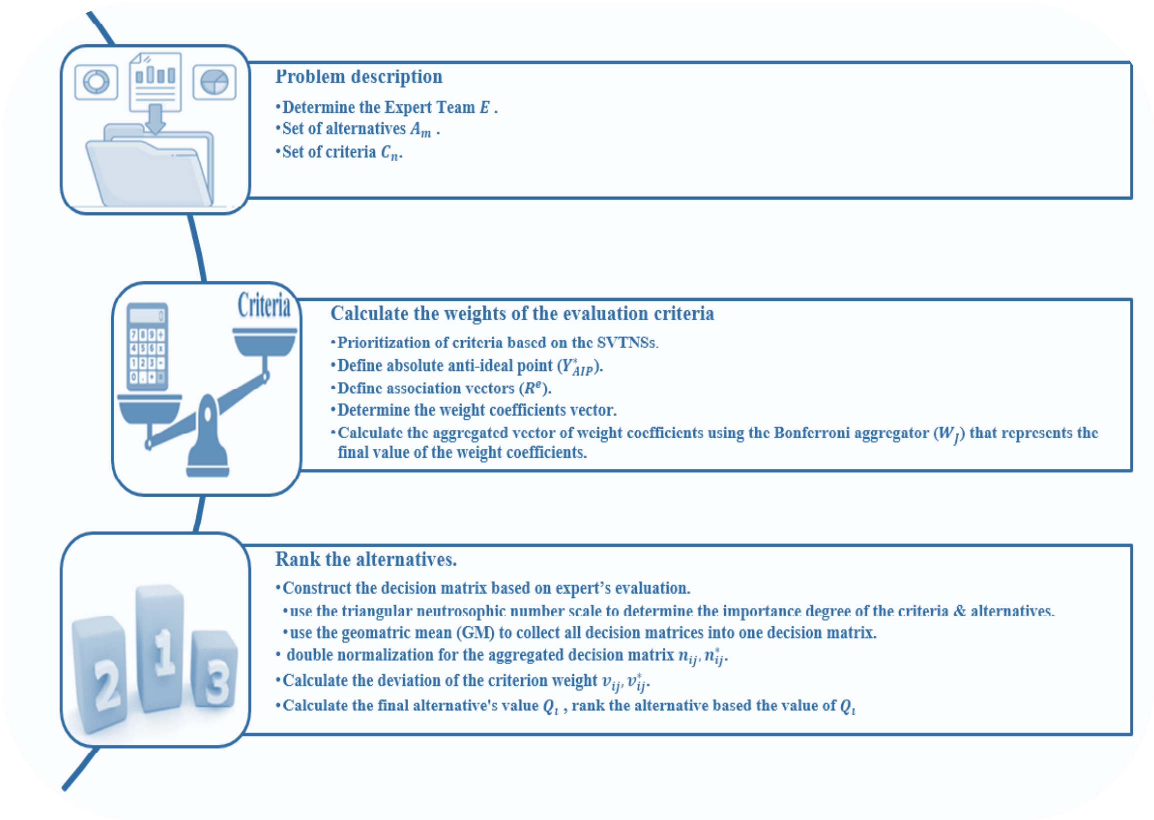

Figure 1. The steps of our approach.

Step 1. Problem description.

For an MCDM process, let a team of experts in the problem domain $E = \{e1, e2 \dots e_k\}$ construct set of linguistic decision matrices $DM = \{DM1, DM2 \dots \dots DM_k\}$ based on the predefined linguistic scale to find out the optimal alternative amongst a set of A alternatives $A = \{A1, A2, \dots \dots A_m\}$ under the set of criteria $c = \{c1, c2, \dots \dots c_n\}$. Also, the weight coefficients of the criteria are defined $w_j = \{w_1, w_2, \dots w_n\}$, where$\sum_{j=1}^{n} w_j = 1$.

Step 2. Calculate the weights of the evaluation criteria.

Determine the weight coefficient of the criteria using the LMAW approach. The LMAW approach is akin to the TOPSIS method but is more dependable in dynamic environments [19]. It tackles the problem of rank reversal that TOPSIS encounters and is effective in handling substantial amounts of data. Furthermore, adjusting the number of possibilities and criteria does not impact the consistency of the mathematical structure of the LMAW approach.

Step 2.1. Prioritization of criteria.

Each expert from the expert team $E = \{e1, e2 \dots e_k\}$ ranks the criteria $c = \{c1, c2, \dots \dots c_n\}$according to the degree of priority. When assigning priority to a criterion, linguistic values like "very good" or "good" are used. However, these values are incomplete and ambiguous because they don't provide the degree of certainty for the evaluation. As a result, priority is based on unclear information. To address these issues, we utilize the triangular neutrosophic number scale to assign priority to the criteria. The experts' preferences are represented using the triangular neutrosophic number scale which appears in Table 1. After that, we convert these linguistic terms into clear values using the score function in Eq. (7). Thus, we obtain the priority vector $p^e = \{\Upsilon_{c1}^e, \Upsilon_{c2}^e, .. \Upsilon_{cn}^e\}$, where the Υ_{cn}^e represents the value from the linguistic scale assigned by expert e $(1 < e < k)$ to criterion $c_i(1 < i < n)$.

Table 1. Linguistic variables to determine the degree of priority for criteria [24].

Terms	L,M,U	Validation degree (T,I,F)
Absolutely Not Important (ANI)	$<(0,0,0)>$	Absolutely not sure (ANS) $<(0,1,1)>$
Not Important (NI)	$<(0,0,1)>$	Not sure (NS) $<(0.25, 0.75, 0.75)>$
Slightly Important (SI)	$<(1,2,3)>$	Slightly sure (SLS) $<(0.45,0.60,0.60>)$
Median Important (MI)	$<(2,3,4)>$	Median sure (MS) $<(0.5,0.5,0.5)>$
Important (I)	$<(3,4,5)>$	Sure (S) $<(0.75,0.20,0.20)>$
Strongly Important (SI)	$<(5,6,7)>$	Strongly sure (STS) $<(0.85,0.15,0.15)>$
Very Strongly Important (VSI)	$<(6,7,8)>$	Very strongly sure (VSS) $<(0.90,0.10,0.10)>$
Absolutely Important (AI)	$<(7,8,9)>$	Absolutely sure (AS) $<(1.00,0.00,0.00)>$

Step 2.2. Define absolute anti-ideal point (Υ^*_{AIP}), the value denotes the least significant value among all the values in the set of all priority vectors, as follows:

$$\Upsilon^*_{AIP} = \frac{\Upsilon_{min}^e}{s} = \frac{\min\{\Upsilon_{c1}^e, \Upsilon_{c2}^e, .. \Upsilon_{cn}^e\}}{s} \tag{1}$$

Where s is the number greater than the base of the (ln) logarithm function.

Step2.3. Define association vectors (R^e), the association is determined between each element of the priority vector and the absolute anti-ideal point (Υ^*_{AIP}) to lower the criteria scores' value, as follows:

$$av_{cn}^e = \frac{\Upsilon_{cn}^e}{\Upsilon^*_{AIP}} \tag{2}$$

$$R^e = (av_{c1}^e, av_{c2}^e, \dots av_{cn}^e) \tag{3}$$

Where av_{cn}^e is the value from the association vector obtained by Eq. (2), and R^e is the association vector of expert e $(1 < e < k)$.

Step2.4. Determine the weight coefficients vector (w_j) for each expert $(1 < e < k)$, as follows:

$$w_j^e = \frac{\ln(\Upsilon_{cn}^e)}{\ln(\prod_{j=1}^{n} \Upsilon_{cn}^e)} \tag{4}$$

$$w_j = (w_1, w_2, \dots w_n)^T \tag{5}$$

Step 2.5. Calculate the aggregated vector of weight coefficients, and apply The Bonferroni aggregator to calculate these, as follows:

$$w_j = \left(\frac{1}{k(k-1)} \sum_{\substack{i,j=1}}^{k} \left(w_j^{(e)}\right)^p \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \left(w_j^{(e)}\right)^q \right)^{\frac{1}{p+q}} \tag{6}$$

Where $p, q \geq 0$ present stabilization parameters of the Bonferroni aggregator, while w_j^e presents the weight coefficients obtained based on the evaluations of the e-th expert $1 \leq e \leq k$.

Step 2.6. Calculate the final value of the weight coefficients.

Step 3. Rank the alternatives.

We use novel single-value triangular neutrosophic number-ranking alternatives with weights of criterion approach (SVTrN - RAWEC) to rank the alternative for the selection of the optimal candidate. The RAWEC (Ranking Alternatives with Weights of Criterion) approach is distinguished from other methods by its simplicity in calculations and lack of complexity, which facilitates the decision-making process for decision-makers and the number of steps is few [16]. Decisions are often characterized by a degree of uncertainty and ambiguity, in addition to being based on subjective preferences. For example, when deciding to purchase a new mobile phone, all candidate mobile phones will take priority based on the required attributes such as quality, battery efficiency, etc. In addition to the fact that decisions depend on linguistic variables (excellent, very good), these values represent unclear information and therefore dealing with the lack of clarity using linguistic variables is not sufficient. Given the problems mentioned above, the neutrosophic set is the best solution due to its ability to deal with ambiguity and contradiction in the decision-making process [25].

In this research, for the first time, we will present the RAWEC approach within the scope of the neutrosophic environment. The proposed method of SVTNSs - RAWEC includes the following steps:

Step 3.1. Construct the decision matrix based on the expert's evaluation, as follows:

Step 3.1.1. The linguistic decision matrix is constructed by each expert based on the scale in Table 2. Then, using neutrosophic addressed the problem of ambiguity and uncertainty in the decision-making process, helping decision-makers to evaluate criteria and alternatives effectively to make sound scientific decisions thoughtfully [27]. As an example, if the expert's opinion on the first criterion is very good, then it falls under the "Very high" linguistic variable and if the degree (T, I, F) is "Strongly sure", then the evaluation value based on the triangular neutrosophic number will be in this form: $< (4,5,6); 0.8,0.2,0.2 >$ where $(4,5,6)$ donates the lower, median, and upper bound for triangular neutrosophic number, and $(0.8,0.2,0.2)$ donates the values of truthiness, indeterminacy, and falsity membership degree. After that, use the score function in Eq. (7) to get the final crisp value.

$$Score\ Function\ (SF) = \frac{(L_{ij} + M_{ij} + U_{ij})}{9} * (2 + T - I - F) \tag{7}$$

Where l, m, u donates the lower, median, and upper of the scale neutrosophic number, T, I, F donates the values of truthiness, indeterminacy, and falsity membership degree.

Table 2. SVTNSs - Number scale [26].

Terms	L, M, U	Validation degree (T, I, F)
Absolutely Low (AL)	$<(0,0,1)>$	Absolutely not sure (ANS) <(0,1,1)>
Very Low (VL)	$<(0,1,2)>$	Not sure (NS) $<(0.2, 0.8, 0.8)>$
Low (L)	$<(1,2,3)>$	Slightly sure (SLS) $<(0.3,0.7,0.7>)$
Medium (M)	$<(2,3,4)>$	Median sure (MS) $<(0.5,0.5,0.5)>$
High (H)	$<(3,4,5)>$	Sure (S) $<(0.7,0.4,0.4)>$
Very High (VH)	$<(4,5,6)>$	Strongly sure (STS) $<(0.8,0.2,0.2)>$
Strongly very high (SVH)	$<(5,6,7)>$	Very strongly sure (VSS) $<(0.9,0.1,0.1)>$
Absolutely High (AH)	$<(7,8,9)>$	Absolutely sure (AS) $<(1,0,0)>$

Step 3.1.2. Collect all the decision matrices into one matrix, named an aggregated decision matrix by using the geometric mean (GM), its primary benefits are its impartial data representation since it treats all values equally and is unaffected by outliers. That is represented as follows:

$$(\prod_{i=1}^{N} q_i)^{\frac{1}{N}} = \sqrt[N]{q_1\, q_2 \, \ldots . \, q_N} \tag{8}$$

Where q_i represents the value of the criterion in the decision matrix and N represents the number of experts.

Step 3.2: Normalize the aggregated decision matrix, the two-fold normalization is used as follows [16]:

$$n_{ij} = \frac{x_{ij}}{x_{j\,max}} \ \ and,\ \ n_{ij}{}^{*} = \frac{x_{j\,min}}{x_{ij}} \ \ , for\ benefit\ criteria \tag{9}$$

$$n_{ij} = \frac{x_{j\,min}}{x_{ij}} \ \ and, n_{ij}{}^{*} = \frac{x_{ij}}{x_{j\,max}} \ \ , for\ non - benefit\ criteria \tag{10}$$

The normalization process is done in two ways, the first way is (n_{ij}) all criteria are converted into benefit criteria, and the second way is $(n_{ij}{}^{*})$ All criteria are converted into non-benefit criteria.

Step 3.3: Calculate the deviation of the criterion weight, as follows:

$$v_{ij} = \sum_{i=1}^{n} w_j . (1 - n_{ij}) \tag{11}$$

$$v_{ij}{}^{*} = \sum_{i=1}^{n} w_j . (1 - n_{ij}{}^{*}) \tag{12}$$

Where, w_j is the weight of criteria that was calculated before by the LMAW method. The deviation v_{ij} is preferred to be as small as possible, however the deviation $v_{ij}{}^{*}$ is preferred to be as large as possible.

Step 3.4: Make the rank process

The final alternative's value Q_i is calculated based on v_{ij} and $v_{ij}{}^{*}$. The value of $Q_i \in [-1{:}\,1]$, the alternative that has the highest Q_i represents the optimal one, this value is calculated as follows:

$$Q_i = \frac{v_{ij}{}^{*} - v_{ij}}{v_{ij}{}^{*} + v_{ij}} \tag{13}$$

3 | Case Study

In our case study, we are examining four commonly used materials for constructing the drone's wing: polymer reinforced with carbon fibers, Kevlar, aluminum alloys, and titanium alloys. These materials are represented as candidate alternatives in Table 5. The team of experts, who have a high level of knowledge in the field described in Table 3, is evaluating them based on six criteria: stability, heat resistance, and rigidity, which have larger values that are desirable and known as beneficial criteria, as well as budget, weight, and deformation, which have smaller values that are desirable and known as non-beneficial criteria, as shown in Table 4. This is considered Step 1, which is named problem definition.

Table 3. Details about experts.

Expert	Degree	Field
$E1$	PhD	Materials engineering
$E2$	PhD	Mechanical engineering
$E3$	M.Sc.	Artificial intelligence
$E4$	PhD	Data Science

Table 4. The evaluation criteria.

ID	Criteria	Description	Type
$C1$	Stability	stable structure [28]	Max
$C2$	Heat resistance	High ability to resist heat	Max
$C3$	Budget	The cost, purchase	Min
$C4$	Weight	Make the weight as light as possible while preserving the bladder [29]	Min
$C5$	Rigidity	Hardness at minimum weight [30]	Max
$C6$	Deformation	Reduce distortion [5]	Min

Table 5. The alternatives.

ID	Alternatives	Characteristics	Ref
$A1$	Polymer reinforced with carbon fibers	Simple to produce, with low-density strength, it can withstand UV radiation and reduce costs	[31, 32]
$A2$	Kevlar	Heat-resistant and light in weight	[33]
$A3$	Aluminum alloys	Strength but heavy as compared to other materials	[34]
$A4$	Titanium alloys	Strength, low density, and light as compared to aluminum alloys	[35]

Step 2. Four experts rank the criteria in order of importance by using the triangular neutrosophic number scale in Table 1. After that, use Eq. (7) to convert it into a clear value. Table 6 shows the calculation of the triangular neutrosophic for criteria priority. Thus, four priority vectors are established because four specialists evaluate as shown in Table 7. As an example, to rank $C1$, expert $E1$ evaluates $C1$ as very strongly important (VSI). The lower, median, and upper values of triangular neutrosophic numbers are 6, 7, and 8 respectively. The confirmation degree of the expert's opinion is very strongly sure (VSS), with a truthiness degree of 0.9, an indeterminacy degree of 0.1, and a falsity degree of 0.1. Using the score function in Eq. (7), we can calculate the clear value as follows:

$$SF_{C1} = \frac{(6+7+8)}{9}.(2+0.9-0.1-0.1) = 6.3$$

Although expert $E4$, evaluates $c1$ as very strongly important (VSI) also the confirmation degree of his opinion is absolute sure (AS) where the values of (T,I, F) = (1,0,0) thus the crisp value is calculated as :

$$SF_{C1} = \frac{(6+7+8)}{9}.(2+1-0-0) = 7$$

We apply the same steps to the rest of the criteria until we obtain four priority vectors.

Table 6. Calculation of the triangular neutrosophic for criteria priority in the LMAW method.

Alternatives	C1	C2	C3	SVTrN- Number scale			Crisp value		
				C1	C2	C3	C1	C2	C3
E1	VSI;VSS	AI;VSS	NI;VSS	((6,7,8);0.9,0.1,0.1)	((7,8,9);0.9,0.1,0.1)	((0,0,1);0.9,0.1,0.1)	6.3	7.2	0.3
E2	SI;VSS	VSI;VSS	I;VSS	((5,6,7);0.9,0.1,0.1)	((6,7,8);0.9,0.1,0.1)	((3,4,5);0.9,0.1,0.1)	5.4	6.3	3.6
E3	SI;STS	AI;STS	SI;STS	((5,6,7);0.85,0.15,0.15)	((7,8,9);0.85,0.15,0.15)	((5,6,7);0.85,0.15,0.15)	5.1	6.8	5.1
E4	VSI;AS	AI;AS	I;STS	((6,7,8);1,0,0)	((7,8,9);1,0,0)	((3,4,5);0.85,0.15,0.15)	7	8	3.4
Alternatives	C4	C5	C6	C4	C5	C6	C4	C5	C6
E1	VSI;VSS	I;VSS	AI;VSS	((6,7,8);0.9,0.1,0.1)	((3,4,5);0.9,0.1,0.1)	((7,8,9);0.9,0.1,0.1)	6.3	3.6	7.2
E2	SI;VSS	SI;VSS	SI;STS	((5,6,7);0.9,0.1,0.1)	((5,6,7);0.9,0.1,0.1)	((5,6,7);0.85,0.15,0.15)	5.4	5.4	5.1
E3	SI;VSS	VSI;STS	VSI;VSS	((5,6,7);0.9,0.1,0.1)	((6,7,8);0.85,0.15,0.15)	((6,7,8);0.9,0.1,0.1)	5.4	5.95	6.3
E4	SI;AS	VSI;AS	SI;STS	((5,6,7);1,0,0)	((6,7,8);1,0,0)	((5,6,7);0.85,0.15,0.15)	6	7	5.1

Table 7. The priority vectors p^e.

$p^e = \{\Upsilon_{c1}^e, \Upsilon_{c2}^e, .. \Upsilon_{cn}^e\}$	Value
$p^1 = (VSI, AI, NI, VSI, I, AI)$	(6.3,0.7,0.3,0.6,3.6,7.2)
$p^2 = (SI, VSI, I, SI, SI, SI)$	(5.4,6.3,3.6,5.4,5.4,5.1)
$p^3 = (SI, SI, SI, SI, VSI, VSI)$	(5.1,6.8,5.1,5.4,5.95,6.3)
$p^4 = (VSI, AI, I, SI, VS, SI)$	(7,8,3.4,6,7,5.1)

Step 2.1. Absolute anti-ideal point $\Upsilon^*_{AIP}$is arbitrarily defined as a value $\Upsilon^*_{AIP} = 0.5$.

Step 2.2. The association vectors R^e calculated based on the priority vectors p^e and the absolute anti-ideal point Υ^*_{AIP}, by utilizing the Eqs. (2) and (3), as shown in Table 8.

Table 8. The association vectorsR^e.

$R^e = (av_{c1}^e, av_{c2}^e, \dots av_{cn}^e)$
$R^1 = (12.6, 14.4, 0.6, 12.6, 7.2, 14.4)$
$R^2 = (10.8, 12.6, 7.2, 10.8, 10.8, 10.2)$
$R^3 = (10.2, 13.6, 10.2, 10.8, 11.9, 12.6)$
$R^4 = (14, 16, 6.8, 12, 14, 10.2)$

Step 2.3. the weight coefficients vector (w_j) for each expert are calculated by utilizing Eqs. (4) and (5), the weight coefficient values are satisfied the condition where$\sum_{j=1}^{6} w_j = 1$, as shown in Table 9.

Table 9. The weight coefficients vector (w_j) for 4 experts.

w_j	w_1^e	w_2^e	w_3^e	w_4^e	w_5^e	w_6^e	$\sum_{j=1}^{6} w_j.$
w_1	0.213542	0.224796	-0.04305	0.213542	0.166377	0.224796	1
w_2	0.170347	0.181383	0.141321	0.170347	0.170347	0.166255	1
w_3	0.158583	0.178227	0.158583	0.162486	0.169109	0.173012	1
w_4	0.178617	0.187655	0.129742	0.168184	0.178617	0.157184	1

As an example: the element of the vector w_j^1 for the first expert are calculated utilizing Eq. (4) as follows:

$$w_1^1 = \frac{\ln(12.6)}{\ln(12.6 \times 14.4 \times 0.6 \times 12.6 \times 7.2 \times 14.4)} = 0.213542,$$

$$w_2^1 = \frac{\ln(14.4)}{\ln(12.6 \times 14.4 \times 0.6 \times 12.6 \times 7.2 \times 14.4)} = 0.224796$$

$$w_3^1 = \frac{\ln(0.6)}{\ln(12.6 \times 14.4 \times 0.6 \times 12.6 \times 7.2 \times 14.4)} = -0.04305,$$

$$w_4^1 = \frac{ln(12.6)}{ln(12.6 \times 14.4 \times 0.6 \times 12.6 \times 7.2 \times 14.4)} = 0.213542$$

$$w_5^1 = \frac{\ln(7.2)}{\ln(12.6 \times 14.4 \times 0.6 \times 12.6 \times 7.2 \times 14.4)} = 0.166377$$

$$w_6^1 = \frac{\ln(14.4)}{\ln(12.6 \times 14.4 \times 0.6 \times 12.6 \times 7.2 \times 14.4)} = 0.224796$$

Then, $w_j{}^1 = (0.213542,$ 0.224796, -0.04305, 0.213542, 0.166377, 0.224796). The remaining vectors $w_j{}^2$, $w_j{}^3$, $w_j{}^4$ are computed in an identical manner.

Step 2.4. We calculate the aggregated vector of the weighted coefficients to get the final weight of the criteria by utilizing Eq. (6) where the first element of the aggregated vector represents the final weight of $c1$ as shown in Table 10. Hint: we set the values of p and q to be 1.

As an example: The aggregated vector of the weighted coefficients $w_j = (0.179884\,, 0.192714, 0.084482, 0.178253, 0.171092, 0.179672)$ are calculated as follows:

$$w_1 = \left[\left(\frac{1}{4(4-1)}(0.213542 \times 0.170347 + 0.213542 \times 0.158583 + 0.213542 \times 0.178617 + 0.170347 \times 0.213542 + \cdots \ldots 0.178617 \times 0.213542 + 0.178617 \times 0.170347 + 0.178617 \times 0.158583)\right]^{\frac{1}{1+1}} = 0.179884$$

The remaining values are computed identically.

Table 10. The final weight of criteria by LMAW method.

Criteria	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
Final weight	0.179884	0.192714	0.084482	0.178253	0.171092	0.179672

As shown in Figure 2, $c2$ is the highest criterion with a value equal to 0.192714 however $c3$ is the lowest criterion with a value equal to 0.084482.

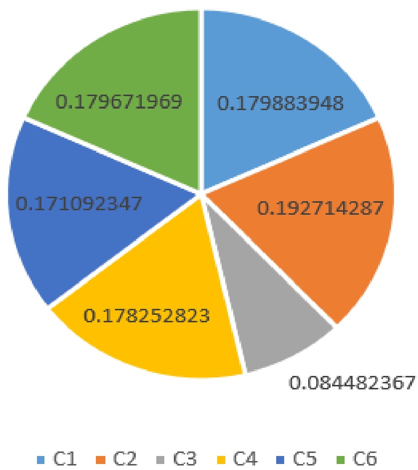

Figure 2. The final weight of the evaluated criteria.

Step 3.1. The team of experts, represented in Table 3, started evaluating the criteria listed in Table 4. They used the SVTRN number scale in Table 2 and applied the score function in Eq. (7) to obtain the precise values of the four decision matrices. Table 11 displays the neutrosophic computation for the first expert evaluation. Repeat these computations for the remaining experts to create all decision matrices as shown in Tables 12, 13, and 14.

Table 11. Computation of the neutrosophic values for the criteria evaluation by 1^{st} expert.

Alternatives	$C1$	$C2$	$C3$	SVTrN- Number scale		
				$C1$	$C2$	$C3$
A1	AH;VSS	L;VSS	M;VSS	((7,8,9); 0.9,0.1,0.1)	((1,2,3); 0.9,0.1,0.1)	((2,3,4); 0.9,0.1,0.1)
A2	SVH;STS	L;STS	L;STS	((5,6,7); 0.8,0.2,0.2)	((1,2,3); 0.8,0.2,0.2)	((1,2,3); 0.8,0.2,0.2)
A3	H;VSS	VL;S	VL;VSS	((3,4,5); 0.9,0.1,0.1)	((0,1,2); 0.7,0.4,0.4)	((0,1,2); 0.9,0.1,0.1)
A4	VH;S	VL;S	VL;STS	((4,5,6); 0.7,0.4,0.4)	((0,1,2); 0.7,0.4,0.4)	((0,1,2); 0.8,0.2,0.2)
Alternatives	$C4$	$C5$	$C6$	$C4$	$C5$	$C6$
A1	H;VSS	M;VSS	L;S	((3,4,5); 0.9,0.1,0.1)	((2,3,4); 0.9,0.1,0.1)	((1,2,3); 0.7,0.4,0.4)
A2	M;STS	M;S	L;STS	((2,3,4); 0.8,0.2,0.2)	((2,3,4); 0.7,0.4,0.4)	((1,2,3); 0.8,0.2,0.2)
A3	L;VSS	L;S	VL;VSS	((1,2,3); 0.9,0.1,0.1)	((1,2,3); 0.7,0.4,0.4)	((0,1,2); 0.9,0.1,0.1)
A4	M;STS	L;S	VL;VSS	((2,3,4); 0.8,0.2,0.2)	((1,2,3); 0.7,0.4,0.4)	((0,1,2); 0.9,0.1,0.1)
Crisp values						
	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
A1	7.2	1.8	2.7	3.6	2.7	1.26666667
A2	4.8	1.6	1.6	2.4	1.9	1.6
A3	3.6	0.63333333	0.9	1.8	1.26666667	0.9
A4	3.16666667	0.63333333	0.8	2.4	1.26666667	0.9

Table 12. Computation of the neutrosophic values for the criteria evaluation by 2^{nd} expert.

Alternatives	$C1$	$C2$	$C3$	SVTrN- Number scale		
				$C1$	$C2$	$C3$
A1	SVH;S	M;STS	L;S	((5,6,7); 0.7,0.4,0.4)	((2,3,4); 0.8,0.2,0.2)	((1,2,3); 0.7,0.4,0.4)
A2	VH;STS	L;STS	VL;STS	((4,5,6); 0.8,0.2,0.2)	((1,2,3); 0.8,0.2,0.2)	((0,1,2); 0.8,0.2,0.2)
A3	M;S	VL;S	VL;S	((2,3,4); 0.7,0.4,0.4)	((0,1,2); 0.7,0.4,0.4)	((0,1,2); 0.7,0.4,0.4)
A4	H;VSS	VL;VSS	VL;VSS	((3,4,5); 0.9,0.1,0.1)	((0,1,2); 0.9,0.1,0.1)	((0,1,2); 0.9,0.1,0.1)
Alternatives	$C4$	$C5$	$C6$	$C4$	$C5$	$C6$
A1	VH;VSS	H;AS	L;STS	((4,5,6); 0.9,0.1,0.1)	((3,4,5); 1,0,0)	((1,2,3); 0.8,0.2,0.2)
A2	H;S	M;STS	VL;VSS	((3,4,5); 0.7,0.4,0.4)	((2,3,4); 0.8,0.2,0.2)	((0,1,2); 0.9,0.1,0.1)
A3	L;S	VL;S	VL;S	((1,2,3); 0.7,0.4,0.4)	((0,1,2); 0.7,0.4,0.4)	((0,1,2); 0.7,0.4,0.4)
A4	M;VSS	L;VSS	VL;VSS	((2,3,4); 0.9,0.1,0.1)	((1,2,3); 0.9,0.1,0.1)	((0,1,2); 0.9,0.1,0.1)
Crisp values						
Alternatives	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
A1	3.8	2.4	1.266667	4.5	4	1.6
A2	4	1.6	0.8	2.533333	2.4	0.9
A3	1.9	0.63333333	0.633333	1.266667	0.63333333	0.63333333
A4	3.6	0.9	0.9	2.7	1.8	0.9

Table 13. Computation of the neutrosophic values for the criteria evaluation by 3^{rd} expert.

Alternatives	$C1$	$C2$	$C3$	SVTrN- Number scale		
				$C1$	$C2$	$C3$
$A1$	AH;VSS	H;S	L;VSS	((7,8,9); 0.9,0.1,0.1)	((3,4,5); 0.7,0.4,0.4)	((1,2,3); 0.9,0.1,0.1)
$A2$	SVH;NS	M;S	VL;S	((5,6,7); 0.2,0.8,0.8)	((2,3,4); 0.7,0.4,0.4)	((0,1,2); 0.7,0.4,0.4)
$A3$	H;VSS	VL;VSS	VL;VSS	((3,4,5); 0.9,0.1,0.1)	((0,1,2); 0.9,0.1,0.1)	((0,1,2); 0.9,0.1,0.1)
$A4$	H;MS	L;MS	VL;MS	((3,4,5); 0.5,0.5,0.5)	((1,2,3); 0.5,0.5,0.5)	((0,1,2); 0.5,0.5,0.5)
Alternatives	$C4$	$C5$	$C6$	$C4$	$C5$	$C6$
$A1$	VH;S	VH;VSS	M;S	((4,5,6); 0.7,0.4,0.4)	((4,5,6); 0.9,0.1,0.1)	((2,3,4); 0.7,0.4,0.4)
$A2$	VH;S	H;S	L;S	((4,5,6); 0.7,0.4,0.4)	((3,4,5); 0.7,0.4,0.4)	((1,2,3); 0.7,0.4,0.4)
$A3$	M;VSS	M;VSS	VL;VSS	((2,3,4); 0.9,0.1,0.1)	(2,3,4; 0.9,0.1,0.1)	((0,1,2); 0.9,0.1,0.1)
$A4$	H;MS	M;MS	L;MS	((3,4,5); 0.5,0.5,0.5)	((2,3,4); 0.5,0.5,0.5)	((1,2,3); 0.5,0.5,0.5)
Crisp values						
Alternatives	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
$A1$	7.2	2.53333333	1.8	3.16666667	4.5	1.9
$A2$	1.2	1.9	0.63333333	3.16666667	2.53333333	1.26666667
$A3$	3.6	0.9	0.9	2.7	2.7	0.9
$A4$	2	1	0.5	2	1.5	1

Table 14. Computation of the neutrosophic values for the criteria evaluation by 4^{th} expert.

Alternatives	$C1$	$C2$	$C3$	SVTrN- Number scale		
				$C1$	$C2$	$C3$
$A1$	SVH;S	M;STS	L;S	((5,6,7); 0.7,0.4,0.4)	((2,3,4); 0.8,0.2,0.2)	((1,2,3); 0.7,0.4,0.4)
$A2$	H;VSS	M;VSS	L;VSS	((3,4,5); 0.9,0.1,0.1)	((2,3,4); 0.9,0.1,0.1)	((1,2,3); 0.9,0.1,0.1)
$A3$	L;NS	VL;S	VL;S	((1,2,3); 0.2,0.8,0.8)	((0,1,2); 0.7,0.4,0.4)	((0,1,2); 0.7,0.4,0.4)
$A4$	M;STS	L;STS	VL;STS	((2,3,4); 0.8,0.2,0.2)	((1,2,3); 0.8,0.2,0.2)	((0,1,2); 0.8,0.2,0.2)
Alternatives	$C4$	$C5$	$C6$	$C4$	$C5$	$C6$
$A1$	H;STS	H;S	M;STS	((3,4,5); 0.8,0.2,0.2)	((3,4,5); 0.7,0.4,0.4)	((2,3,4); 0.8,0.2,0.2)
$A2$	M;S	M;S	M;S	((2,3,4); 0.7,0.4,0.4)	((2,3,4); 0.7,0.4,0.4)	((2,3,4); 0.7,0.4,0.4)
$A3$	M;S	VL;S	L;NS	((2,3,4); 0.7,0.4,0.4)	((0,1,2); 0.7,0.4,0.4)	((1,2,3); 0.2,0.8,0.8)
$A4$	M;STS	L;STS	M;STS	((2,3,4); 0.8,0.2,0.2)	((1,2,3); 0.8,0.2,0.2)	((2,3,4); 0.8,0.2,0.2)
Crisp values						
Alternatives	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
$A1$	3.8	2.4	3.2	3.2	2.53333333	2.4
$A2$	3.6	2.7	1.8	1.9	1.9	1.9
$A3$	0.4	0.63333333	0.63333333	1.9	0.63333333	0.4
$A4$	2.4	1.6	0.8	2.4	1.6	2.4

Step 3.2. Since there are four different expert opinions, four decision matrices were created. These matrices were then combined into one aggregated decision matrix, which is shown in Table 15. The aggregation function used to create this matrix was the geometric mean, as defined in Eq. (8).

Table 15. The aggregated decision matrix.

Alternatives	C1	C2	C3	C4	C5	C6
	Stability (max)	Heat resistance (max)	Budget (min)	Weight (min)	Rigidity (max)	Deformation (min)
$A1$	5.23067873	2.26384575	2.10674585	3.57945441	3.33105767	1.74355958
$A2$	3.01784023	1.90365977	1.09907848	2.4593191	2.1644756	1.3644091
$A3$	1.77155503	0.69148838	0.75498344	1.8493242	1.0822378	0.67304537
$A4$	2.7197972	0.97723432	0.7325683	2.36158761	1.52945436	1.1807938

Step 3.3. After obtaining the aggregated matrix representing the initial decision matrix, this matrix is normalized to produce the normalized decision matrix, as shown in Table 16. The normalization process

involves two steps: the first step converts all criteria into benefit type using Eq. (9) (benefit normalization n_{ij}), and the second step converts all criteria into non-benefit type using Eq. (10) (non-benefit normalization $n_{ij}^{\ *}$).

Table 16. The two-fold normalization aggregated decision matrix.

Benefit normalization n_{ij}						
Alternatives	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
$A1$	1	1	0.347725047	0.51664974	1	0.38601799
$A2$	0.57695003	0.84089642	0.666529563	0.75196594	0.64978629	0.49328707
$A3$	0.3386855	0.30544854	0.970310418	1	0.32489314	1
$A4$	0.51997023	0.43167001	1	0.78308516	0.45914977	0.56999399
Non-benefit normalization $n_{ij}^{\ *}$						
Alternatives	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
$A1$	0.3386855	0.30544854	1	1	0.32489314	1
$A2$	0.58702744	0.36324158	0.52169486	0.68706535	0.5	0.78254229
$A3$	1	1	0.358364747	0.51664974	1	0.38601799
$A4$	0.65135556	0.70759732	0.347725047	0.65976189	0.70759732	0.67723169

Step 3.4. In this step, we calculate the deviation of the criterion weight shown in Table 17 by applying Eq. (11) for benefit normalization and Eq. (12) for non-benefit normalization, using the weight of the LMAW approach calculated previously.

Table 17. The deviation of the criterion weight.

Weight	**0.21267**	**0.168584**	**0.113349**	**0.204447**	**0.176823**	**0.120904**	$v_{ij} = \sum_{i=1}^{n} w_j.(1 - n_{ij})$
Alternatives	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$	
$A1$	0	0	0.055105732	0.08615855	0	0.11031536	0.25157964
$A2$	0.0760999	0.03066153	0.028172372	0.04421277	0.05991889	0.09104211	0.33010757
$A3$	0.11895986	0.13384999	0.002508246	0	0.11550562	0	0.37082372
$A4$	0.08634965	0.10952531	0	0.03866568	0.09253534	0.07726003	0.40433601
Alternatives	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$	$v_{ij}^{\ *} = \sum_{i=1}^{n} w_j.(1 - n_{ij}^{\ *})$
$A1$	0.11895986	0.13384999	0	0	0.11550562	0	0.36831547
$A2$	0.07428713	0.01952399	0.04040835	0.05578148	0.08554617	0.03907105	0.31461819
$A3$	0	0	0.054206865	0.08615855	0	0.11031536	0.25068077
$A4$	0.06271554	0.05635017	0.055105732	0.0606484	0.05002786	0.05799242	0.34284013

Step 3.5. In Table 18, we calculate the values of the alternative (Q_i) by applying Eq. (13). The final rank of the alternatives is determined based on the value of Q_i, where the alternative with the highest value of Q_i is considered optimal. According to Figure 3, the rank of the alternatives is as follows: $A1 > A2 > A4 > A3$. Therefore, Polymer reinforced with carbon fibers is the optimal alternative with a Q_1 value of 0.188315462 while, the Aluminum alloys are the worst alternative with a Q_3 value of -0.193309863.

Table 18. The final rank of the alternatives by SVTNSs - RAWEC approach.

Alternatives	$v_{ij}^{\ *}$	v_{ij}	$Q_i = \frac{v_{ij}^{\ *} - v_{ij}}{v_{ij}^{\ *} + v_{ij}}$	Rank
$A1$	0.36831547	0.25157964	0.188315462	1
$A2$	0.31461819	0.33010757	-0.024024765	2
$A3$	0.25068077	0.37082372	-0.193309863	4
$A4$	0.34284013	0.40433601	-0.082304393	3

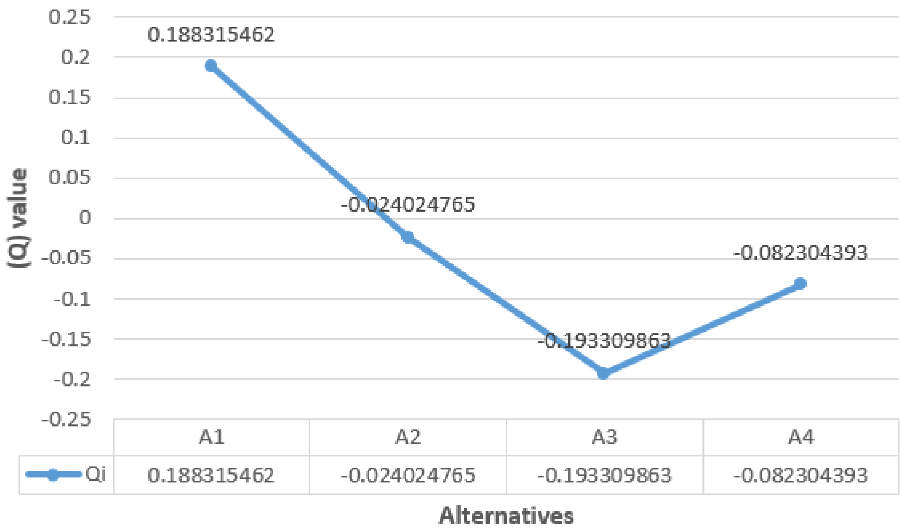

Figure 3. Rank of the alternatives based on SVTNSs – LMAW-RAWEC approach.

4 | Sensitivity Analysis

The effectiveness and efficiency of the suggested method depend on conducting a sensitivity analysis of the SVTNSs–LMAW-RAWEC results. This analysis will demonstrate how different criteria weights will impact the final ranking of alternatives. The examination involves six cases as shown in Figure 4:

Case 1: In this case, we take the weight of the first criterion w_1 is equal to 0.5, and the weights of the remaining criteria from the second to the sixth w_2: w_6 are equal in value, which is 0.1, to fulfill a condition $\sum_{i=1}^{n} w_j = 1$. Accordingly, it was found that the order of alternatives is as follows: $A_1 > A_2 > A_4 > A_3$.

Case 2: We take the weight of the second criterion w_2 is equal to 0.5 and the weights of the remaining criteria w_1 and w_3: w_6 are equal in value, which is 0.1. Accordingly, it was found that the order of alternatives is as follows: $A_1 > A_2 > A_4 > A_3$.

Case 3: We take the weight of the third criterion w_3 is equal to 0.5 and the weights of the remaining criteria w_1: w_2 and w_4: w_6 are equal in value, which is 0.1. Accordingly, it was found that the order of alternatives is as follows: $A_4 > A_3 > A_2 > A_1$.

Case 4: We take the weight of the fourth criterion w_4 is equal to 0.5, and the weights of the remaining criteria w_1: w_3 and w_5: w_6 are equal in value, which is 0.1, to fulfill a condition $\sum_{i=1}^{n} w_j = 1$. Accordingly, it was found that the order of alternatives is as follows: $A_3 > A_4 > A_2 > A_1$.

Case 5: We take the weight of the fifth criterion w_5 is equal to 0.5 and the weights of the remaining criteria w_1: w_4 and w_6 are equal in value, which is 0.1. Accordingly, it was found that the order of alternatives is as follows: $A_1 > A_2 > A_4 > A_3$.

Case 6: We take the weight of the sixth criterion w_6 is equal to 0.5 and the weights of the remaining criteria w_1: w_5 are equal in value, which is 0.1. Accordingly, it was found that the order of alternatives is as follows: $A_3 > A_4 > A_2 > A_1$.

Based on the sensitivity analysis, it was noted that in the first, second, and fifth cases, Alternative A_1 is the best, and Alternative A_3 is the worst. While, in the third and sixth cases, the third alternative A_3 is the best, while the first alternative A_1 is the worst. For case four, alternative A_4 is the best one, while A_1 is the worst as shown in Table 19.

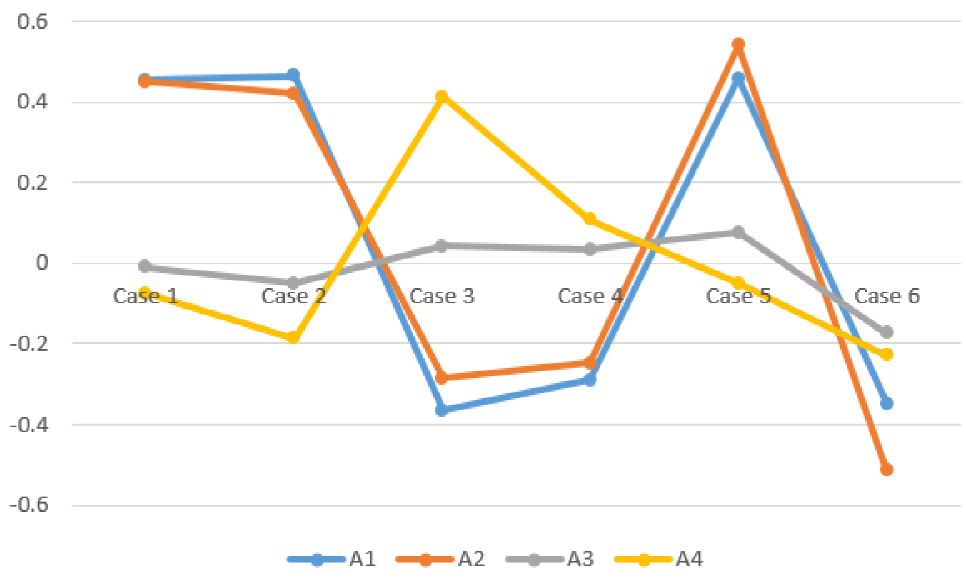

Figure 4. Various weights of alternatives from cases 1:6 under sensitivity analysis.

Table 19. Various ranks of alternatives using different weights from cases 1:6 under sensitivity analysis.

Cases	A1	A2	A3	A4
Case 1	1	2	4	3
Case 2	1	2	4	3
Case 3	4	3	2	1
Case 4	4	3	1	2
Case 5	1	2	4	3
Case 6	4	3	1	2

Also, we will demonstrate how the change in the normalization method impacts the final ranking of the alternatives.

Case 7: After changing the two-fold normalization method to another normalization method shown in Equations 14 and 15, we found that the ranking of the alternatives is $A1 > A2 > A3 > A4$. Specifically, $A1$ is the best with a Q value of 0.102711344, while $A4$ is the worst with a Q value of -0.142542621.

$$n_{ij} = \frac{x_{ij}-\min(x_{ij})}{\max(x_{ij})-\min(x_{ij})}, n_{ij}^{*} = \frac{\max(x_{ij})-x_{ij}}{\max(x_{ij})-\min(x_{ij})} \quad if\ criteria \in benefit \tag{14}$$

$$n_{ij} = \frac{\max(x_{ij})-x_{ij}}{\max(x_{ij})-\min(x_{ij})}, n_{ij}^{*} = \frac{x_{ij}-\min(x_{ij})}{\max(x_{ij})-\min(x_{ij})} \quad if\ criteria \in non-benefit \tag{15}$$

Case 8: We take Eqs. (16) and (17) as the two-fold normalization function, the ranking of the alternatives is $A1 > A4 > A2 > A3$.Specifically, $A1$ is the best one with a Q value of 0.102711344, while the $A3$ is the worst with a Q value of -0.129849259.

$$n_{ij} = \frac{x_{ij}}{\max(x_{ij})}, n_{ij}^{*} = 1 - \frac{x_{ij}}{\max(x_{ij})} \quad if\ criteria \in benefit \tag{16}$$

$$n_{ij} = 1 - \frac{x_{ij}}{\max(x_{ij})}, n_{ij}^{*} = \frac{x_{ij}}{\max(x_{ij})} \quad if\ criteria \in non-benefit \tag{17}$$

Case 9: We take Eqs. (18) and (19) as the normalization function, the ranking of the alternative is A3>A4>A1>A2. Specifically, $A3$ is the best one with a Q value of 0.261810649, while the $A2$ is the worst with a Q value of 0.034015856. Figure 5, shows the rank of the alternatives of cases 7, 8, and 9.

$$n_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} , n_{ij}^{*} = \frac{1/x_{ij}}{1/\sum_{i=1}^{m} x_{ij}} \; if \; criteria \in benefit \quad (18)$$

$$n_{ij} = \frac{1/x_{ij}}{1/\sum_{i=1}^{m} x_{ij}} , \; n_{ij}^{*} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (19)$$

Figure 6, shows the impact of the various normalization methods on the final rank of the alternatives from cases 7:9 under sensitivity analysis. Table20 shows the Q value of the alternatives obtained from cases 7, 8, and 9.

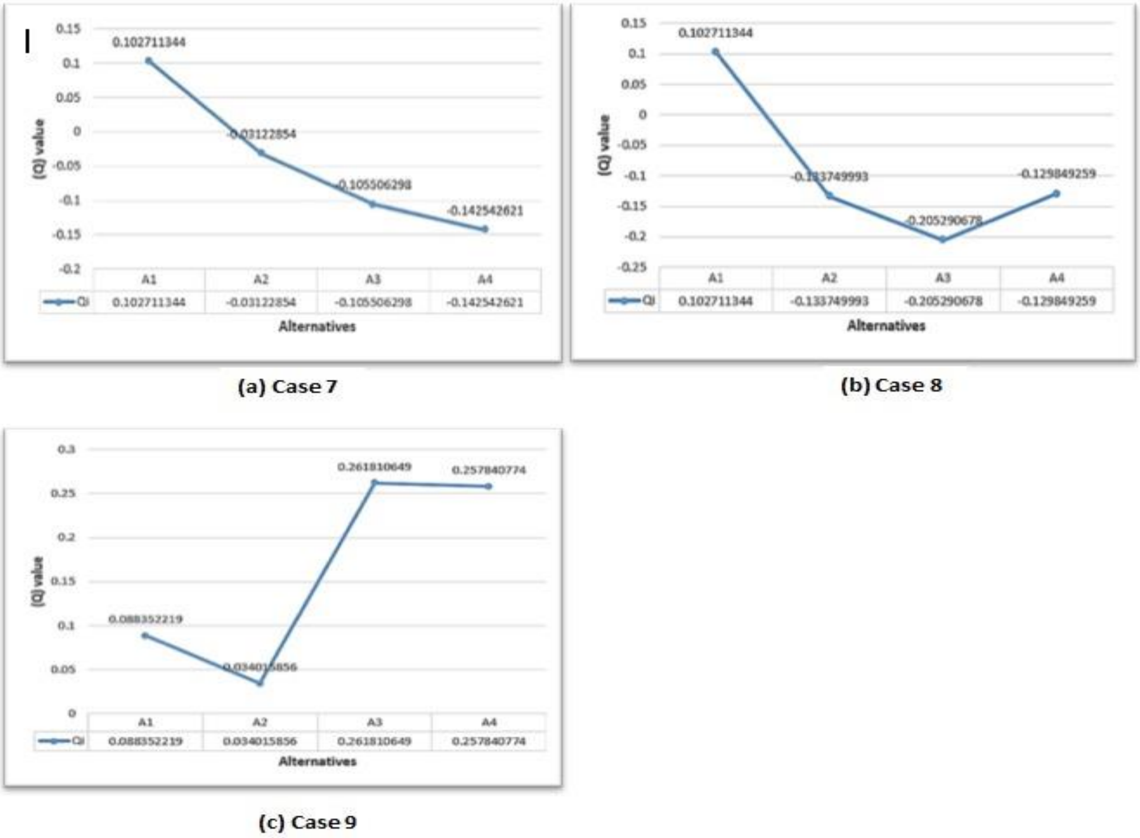

Figure 5. Rank the alternatives of cases 7, 8, and 9.

Figure 6. Impact of the various normalization methods on the rank of the alternatives.

Table 20. The Q value of the alternatives under sensitivity analysis under cases 7:9

Alternatives	Case 7		Case 8		Case 9	
	Q values	Rank	Q values	Rank	Q values	Rank
$A1$	0.102711344	1	0.102711344	1	0.088352219	3
$A2$	-0.03122854	2	-0.133749993	3	0.034015856	4
$A3$	-0.105506298	3	-0.205290678	4	0.261810649	1
$A4$	-0.142542621	4	-0.129849259	2	0.257840774	2

The STVNSs-LMAW-REWAC approach proposed in this research demonstrates sufficient stability across various sets of weights for the criteria. Additionally, sensitivity analysis showed the extent of the effect of using different methods of normalization on the rank of alternatives, which provides an effective solution to the limitations of the RAWEC method.

5 | Comparative Analysis

We compared the outcomes of the proposed (STVNSs-LMAW-REWAC) approach with the outcomes of traditional RAWEC presented in [16].

To compare the ranks derived from the two procedures, we employ Spearman's correlation, which is among the most effective ways to determine if two ordinal variables are correlated or not. that calculates as follows [36]:

$$SpCorrel = 1 - \left[\frac{6.\sum_{m=1}^{A}(diff)^2}{A.(A^2-1)}\right] \quad (20)$$

Where A is the number of alternatives and $diff$ is the difference between the two ranks.

After calculating the value of $SpCorrel$, it will be a number between -1 and +1, thus the values close to -1 or $+1$ always show a strong correlation, and the values close to 0 show a weak correlation.

The Spearman's correlation coefficient is equal to 1, which demonstrates the strong correlation between the two approaches.

The outcomes of RAWEC, which were presented in [16], the result showed that the alternative A_1 is the best one as shows in Table 21 and Figure 7. Table 22 shows comparison between the output of Q_i in both the proposed approach and RAWEC approach. Also, Table 23 shows a comparison between the weight of criteria in both the proposed approach and the RAWEC approach.

Since the two approaches have the same ranks, this is because the RAWEC calculates the rank based on the deviations from ideal values. The proposed approach handles ambiguity in the decision-making process that occurs in real life, as there is always ambiguity and uncertainty in real life.

Although the RAWEC method is easy to calculate since it consists of only three steps, it faces a very important drawback, which is that the ranking of the alternatives does not depend on the evaluations of the decision matrix, but rather on deviations from the ideal values. This ignores the opinions of experts and their evaluations of the alternatives, which is considered one of the most important steps in the decision-making process.

Table 21. The Q value of alternatives by RAWEC approach presented in [16].

Alternatives	v_{ij}^*	v_{ij}	$Q_i = \frac{v_{ij}^* - v_{ij}}{v_{ij}^* + v_{ij}}$	Rank
$A1$	0.26269747	0.19936729	0.137059101	1
$A2$	0.23114919	0.20558559	0.058533459	2
$A3$	0.19936729	0.26269747	-0.137059101	4
$A4$	0.23472541	0.28555506	-0.097696638	3

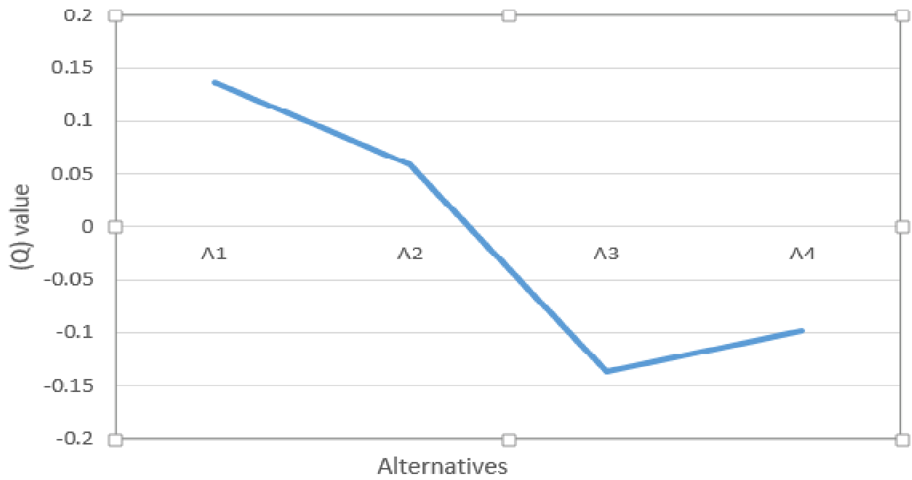

Figure 7. The rank of alternatives by the RAWEC approach presented in [16].

Table 22. A comparison between the output of Q_i in both SVTNSs –LMAW- RAWEC and RAWEC approach.

Alternatives	The proposed approach		RAWEC	
	Q_i	Rank	Q_i	Rank
$A1$	0.188315462	1	0.137059101	1
$A2$	-0.024024765	2	0.058533459	2
$A3$	-0.193309863	4	-0.137059101	4
$A4$	-0.082304393	3	-0.097696638	3

Table 23. A comparison between the weight of criteria in both SVTNSs –LMAW- RAWEC and RAWEC approach.

Criteria	The proposed approach	RAWEC
$C1$	0.179884	0.171927
$C2$	0.192714	0.181736
$C3$	0.084482	0.135355
$C4$	0.178253	0.169833
$C5$	0.171092	0.166153
$C6$	0.179672	0.1738

6 | Managerial Implications

Factories and manufacturing companies produce and develop drones, so they need to select the most sustainable materials for making drones, especially for the wings. This selection process is complex due to the many alternatives and criteria involved. In this research, we present for the first time a new SVTNSs -LMAW-RAWEC approach in a neutrosophic environment, which deals with ambiguity in the decision-making process efficiently. The proposed model will assist factories and institutions in making accurate and well-informed decisions when selecting sustainable materials for aircraft wings.

7 | Conclusion

In this study, we introduce a new version of the LMAW and RAWEC methods in a neutrosophic environment (SVTNSs-LMAW-RAWEC) for choosing the best material for drone construction. We consulted with four experts from different fields. They created a decision matrix based on four candidate alternatives and six criteria. The results indicated that the polymer reinforced with carbon fibers is the best option. The approach we proposed has proven effective in dealing with ambiguity and uncertainty during the decision-making process where the expert evaluation is based on the triangular neutrosophic number scale and represents the confirmation degree of the expert evaluation which is simulated the real-life. Furthermore, our approach has shown consistent results with different sets of weights for the criteria. The RAWEC method makes it easy to calculate and involves only a few steps. However, it ranks alternatives based on deviations from ideal values. In this way, the rank does not rely on experts' opinions in decision-making. Additionally, if the decision matrix contains at least one zero element, then the normalization method using the RAWEC data can’t be applied, as division by zero has no meaning. So we demonstrate the impact of the normalization method in the rank of the alternatives, we used three different normalize methods as shown in the sensitivity analysis section that handles the limitation of the RAWEC method.

Our approach was applied to only four alternatives and six criteria. In future work, we will apply our approach to a large number of criteria and alternatives and conduct a sensitivity analysis to explore our approach with big data.

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Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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