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Effective Approach to Shock Absorption Performance Evaluation of Mechanical Component Springs Using the Single Valued Trapezoidal Neutrosophic Numbers for Structural Stability

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Abstract: We propose a decision-making approach for shock absorption performance evaluation of mechanical component springs. The main goal of this research is to provide a decision support system that will help decision makers to select the best alternative to alleviate this ambiguity. The selection of the best alternative is done using the multi-attribute group decision-making approach. The hybrid model is created utilizing two-step logarithmic normalization (ARLON) and Single Valued Trapezoidal Neutrosophic Numbers (SVTNNs) for MEREC and alternative ranking. The criteria's relevance levels are ascertained using the innovative SVTNN-MEREC approach. The alternatives are ranked using the recently developed SVTNN-ARLON technique. The suggested hybrid model's application procedures are illustrated by an algorithm that is created. This algorithm is used as the basis for real-world research.

Keywords: Single Valued Trapezoidal Neutrosophic Numbers; Uncertainty; Shock Absorption Performance; Mechanical Component Springs.

1. Introduction

The neutrophilic set, which emphasizes the nature and cause of neutralities in various sectors, is a generalization of the classical set, fuzzy set, intuitionistic fuzzy set, and so forth. Smarandache invented this multidimensional logic, which contains more information than fuzzy logic and imports the term indeterminacy. Compared to fuzzy logic, this results in greater performance. A proposition in neutrosophic logic has three degrees: truth (T), indeterminacy (I), and falsity (F). The single-valued neutrosophic set, which accepts values in the standard interval [0, 1], was introduced because it is challenging to manage data with non-standard intervals[1], [2]. Smarandache introduced the concepts of neutrosophic measure, neutrosophic integral, and neutrosophic probability. Since there are many kinds of indeterminacies depending on the problem, the neutrosophic integral and neutrosophic probability are also defined in a variety of ways. This is because neutrosophic measure presents numerous real-world examples. The neutrosophic logic has been used by numerous scholars in a variety of domains[3], [4].

The use of single-valued, triangular, and trapezoidal neutrosophic numbers in decision-making is examined regarding their applications. In addition to introducing the neutrosophic number from various perspectives, the various linear and non-linear generalized triangular neutrosophic numbers—which are crucial for uncertainty theory—and the de-neutrosophication concept for neutrosophic numbers—which aids in turning a neutrosophic number into a crisp number—are also covered. This has been used in the problems of MCDM selection assessment review techniques[5], [6].

Type 2 neutrosophic numbers (T2NN) are an enhanced sort of neutrosophic approach that was established. To demonstrate the effectiveness and usefulness of the type 2 neutrosophic number, a real-world scenario involving a decision-making based on T2NN was presented. According to the judgments of experts and decision-makers, the linguistic factors were presented using the triangular neutrosophic numbers (TriNs). One of the most important tools for resolving challenging and complex choice problems is the multicriteria decision-making (MCDM) methodology[7], [8]. Group decision-making and the definition of the bipolar neutrosophic number were established.

1.1. Aims of the study

The main goal is to create a MAGDM-based decision assistance system for Shock Absorption Performance Evaluation of Mechanical Component Springs. According to the main goal, the following are the predetermined goals:

Selecting the best alternative: Using the MAGDM framework, a new decision support system is developed to identify the optimal alternative.

Creation of hybrid methodology centers on the creation of the SVTN-MEREC-ARLON hybrid technique, which combines the phases of alternative selection, criteria weighing, and expertise appraisal into a unified approach to decision-making.

1.2. Contributions of the study

This study mainly adds a new hybrid model for choosing the best alternative to the body of literature. The following is a breakdown of the contributions made to the body of current knowledge:

- To identify the best alternative, a new decision support system is created within the MAGDM framework.
- To illustrate the usefulness of the established approach, a case study is created that contrasts the findings of assessments conducted by information system experts and users.
- We used the single valued triangular neutrosophic sets to deal with uncertainty and vague information.
- The MEREC method is used to compute the criteria weights and the ARLON method is used to rank the alternatives.

1.3. Organization of the study

Each of the five components that make up this study has a specific function within the research framework. The function of authentication in the performance evaluation system is explained in Section 2. The research approach is outlined in Section 3, which also provides a detailed explanation of the newly created SVTNS-MEREC-ARLON hybrid model. The hybrid model created using two case studies is put into practice and put through robustness testing in Section 4, which is the application phase. The study's conclusions and ramifications are presented in Section 5.

2. Preliminaries

We can define some operations of neutrosophic numbers[9], [10].

Definition 2.

We can define the single valued trapezoidal neutrosophic sets (SVTNSs) such as:

$a = \left((a_1, a_2, a_3, a_4); \alpha_a(x)\right), \beta_a(x), \gamma_a(x)$. Then we can compute the three-membership functions such as:

$$T_a(x) = \begin{cases} \alpha_a\left(\frac{x-a_1}{a_2-a\_1}\right) & (a_1 \leq x \leq a_2) \\ \alpha_a & (a_2 \leq x \leq a_3) \\ \alpha_a\left(\frac{a_4-x}{a_4-a_3}\right) & (a_3 \leq x \leq a_4) \\ 0 & otherwise \end{cases} \quad (1)$$

$$I_a(x) = \begin{cases} \frac{(a_2-x+\beta_a(x-a_1))}{(a_2-a_1)} & (a_1 \leq x \leq a_2) \\ \beta_a & (a_2 \leq x \leq a_3) \\ \left(\frac{x-a_3+\beta_a(a_4-x)}{a_4-a_3}\right) & (a_3 \leq x \leq a_4) \\ 0 & otherwise \end{cases} \quad (2)$$

$$F_a(x) = \begin{cases} \frac{(a_2-x+\gamma_a(x-a_1))}{(a_2-a_1)} & (a_1 \leq x \leq a_2) \\ \gamma_a & (a_2 \leq x \leq a_3) \\ \left(\frac{x-a_3+\gamma_a(a_4-x)}{a_4-a_3}\right) & (a_3 \leq x \leq a_4) \\ 0 & otherwise \end{cases} \quad (3)$$

Where $\alpha_a, \beta_a, \gamma_a$ refer to the maximum truth-membership function, minimum indeterminacy-membership function, and minimum falsity-membership function.

Definition 2.

Let two single valued trapezoidal neutrosophic numbers (SVTNNs) such as:

$a = \left(\left((a_1, a_2, a_3, a_4)\right); \alpha_a(x), \beta_a(x), \gamma_a(x)\right)$

$b = \left(\left((b_1, b_2, b_3, b_4); \alpha_b(x)\right), \beta_b(x), \gamma_b(x)\right)$

Addition

$$a + b = \begin{pmatrix} (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \\ \alpha_a(x) \wedge \alpha_b(x), \beta_a(x) \vee \beta_b(x), \gamma_a(x) \vee \gamma_b(x) \end{pmatrix} \quad (4)$$

Subtraction

$$a - b = \begin{pmatrix} (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \\ \alpha_a(x) \wedge \alpha_b(x), \beta_a(x) \vee \beta_b(x), \gamma_a(x) \vee \gamma_b(x) \end{pmatrix} \quad (5)$$

Inverse

$$a^{-1} = \left(\left(\frac{1}{a_4}, \frac{1}{a_3}, \frac{1}{a_2}, \frac{1}{a_1}\right); \alpha_a(x), \beta_a(x), \gamma_a(x)\right) \text{ } where \text{ } a \neq 0 \quad (6)$$

Multiplication by constant

$$\mu a = \begin{cases} \begin{pmatrix} (\mu a_1, \mu a_2, \mu a_3, \mu a_4); \\ \alpha_a(x), \beta_a(x), \gamma_a(x) \end{pmatrix} & if \ \mu > 0 \\ \begin{pmatrix} (\mu a_1, \mu a_2, \mu a_3, \mu a_4); \\ \alpha_a(x), \beta_a(x), \gamma_a(x) \end{pmatrix} & if \ \mu > 0 \end{cases} \quad (7)$$

Division

$$\frac{a}{b} = \begin{cases} \begin{pmatrix} \left(\frac{a_1}{b_4}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_4}{b_1}\right); \\ \alpha_a(x) \wedge \alpha_b(x), \beta_a(x) \vee \beta_b(x), \gamma_a(x) \vee \gamma_b(x) \end{pmatrix} \\ if \ a_4 > 0, b_4 > 0 \\ \begin{pmatrix} \left(\frac{a_4}{b_4}, \frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \\ \alpha_a(x) \wedge \alpha_b(x), \beta_a(x) \vee \beta_b(x), \gamma_a(x) \vee \gamma_b(x) \end{pmatrix} \\ if \ a_4 < 0, b_4 > 0 \\ \begin{pmatrix} \left(\frac{a_4}{b_1}, \frac{a_3}{b_2}, \frac{a_2}{b_3}, \frac{a_1}{b_4}\right); \\ \alpha_a(x) \wedge \alpha_b(x), \beta_a(x) \vee \beta_b(x), \gamma_a(x) \vee \gamma_b(x) \end{pmatrix} \\ if \ a_4 < 0, b_4 < 0 \end{cases} \quad (8)$$

3. The SVTNS-MEREC-ARLON method

It is necessary to provide a summary of the use of the SVTNS-MEREC-ARLON hybrid approach before going into great depth about each stage. SVTNS sets are used in Stage 1 to assess the expertise levels of experts. Experts' effects on the decision-making process are then determined. In Stage 2, criteria are evaluated by generating an initial matrix using the SVTNS-MEREC approach. After that, SVTN numbers are converted into distinct values via a score function. After that, the criteria evaluation decision matrix is weighted and normalized. Weights are computed based on the identification of maximum and minimum values. The final criteria weights are then calculated, and reliability indices are used to verify the criteria weights.

An initial decision matrix is produced in Stage 3 by using the SVTNS-ARLON approach for expert evaluation of alternatives based on criteria. After combining expert opinions, values are subjected to a two-step logarithmic normalization procedure to further normalize them. The final ranking scores for authentication systems are then calculated by weighing the normalized data. The following describes the steps in the SVTNS-MEREC-ARLON hybrid methodology's procedural sequence:

Stage 1- Construction of the decision matrix by the opinions of experts

A1. Experts and decision makers are using the linguistic terms of the SVTNs to evaluate the criteria and alternatives.

A2. The linguistic terms are replaced by the SVTNNs. These numbers are used to evaluate the criteria and alternatives.

Stage 2 – Establishing criteria weighting utilizing the SVTN-MEREC method.

B1. Compute the crisp criterion assessment matrix

B2. Combine the assessment matrix

We use the average method to compute the one matrix.

B3. Normalize the assessment matrix.

$$n_{ij} = \begin{cases} \frac{\min x_{ij}}{x_{ij}} \; for \; positive \; criteria \\ \frac{x_{ij}}{\max x_{ij}} \; for \; negative \; criteria \end{cases} \tag{9}$$

B4. Compute the overall performance of the alternatives such as:

$$S_i = \ln\left(1 + \left(\frac{1}{m}\sum_j \left|\ln\left(n_{ij}\right)\right|\right)\right) \tag{10}$$

B5. Compute the performance of the alternatives by removing each criterion.

$$S_{ij}^{'} = \ln\left(1 + \left(\frac{1}{m}\sum_{k,k\neq j} \left|\ln(n_{ik})\right|\right)\right) \tag{11}$$

B6. Compute the summation of absolute deviation.

$$E_j = \sum_i \left|S_{ij}^{'} - S_i^{'}\right| \tag{12}$$

B7. Compute the final weights of criteria

$$w_j = \frac{E_j}{\sum_k E_k} \tag{13}$$

Stage 3 – The process of ranking alternatives employing the SVTNSs-ARLON method[11], [12].

D1. Generate the decision matrix

D2. Compute two logarithmic normalization methods such as

The first normalization

$$Y_{ij}^{1st} = \begin{cases} Y_{ij}^{1st(+)} = \frac{\ln\left(x_{ij}\right)}{\ln\left(\prod_{i=1}^{m} x_{ij}\right)} \; positive \; criteria \\ Y_{ij}^{1st(-)} = \left(\frac{1-\frac{\ln\left(x_{ij}\right)}{\ln\left(\prod_{i=1}^{m} x_{ij}\right)}}{m-1}\right) negative \; criteria \end{cases} \tag{14}$$

The second normalization

$$Y_{ij}^{2st} = \begin{cases} Y_{ij}^{2st(+)} = \frac{\log_2\left(x_{ij}\right)}{\sum_{i=1}^{m}\left(\log_2\left(x_{ij}\right)\right)} \; positive \; criteria \\ Y_{ij}^{2st(-)} = \left(1 - \frac{\log_2\left(x_{ij}\right)}{\sum_{i=1}^{m}\left(\log_2\left(x_{ij}\right)\right)}\right) negative \; criteria \end{cases} \tag{15}$$

D3. Combine the normalization matrix.

$$Y_{ij}^{com} = \left((1-\alpha)\sqrt{\left(Y_{ij}^{1st} + Y_{ij}^{2st}\right)} + (\alpha)\left(\frac{Y_{ij}^{1st}+Y_{ij}^{2st}}{2}\right)\right) \tag{16}$$

D4. Compute the weighted normalized decision matrix

$$q_{ij} = w_j Y_{ij}^{com} \tag{17}$$

D5. Compute the summations of the weighted combined normalized values for positive and negative criteria

$$Z_i^- = sum\left(q_{ij}\right) for\ positive\ criteria \tag{18}$$

$$Z_i^+ = sum\left(q_{ij}\right) for\ negative\ criteria \tag{19}$$

D6. Obtain final rank of alternatives.

$$Z_i = (Z_i^+)^{\beta} + (Z_i^-)^{(1-\beta)} \tag{20}$$

The model steps are shown in Table 1.

Table 1. The algorithm steps.

Algorithm	**Computing the criteria weights and ranking the alternatives.**
Input	In the given model, we used a set of criteria ($C = \left(c_1, \dots, c_j\right)$), alternatives ($A = (A_1, \dots, A_i)$), criteria weights ($W = \left(w_1, \dots, w_j\right)$), and experts.
Output	Select the best alternative.
Begin	
First stage	A1. Experts and decision makers are using the linguistic terms of the SVTNs to evaluate the criteria and alternatives. A2. The linguistic terms are replaced by the SVTNNs. These numbers are used to evaluate the criteria and alternatives.
Second stage	B1. Compute the crisp criterion assessment matrix B2. Combine the assessment matrix We use the average method to compute the one matrix. B3. Normalize the assessment matrix. n_{ij} B4. Compute the overall performance of the alternatives such as: S_i B5. Compute the performance of the alternatives by removing each criterion. S'_{ij} B6. Compute the summation of absolute deviation. E_j B7. Compute the final weights of criteria w_j
Third stage	D1. Generate the decision matrix D2. Compute two logarithmic normalization methods such as The first normalization Y_{ij}^{1st} The second normalization Y_{ij}^{2st} D3. Combine the normalization matrix. Y_{ij}^{com} D4. Compute the weighted normalized decision matrix

q_{ij}

D5. Compute the summations of the weighted combined normalized values for positive and negative criteria

Z_i^-

Z_i^+

D6. Obtain final rank of alternatives.

Z_i

End

4. Application

This section shows the results of the Shock Absorption Performance Evaluation of Mechanical Component Springs under neutrosophic numbers. Three experts have evaluated the criteria and alternatives. This study has 8 criteria and 12 alternatives to be evaluated as Fatigue Resistance & Durability, Environmental Adaptability, Manufacturing Precision, Damping Efficiency, Material Quality and Composition, Energy Absorption Capacity, Load-Bearing Capacity, Cost-Effectiveness and Maintenance. The alternatives can be defined such as: Metal Mesh Springs, Progressive Rate Coil Springs, Rubber Springs, Compression Springs, Hydraulic-Damped Coil Springs, Wave Springs, Helical Compression Springs, Air Springs, Gas Springs, Torsion Bar Springs, Leaf Springs with Composite Materials, Nested Belleville Springs.

Stage 1- Construction of the decision matrix by the opinions of experts

We build the three-decision matrix between the criteria and the alternatives as shown in Tables 2-4. These assessment matrices are evaluated using the SVTNNs to deal with uncertainty information in the evaluation

Table 2. The first SVTNNs.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)
A2	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)
A3	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)
A4	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)
A5	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)
A6	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)
A7	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)

A_8	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)
A_9	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)
A_{10}	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)
A_{11}	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)
A_{12}	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)

Table 3. The second SVTNNs.

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**
A_1	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)
A_2	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)
A_3	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)
A_4	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)
A_5	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)
A_6	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)
A_7	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)
A_8	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)
A_9	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)
A_{10}	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)
A_{11}	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)
A_{12}	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)

Table 4. The third SVTNNs.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)
A2	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)
A3	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)
A4	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)
A5	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)
A6	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)
A7	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)
A8	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)
A9	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)
A10	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)
A11	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.6,0.7,0.75,0.9;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.1,0.4,0.65,1;0.5,0.2,0.1)	(0.1,0.4,0.65,1;0.5,0.2,0.1)
A12	(0.3,0.5,0.65,0.9;0.5,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.1,0.35,0.5,0.7;0.8,0.2,0.1)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.2,0.3,0.4,0.5;0.7,0.2,0.5)	(0.3,0.4,0.5,0.8;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)	(0.5,0.6,0.7,0.8;0.7,0.2,0.5)

Stage 2 – Establishing criteria weighting utilizing the SVTN-MEREC method.

Then we obtain crisp values between the criteria and alternatives. Then we combine the assessment matrices into a single matrix. Then we normalize the decision matrix using Eq. (9) as shown in Table 5. Then we compute the overall performance of the alternatives using Eq. (10). Then we compute the overall performance of the alternatives by removing each criterion using Eq. (11) as shown in Table 6. Then we compute the summation of the absolute value using Eq. (12). Then we computed the final criteria weights as shown in Fig 1.

Table 5. The normalization matrix.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	1	1.975	1.717557	1.444444	2.370629	3.25	1.111111	1.451613
A2	1.324074	1	2.083969	2.574074	1.090909	2.678571	1	1.006452
A3	2.305556	1.483333	1.19084	2.787037	1.636364	2.821429	1.796296	2.187097

A_4	1.787037	1.583333	1.419847	1.25	1	1	2.268519	1.76129
A_5	1.898148	1.625	1.450382	1.25	1.027972	1.285714	1.787037	1.245161
A_6	2.222222	2.316667	1.48855	1.787037	1.111888	2.178571	1.898148	1.76129
A_7	2.268519	1.816667	2.007634	2.527778	1.79021	3.321429	2.37963	2.187097
A_8	1.833333	1.616667	1.603053	2.462963	1.678322	2.904762	2.148148	1.496774
A_9	1	1.125	1	1	1.440559	1.845238	1.25	1.025806
A_{10}	1.111111	1.225	1.21374	2.157407	1.272727	2.309524	1.722222	1.722581
A_{11}	1.361111	2.008333	1.603053	2.12037	1.027972	2.357143	1.759259	1.303226
A_{12}	2.509259	1.808333	2.587786	1.222222	1.027972	2.154762	1.805556	1

Table 6. The Overall performance matrix.

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**
A_1	0.317398	0.271308	0.280942	0.292759	0.258573	0.236177	0.3104	0.292423
A_2	0.223761	0.243958	0.190239	0.174237	0.237741	0.171193	0.243958	0.2435
A_3	0.342425	0.370496	0.384187	0.330107	0.364315	0.329306	0.358408	0.345824
A_4	0.198732	0.207711	0.215728	0.225019	0.241088	0.241088	0.180792	0.199812
A_5	0.179226	0.190964	0.199466	0.210477	0.224778	0.2084	0.1838	0.210763
A_6	0.304147	0.301351	0.330666	0.318658	0.349542	0.305476	0.314663	0.319617
A_7	0.414728	0.427978	0.422037	0.408209	0.428847	0.391568	0.411853	0.41692
A_8	0.349741	0.357768	0.358306	0.330642	0.355386	0.319808	0.339535	0.362654
A_9	0.115279	0.105691	0.115279	0.115279	0.085261	0.064377	0.097036	0.113212
A_{10}	0.264544	0.257711	0.25836	0.217137	0.255022	0.212139	0.233486	0.233471
A_{11}	0.28556	0.258621	0.274318	0.254804	0.304559	0.247317	0.267873	0.288525
A_{12}	0.250406	0.273325	0.248223	0.30006	0.311648	0.261127	0.273431	0.313483

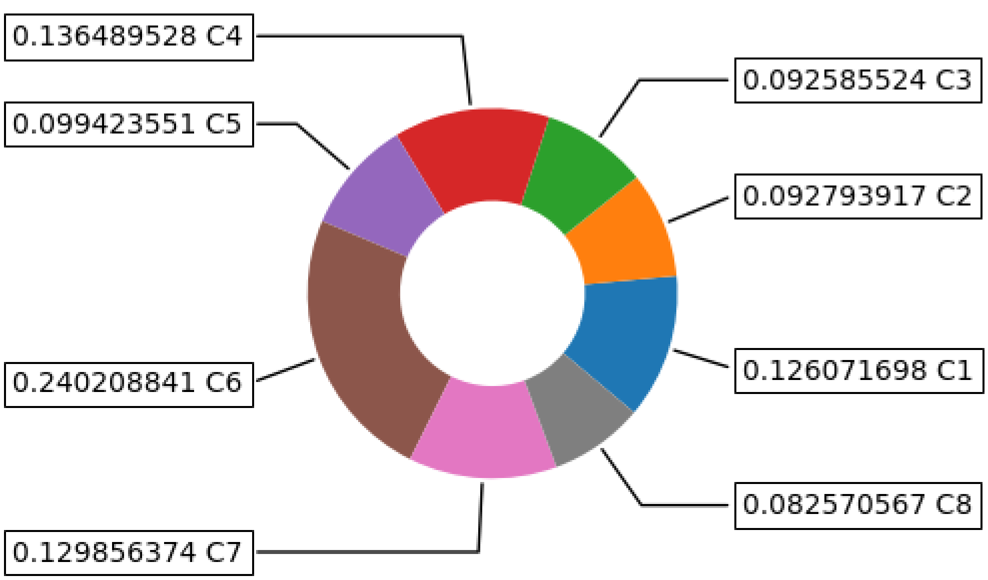

Fig 1. The criteria weights.

Stage 3 – The process of ranking alternatives employing the SVTNSs-ARLON method.

Then we applied the steps of the ARLON method to rank the alternatives and select the best one. Then we used Eqs. (14 and 16) to obtain the first second logarithmic normalization matrix as shown in Table 7 and 8. Then we used Eq. (16) to obtain the combined decision matrix as shown in Table 9. Then we compute the weighted decision matrix using Eq. (17) as shown in Table 10. Then we compute the summations of the weighted combined normalized values for positive and negative criteria using Eqs. (18 and 19). Then we obtain the final rank of alternatives using Eq. (20) as shown in fig 2.

Table 7. The first normalization matrix.

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
A1	0.067406398	0.088274	0.085435	0.078624	0.096608	0.092007	0.073746	0.114597
A2	0.073483734	0.072868	0.089728	0.091673	0.078996	0.087604	0.071333	0.115587
A3	0.085490787	0.081793	0.077302	0.093468	0.088197	0.088787	0.084752	0.113489
A4	0.079975274	0.08327	0.081208	0.075359	0.077022	0.06517	0.090099	0.114074
A5	0.081281174	0.083858	0.08168	0.075359	0.077648	0.070892	0.084633	0.115012
A6	0.084693779	0.091886	0.082257	0.083431	0.079428	0.082899	0.086015	0.114074
A7	0.085140179	0.086382	0.0889	0.091263	0.090236	0.092502	0.091195	0.113489
A8	0.080529002	0.083742	0.083903	0.090676	0.088771	0.08945	0.08885	0.114514
A9	0.067406398	0.075534	0.073424	0.070319	0.085305	0.079118	0.076445	0.115536
A10	0.069687412	0.077462	0.077725	0.087685	0.082494	0.084229	0.083787	0.114134
A11	0.074081002	0.088653	0.083903	0.087294	0.077648	0.084693	0.084275	0.114889
A12	0.087323772	0.086278	0.094537	0.074851	0.077648	0.082649	0.08487	0.115605

Table 8. The second normalization matrix.

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
A1	0.071977	0.088274	0.085435	0.078624	0.096608	0.092007	0.073746	0.916777
A2	0.078466	0.072868	0.089728	0.091673	0.078996	0.087604	0.071333	0.924699
A3	0.091288	0.081793	0.077302	0.093468	0.088197	0.088787	0.084752	0.90791
A4	0.085398	0.08327	0.081208	0.075359	0.077022	0.06517	0.090099	0.912594
A5	0.086793	0.083858	0.08168	0.075359	0.077648	0.070892	0.084633	0.920095
A6	0.090437	0.091886	0.082257	0.083431	0.079428	0.082899	0.086015	0.912594
A7	0.090913	0.086382	0.0889	0.091263	0.090236	0.092502	0.091195	0.90791
A8	0.085989	0.083742	0.083903	0.090676	0.088771	0.08945	0.08885	0.916114
A9	0.071977	0.075534	0.073424	0.070319	0.085305	0.079118	0.076445	0.924287
A10	0.074413	0.077462	0.077725	0.087685	0.082494	0.084229	0.083787	0.913075
A11	0.079104	0.088653	0.083903	0.087294	0.077648	0.084693	0.084275	0.919109
A12	0.093245	0.086278	0.094537	0.074851	0.077648	0.082649	0.08487	0.924838

Table 9. The combined normalization matrix.

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
A1	0.069672967	0.088274	0.085435	0.078624	0.096608	0.092007	0.073746	0.419908
A2	0.075954656	0.072868	0.089728	0.091673	0.078996	0.087604	0.071333	0.423537
A3	0.088365453	0.081793	0.077302	0.093468	0.088197	0.088787	0.084752	0.415847
A4	0.082664477	0.08327	0.081208	0.075359	0.077022	0.06517	0.090099	0.417992

A_5	0.084014289	0.083858	0.08168	0.075359	0.077648	0.070892	0.084633	0.421428
A_6	0.087541645	0.091886	0.082257	0.083431	0.079428	0.082899	0.086015	0.417992
A_7	0.088003055	0.086382	0.0889	0.091263	0.090236	0.092502	0.091195	0.415847
A_8	0.083236825	0.083742	0.083903	0.090676	0.088771	0.08945	0.08885	0.419605
A_9	0.069672967	0.075534	0.073424	0.070319	0.085305	0.079118	0.076445	0.423348
A_{10}	0.072030682	0.077462	0.077725	0.087685	0.082494	0.084229	0.083787	0.418213
A_{11}	0.076572008	0.088653	0.083903	0.087294	0.077648	0.084693	0.084275	0.420976
A_{12}	0.090260072	0.086278	0.094537	0.074851	0.077648	0.082649	0.08487	0.4236

Table 10. The weighted normalized matrix.

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**
A_1	0.008783789	0.008191	0.00791	0.010731	0.009605	0.022101	0.009576	0.034672
A_2	0.009575733	0.006762	0.008308	0.012512	0.007854	0.021043	0.009263	0.034972
A_3	0.011140383	0.00759	0.007157	0.012757	0.008769	0.021327	0.011006	0.034337
A_4	0.010421651	0.007727	0.007519	0.010286	0.007658	0.015654	0.0117	0.034514
A_5	0.010591824	0.007782	0.007562	0.010286	0.00772	0.017029	0.01099	0.034798
A_6	0.011036524	0.008526	0.007616	0.011387	0.007897	0.019913	0.01117	0.034514
A_7	0.011094695	0.008016	0.008231	0.012456	0.008972	0.02222	0.011842	0.034337
A_8	0.010493808	0.007771	0.007768	0.012376	0.008826	0.021487	0.011538	0.034647
A_9	0.008783789	0.007009	0.006798	0.009598	0.008481	0.019005	0.009927	0.034956
A_{10}	0.00908103	0.007188	0.007196	0.011968	0.008202	0.020232	0.01088	0.034532
A_{11}	0.009653563	0.008226	0.007768	0.011915	0.00772	0.020344	0.010944	0.03476
A_{12}	0.011379241	0.008006	0.008753	0.010216	0.00772	0.019853	0.011021	0.034977

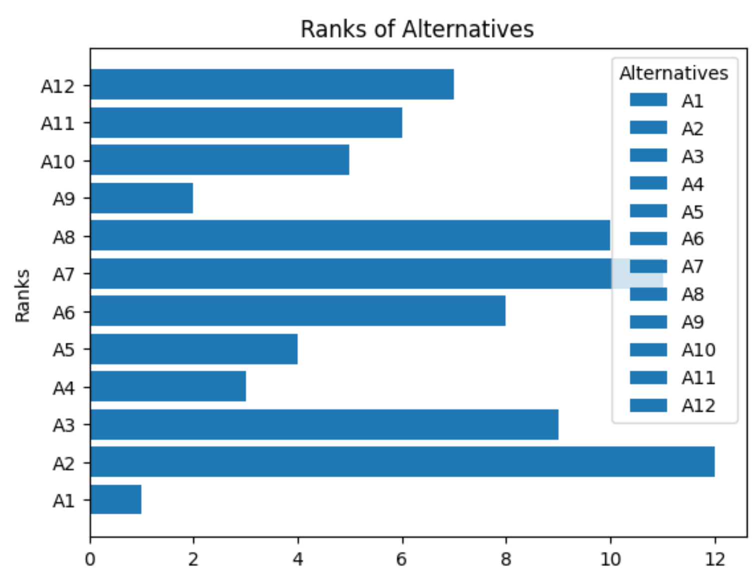

Fig 2. The rank of alternatives.

We conducted the sensitivity analysis between the ranks of the alternatives to show the stability and robustness of the proposed approach. We conducted the sensitivity analysis with two phases. In the first phase, we change the α value between 0 and 1. In the second phase, we change the β value between 0 and 1. Then we ranked the alternatives.

In the first phase, we rank the alternatives under different cases. In the first case, we show alternative 2 is the best and alternative 1 is the worst. In all cases, we show alternative 2 is the best and alternative 1 is the worst we show the ranks of alternatives are stable under different cases. Fig 3 the ranks of alternatives under phase 1. Fig 4 shows the alternatives values.

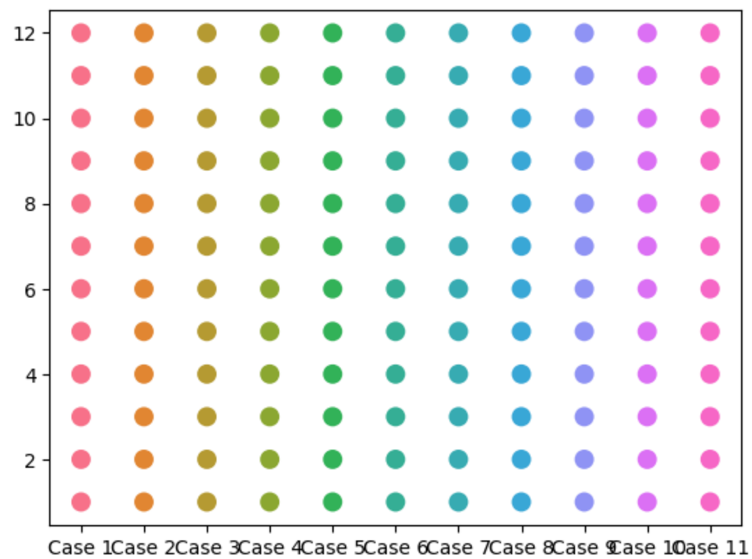

Fig 3. Ranks of alternatives under phase 1.

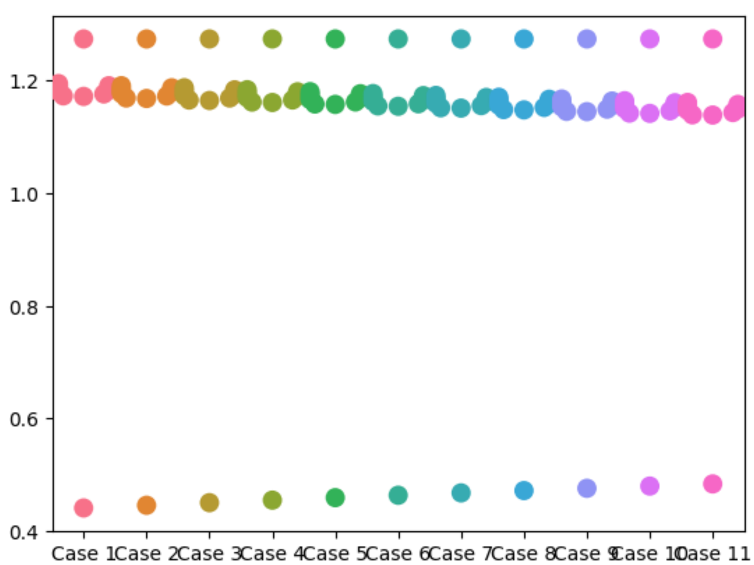

Fig 4. The alternatives values under phase 1.

In the second phase, we rank the alternatives under different cases. In the first case, we show alternative 2 is the best and alternative 1 is the worst. In all cases, we show alternative 2 is the best and alternative 1 is the worst we show the ranks of alternatives are stable under different cases. Fig 5 shows the alternatives values. Fig 6 the ranks of alternatives under phase 1.

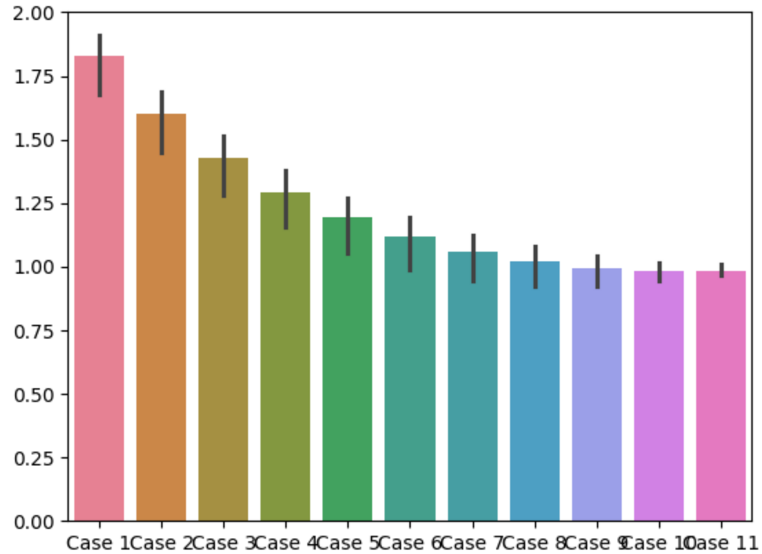

Fig 5. The alternatives values under phase 2.

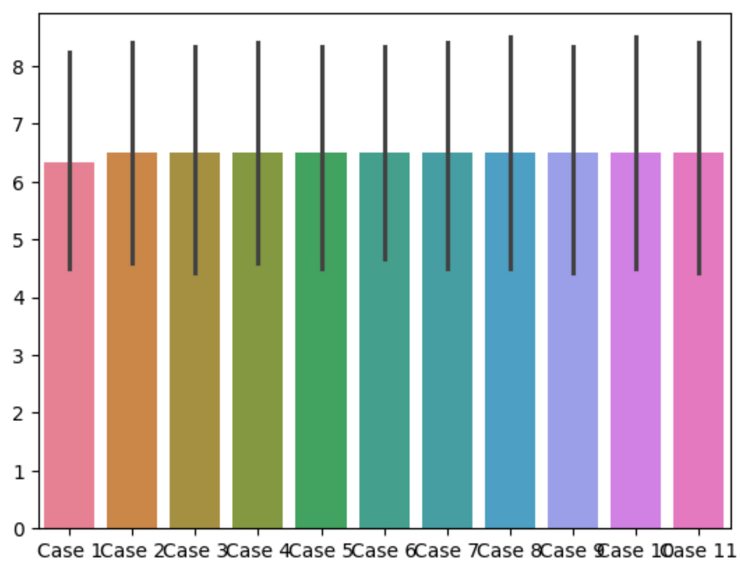

Fig 6. Ranks of alternatives under phase 2.

5. Conclusions

The method of choosing shock absorption performance evaluation of mechanical component springs was clarified by this study. For this goal, the research developed a customized decision support system based on the MAGDM framework. The study emphasized the vital role of shock absorption performance in performance evaluation. The research established a foundational understanding for choosing the best alternative, especially within the MAGDM paradigm. The study presented the SVTN-MEREC-ARLON method as a novel decision support system employing a tripartite methodology that included expert interaction, criteria significance assessment, and best system determination using a hybrid approach. Validation using real-world case study showed how effective and reliable the suggested method is.

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