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Selection a Suitable Supplier for Enhancing Supply Chain Management under Neutrosophic Environment

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Abstract: In supply chain management (SCM), selecting a sustainable supplier has improved as one of the most urgent issues. Several previous research has attempted to determine how to choose a sustainable supplier using various strategies and approaches. A suitable supplier needs to be chosen to improve the quality of products, services, reduce prices of purchasing, and regulate time. This paper aims to Enhance Supply Chain Management for the Suitable Supplier selection by integrating the neutrosophic Analytical Hierarchy Process (AHP) with Multiplicative Multi-Objective Optimization based on Ratio Analysis (MULTIMOORA) approach. Furthermore, this is a Multi-Criteria Decision-Making (MCDM) issue, selecting sustainable providers is complex. because includes unclear information, decision-makers' loss of accuracy, indeterminate, uncertainty, and inconsistent information. For this, we use a single value neutrosophic set (SVNS) to can handle unclear information, the knowledge that is inaccurate, and indeterminate, uncertain information. The proposed study applies integrating Single Valued Neutrosophic AHP for calculating the weights of different criteria taking into account their interdependencies. Then the MULTIOORA technique ranks the different alternatives, then chooses the best provider. A case study is utilized on the pharmaceutical manufacturing company. The case study uses the integrated approach to analyze and choose the ideal supplier.

Keywords: Supply Chain Management; Neutrosophic; AHP; MULTIMOORA; MCDM

1. Introduction

Nowadays, Organizations have understood that to compete in local and global marketplaces, they must implement effective strategies to strengthen the supply chain and achieve a competitive advantage over their competitors. Supply chain management (SCM) is a way of referring to a collection of three or more enterprises (organizations or persons) that participate in the input and output flows of products, resources, finances, and information from a resource to a consumer[1]. SCM allows organizations to efficiently integrate products and services to build long-term relationships[2]. SCM is a concept whose main goal is to "integrate and manage the source, flow, and control of materials across various functions using a whole systems approach." Supply chains include both suppliers and consumers so, the SCM method may be used in the greatest organizations to control the flow of information, goods, and materials and to be more reactive in an organizational environment including Lowering prices, ensuring quick delivery, and reducing shipping times.

The Supplier Selection Problem (SSP) is a great issue for most industrial companies and supply chain management. The fundamental goal of a Supplier Selection Problem is really to identify one supplier with the best chance of meeting the company's demands while lowering costs. A well-known and fundamental component of supply chain planning challenges is the supplier selection problem. The best suppliers are chosen based on a variety of factors, including overall performance ratings, item rejection rates, timely delivery, and meeting aggregate demand. SSP is the main issue we want to solve[3]. Furthermore, we proposed neutrosophic logic to solve it. Neutrosophic logic (NL) is one of the most current fuzzy system suggestions, Smarandache [4] proposed it work with inconsistent, fuzzy, imprecise, and incomplete information simultaneously. Various ways for approximation and uncertain reasoning have been created to deal with an ambiguous choice process involving imprecise, partial, and incomplete information. One is fuzzy logic, intuitionistic, and interval logic. The neutrosophic set is an expansion of the fuzzy sets. It contains three terms (trusty, indeterminacy, falsity) to characterize the uncertain membership at the same time[5]. The neutrosophic set assists specialists and decision-makers in comprehending information in an ambiguous context and expressing their opinions more clearly. Wang et al. [6]proposed a single-valued neutrosophic set as an example of a neutrosophic set (SVNS). The classic set, fuzzy set, interval-valued fuzzy set, and intuitionistic fuzzy set are all extensions of the single-valued neutrosophic set. The terms inclusion, complement, union, and intersection have all been defined on SVNS.

Supplier selection is a multi-criteria decision-making (MCDM) problem that incorporates a variety of criteria, options, and decision-makers in determining the best candidate for the company. MCDM problems using neutrosophic or single-valued neutrosophic information, like the neutrosophic Analytic Hierarchy Process (AHP), have been researched by many researchers[7]. Multi-Criteria Decision-Making (MCDM) techniques use a group of experts and decision-makers to address goal evaluation to numerous criteria utilizing computational and mathematical models to tackle real-life decision-making problems.

Engineering, management, technology, and science are all sectors where MCDM approaches are commonly employed. The use of MCDM methodologies to construct specific MCDM models is a viable solution to such situations. These models differ from one another because they use various MCDM methodologies or have distinct requirements. In this paper, we use integrated AHP with a MULTIMOORA method. The AHP uses a hierarchical structure to express and analyze the link between the criteria, sub-criteria and to assess them.

The MULTIMOORA method is an enhanced version of multi-objective optimization (MOORA), a simple and effective multi-attribute decision making (MADM) tool [8]. MULTIMOORA is now the most reliable multi-objective optimization system, as evidenced by the fact that it is the only multi-criteria methodology capable of meeting numerous criteria employing three or more techniques [9]. Many authors proposed a MULTIMOORA to aid decision-makers in selecting a suitable supplier by assessing multiple risks and benefits and knowing how they impact the supply chain[10]. The main benefit of adopting the combination fuzzy AHP- MULTIMOORA method is the ability to categorize and evaluate the criteria, sub-criteria, and alternatives for each risk. So we proposed a hybrid model AHP and MULTIMOORA by using SVNS for selecting a supplier to enhance the supply chain management SCM.

The paper is organized as follows. Section 2, reviews the literature for sustainable supplier selection. Section 3, the preliminaries of the neutrosophic set and SVNS are provided. Section 4, presents the proposed methodology of AHP and MULTIMOORA. Section 5, the results of the case study are presented and analyzed. Section 6, the conclusion and future work are presented.

2. Literature review

In SCM, one of the really difficult multi-criteria decision-making tasks is supplier selection. especially when it comes to sustainability. Several approaches for determining supplier criteria, evaluations, and selection have been published in major scientific journals. Fallahpour et al (2017). [11]produced a fuzzy AHP-TOPSIS approach to aid the supplier evaluation and selection criteria. The fuzzy preference programming technique was used to generate the relative fuzzy weights of the ranking criterion, and the ranking of possible suppliers was determined using fuzzy TOPSIS. Luthra et al (2017). [12] AHP and VIKOR approaches were utilized to develop a sustainable supplier selection strategy. The suggested framework includes 22 criteria for each of the three sustainability pillars. The sustainable supplier selection (SSS) criteria were weighted using the AHP method, and the VIKOR approach was used to choose the most efficient sustainable supplier. Ghorabaee et al (2017).

[13] A study of multi-attribute decision-making procedures for analyzing and selecting the best providers in a fuzzy environment. Tavana et al (2017). [14] Introduced an integrated ANP-QFD method to calculate the decision criteria and sub-criteria to achieve customer needs and sustainable supplier selection. Qin et al (2017). [15] developed a TODIM method for supplier assessment using fuzzy sets of interval type 2. Liu et al (2018). [16] proposed ANP and VIKOR methods to assess supplier choice using interval type-2 fuzzy sets. The criteria are weighted using an ANP technique, and the VIKOR method was used to select and rank sustainable suppliers.

Abdel-Basset et al (2018). [17] combined ANP with TOPSIS for solving the sustainable supplier selection issue using interval-valued neutrosophic numbers. Kumar et al (2018). [18] a Combined method of fuzzy theory and AHP-DEMATEL to aid the automobile industry in optimizing their supplier selection process for capital procurement. Jain et al (2018). [19] fuzzy multi-criteria decision-making techniques that are combined In an Indian car firm, AHP and the approach for order of preference by similarity to ideal solution (TOPSIS) were applied to the problem of supplier selection. Van et al (2018) [20] Proposed Quality Function Deployment (QFD) for supplier selection and assessment using a neutrosophic interval set. Chen et al (2018). [21] For sustainable supplier selection, OWA distance was used in conjunction with a single-valued neutrosophic linguistic (SVNL) based TOPSIS method. Abdel-Basset et al (2018). [22] For sustainable supplier selection challenges, integrate AHP- TOPSIS with interval-valued neutrosophic sets and a multi-criteria decision-making technique. They calculated criterion weights using the AHP approach and SSS using TOPSIS. Abdel-Basset et al (2018). [23] used a neutrosophic set and the DEMATEL approach for decision making and analysis. to examine and determine the factors impacting the selection of supply chain management vendors. Abdel-Basset et al (2018). [24] combined neutrosophic (AHP) with quality function deployment (QFD) to choose the best provider. Neutrosophic set determines three-way judgments based on the categorization into three parts (acceptance, rejection, and not sure). For selected best supplier should satisfy company requirements, so use (QFD) to determine efficient business requirements. Wang et al (2018). [25] Introduced a 2-tuple linguistic neutrosophic numbers (2TLNNs) operator to handle the MADM difficulty and identify sustainable suppliers.

Sinha et al (2018). [26] developed a decision framework for sustainable supplier selection based on a combination of MCDM approaches and graph theory. Song et al (2019). [27] proposed a large-scale decision-making model that involves many stakeholders in the decision-making process. SSS is accomplished using TOPSIS, and their approach comprises partial language phrases depending on risk attitudes. Matic et al (2019). [28] On a sustainable supply chain, created a novel hybrid MCDM model for evaluating and choosing suppliers. Abdel-Basset et al (2019). [29] Developed the ANP and VIKOR approaches for sustainable supplier selection based on triangular neutrosophic numbers (TriNs). Islam et al (2019). [30] To handle supplier selection difficulties, they developed a neutrosophic goal programming technique based on triangular neutrosophic numbers. to identify the optimum compromise for the company, the authors employ neutrosophic goal programming. A multi-objective linear programming problem (MOLP) is an example of this.

Jain et al (2020). [31] suggested Multi-Criteria Decision Making (MCDM) with Fuzzy Inference System (FIS) techniques for weighting and ordering to Suitable Supplier Selection, and fuzzy AHP and fuzzy TOPSIS algorithms. Wang et al (2020) [32]. created a fuzzy ANP-PROMETHEE II to help the textile sector evaluate and choose suppliers. Selection criteria for the proposed model are based on the widely used Supply Chain Operation Reference (SCOR) model. Zeng and al (2020). [33] Proposed a single value neutrosophic for sustainable supplier selection based on ambiguous information given by decision-makers and established a single value neutrosophic hybrid weighted similarity (SVNHWS) measure. Yalcin et al (2020). [34] combined ANP technique and TODIM approach, under interval-valued neutrosophic sets (IVNSs) to Sustainable Supplier's choice. Amiri et al (2020). [35] presented a novel approach multi-criteria decision method based on Best-Worst technique and α-cut for suitable supplier selection. Pamucar et al (2020). [36] the suggested fuzzy neutrosophic technique for robust supplier selection based on trapezoidal linguistic factors. Tavana et al (2021). [37] For a suitable provider, combine AHP with fuzzy multiplicative multi-objective based on (MULTIMOORA). The MULTIMOORA is also used to select the providers and the AHP is used to evaluate the importance of company risks and benefits. Yazdani et al (2021). [38] proposed criteria Correlation and compromised solution under neutrosophic environment and uses multiple alternatives for evaluation and selection of suppliers. Uluas et al (2021). [39] introduced a novel MULTIMOOSRAL method to the supplier selection issue. From previous works, it is the first study to hybrid the AHP and MULTIMMORA method with large dimension data to enhance the SCM by evaluating the best supplier.

3. Preliminaries

This section covers the most important definitions of neutrosophic sets, as well as single-valued neutrosophic sets and their processes.

3.1. Neutrosophic sets

Definition 1. [40]Let L be a collection of elements (objects). A neutrosophic set B in L is characterized by a truth-membership function $T_A(l)$, an indeterminacy membership function $I_A(l)$, and a falsity-membership function $F_A(l)$. The functions $T_A(l)$, $I_A(l)$, $F_A(l)$ are there any actual normal or non-standard subsets of]⁻0, 1⁺[. That is $T_A(l)$: L →]⁻0, 1⁺[, $I_A(l)$: L →]⁻0, 1⁺[and $F_A(l)$: L →]⁻0, 1⁺[.

The total amount is unrestricted of $T_A(l)$, $I_A(l)$, and $F_A(l)$. So, $0 \le T_A(l) + I_A(l) + F_A(l) \le 3$.

From a philosophical viewpoint, a neutrosophic set derives its worth from a real norm or non-standard subsets of]⁻0, 1⁺[. Because in real-life scientific circumstances, using a neutrosophic set with values from genuine standard or non-standard subsets of]–0, 1+[is impossible. the neutrosophic set (single-valued neutrosophic set) whose value is determined by the subset [0, 1]. Now, we'll make use of the notions. m_A, s_A and z_A instead of notions T_A, I_A and F_A, respectively.

Neutrosophic set is a recent proposal for a strong generic set theory. Therefore, from a technical standpoint, the neutrosophic set should be specified. in this manner, In 2010, Wang et al. [41]presented the single-valued neutrosophic set (SVNS) that is an example of the neutrosophic set.

3.2. Single valued neutrosophic sets

Wang [41] proposed a single-valued neutrosophic as follows:

Definition 2: [41] that L be a universe of discourse with general components indicated by l An SVNS A in L is described by truth-membership function $m_A(l)$, indeterminacy-membership function $s_A(l)$, and falsity-membership function $z_A(l)$. A single valued neutrosophic set An over L is an object with the form:

$$A = \{ \langle l, m_A(l), s_A(l), z_A(l) \rangle \; | l \in L\}, \quad \textbf{(1)}$$

Where m_A : L → [0, 1] , s_A :L → [0, 1] and z_A : L → [0, 1] with the condition

$$0 \le m_A(l) + s_A(l) + z_A(l) \le 3, \; \forall l \in L \quad \textbf{(2)}$$

Definition 3: Let X and B be two single-valued neutrosophic sets,

$$X = \{ \langle l, m_X(l), s_X(l), z_X(l) \rangle : l \in L\} \text{ and} \quad \textbf{(3)}$$

$$B = \{ \langle l, m_B(l), s_B(l), z_B(l) \rangle : l \in L\}. \quad \textbf{(4)}$$

Then some operations can be defined as follows:

1. $X \cup B = \{ \langle l : \max\{m_X(l), m_B(l)\},$
   $\min\{s_X(l), s_B(l)\}, \min\{z_X(l), z_B(l)\} \rangle \}$;
2. $X \cap B = \{ \langle l : \min\{m_X(l), m_B(l)\}, \max\{s_X(l), s_B(l)\}, \max\{z_X(l), z_B(l)\} \rangle \}$;
3. $A \subseteq B$ if and only if $m_X(l) \leq m_B(l)$, $s_X(l) \geq s_B(l)$, and $z_X(l) \geq z_B(l)$, $\forall\, l \in L$
4. X = B if and only if $X \subseteq B$ and $B \subseteq X$;
5. $X^c = \{ \langle l, z_X(l), 1 - s_X(l), m_X(l) \rangle \}$.

Because each membership value is independent of the others, there are definitions of distinct neutrosophic empty sets and, as a result, absolute neutrosophic sets in single-valued neutrosophic information.

Definition 4: Let X be a single-valued neutrosophic set on L.

1. A single valued neutrosophic set X is empty, denoted by 0 = {0, 1, 1} if $m_X(l) = 0$, $s_X(l) = 1$ and $z_X(l) = 1$ for each $l \in L$.

2. A single valued neutrosophic set X is absolute, denoted by 1 = {1, 0, 0} if $m_X(l) = 1$, $s_X(l) = 0$ and $z_X(l) = 0$ for each $l \in L$.

Definition 5: Alternative ratings are in the form of INS $\bar{x}_{ab} = [x_{ab}^M, x_{ab}^U]$ in Interval Target value Based on MULTIMOORA. The maximum, minimum, and ordering of INs are determined using the preference matrix. As well, the IN interval distance is used. In this approach, the normalization ratio $\bar{x}_{ab}^*$ is defined as follows:

$$\bar{x}_{ab}^* = \left[x_{ab}^{*,M}, x_{ab}^{*,U}\right] = \exp\left(-\frac{\bar{l}^*(\bar{x}_{ab},\bar{t}_b)}{\max\limits_a l^*(\bar{x}_{ab},\bar{t}_b)}\right) \tag{5}$$

$$= \exp\left\{-\frac{\begin{cases}\left[\min\{|x_{ab}^M - t_b^U|, |x_{ab}^U - t_b^M|\}, \left|\left((x_{ab}^M + x_{ab}^U)/2\right) - \left((t_b^M + t_b^U)/2\right)\right|\right], & \text{if } \bar{x}_{ab} \cap \bar{t}_b = \emptyset \\ \left[0, \left|\left((x_{ij}^L + x_{ij}^U)/2\right) - \left((t_j^L + t_j^U)/2\right)\right|\right], & \text{if } \bar{x}_{ab} \cap \bar{t}_b \neq \emptyset \end{cases}}{\max\limits_b \begin{cases}\left(\min\{|x_{ab}^M - t_b^U|, |x_{ab}^U - t_b^M|\} + \left|\left((x_{ab}^M + x_{ab}^U)/2\right) - \left((t_b^M + t_b^U)/2\right)\right|\right)/2, & \text{if } \bar{x}_{ab} \cap \bar{t}_b = \emptyset \\ \left|\left((x_{ab}^M + x_{ab}^U)/2\right) - \left((t_b^M + t_b^U)/2\right)\right|/2, & \text{if } \bar{x}_{ab} \cap \bar{t}_b \neq \emptyset \end{cases}}\right\} \tag{6}$$

where $\bar{t}_b$ is the interval target value of each criterion and is computed as $\bar{t}_b = [t_b^M, t_b^U]$ = $\left\{\max\limits_a \bar{x}_{ab},\ if\ b \in A;\ \min\limits_a \bar{x}_{ab},\ if\ b \in B;\ \bar{s}_b,\ if\ b \in K\right\}$ where A, B, and K are the sets of beneficial, non-beneficial, and target-based criteria, together. And, $\bar{s}_b$ is the interval goal number of each target-based criterion. The utility values of the Ratio system, Good Reference

Method, and Complete Multipliers Form interval target-based methods, i.e., $\bar{y}_a^F$, $\bar{T}_a^F$, and $\bar{Z}_a^F$, respectively, are obtained as follows:

are the sets of benefit, non-beneficial, and target-based criteria, together. And, $\bar{s}_b$ is the target-based criterion's interval goal number. Interval target-based approaches are formed by the utility values of the Comparison system, Great Reference Method, i.e., $\bar{y}_a^F$, $\bar{T}_a^F$, and $\bar{Z}_a^F$, are obtained in the following way:

$$\bar{y}_b^F = \left[y_a^{F,M}, y_a^{F,U}\right] = \sum_{b=1}^{s} V_b \bar{x}_{ab}^* = \left[\sum_{j=b}^{s} V_b x_{ab}^{*,M}, \sum_{j=b}^{s} V_b x_{ab}^{*,U}\right] \quad (7)$$

$$\bar{T}_a^F = \left[T_a^{F,M}, T_a^{F,U}\right] = \max_b \bar{l}^*(V_b[1,1], V_b \bar{x}_{ab}^*)$$

$$= \max_b \Big(V_b \cdot \big\{\big[min\{|1 - x_{ab}^U|, |1 - x_{ab}^M|\}, \big|1 - \big((x_{ab}^M + x_{ab}^U)/2\big)\big|\big],$$

$$\text{if } [1,1] \cap \bar{x}_{ab}^* = \emptyset; \big[0, \big|1 - \big((x_{ab}^M + x_{ab}^U)/2\big)\big|\big], \text{if } [1,1] \cap \bar{x}_{ab}^* \neq \emptyset\big\}\Big) \quad (8)$$

$$\bar{Z}_a^F = \left[Z_a^{F,M}, Z_a^{F,U}\right] = \prod_{b=1}^{s} (\bar{x}_{ab}^*)^{V_b} = \left[\prod_{b=1}^{s} \left(x_{ab}^{*,M}\right)^{V_b}, \prod_{b=1}^{s} \left(x_{ab}^{*,U}\right)^{V_b}\right] \quad (9)$$

4. Research Methodology

A hybrid MULTIMOORA method with neutrosophic analytical hierarchy process (AHP) is used to select the best supplier. In this section, we present a summary of the two methods utilized in our proposed research. Figure. 1 summarized the proposed method and its steps.

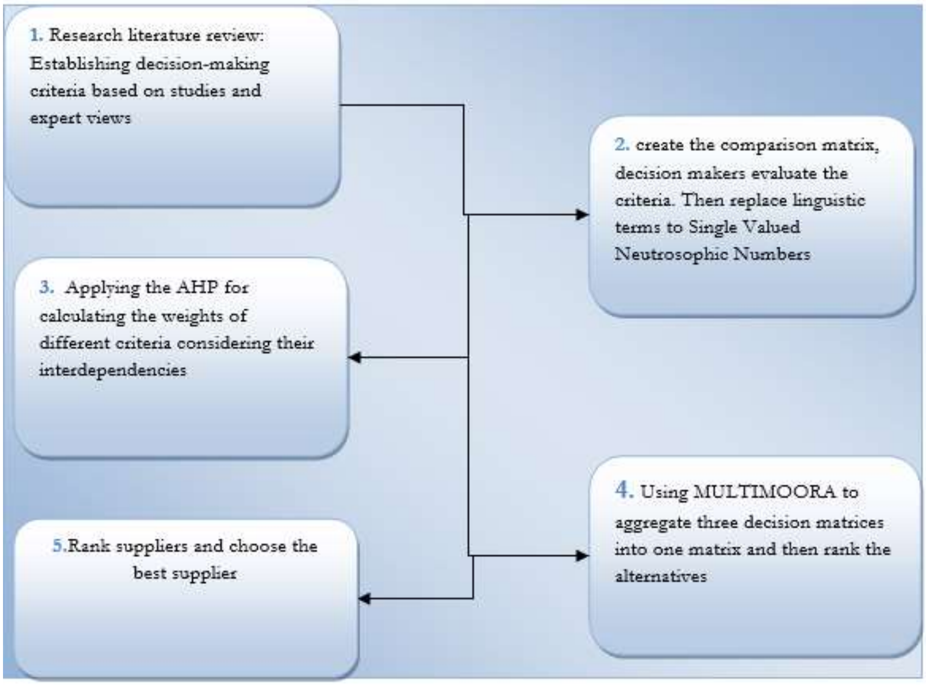

Figure 1. Proposed method framework

4.1 The AHP Approach

Saaty 1980 was the first to introduce the analytical hierarchy approach. The method has been used to solve a wide range of decision-making issues. It also provides a way for calculating the weights of criteria in a structured manner.

Phase 1: In a neutrosophic environment, get expert information.

- Decide on the study's objective, criteria, and alternative.
- Create a pairwise matrix of decision making judgments using the following form:

$$A^U = \begin{bmatrix} M_{11}^U & \cdots & M_{1b}^U \\ \vdots & \ddots & \vdots \\ M_{x1}^U & \cdots & M_{xb}^U \end{bmatrix} \quad \textbf{(10)}$$

Where **u** presents the decision makers, u=1, 2,….d, **x** presents the criteria and **b** presents the alternatives; x=1,2,….a; b =1,2,….c

- Using the score function of M_{ac}, convert neutrosophic scales to crisp values.

$$h(M_{ac}) = \frac{2+T-I-F}{3} \quad \textbf{(11)}$$

where T,I, F presents the truth, indeterminacy, and falsity membership degrees.

- Aggregate a pairwise matrix by:

$$M_{ac} = \frac{\sum_{u=1}^{d} M_{xb}^U}{u} \quad \textbf{(12)}$$

- Create the first pairwise comparison matrix as follows:

$$M = \begin{bmatrix} M_{11} & \cdots & M_{1b} \\ \vdots & \ddots & \vdots \\ M_{X1} & \cdots & M_{xb} \end{bmatrix} \quad \textbf{(13)}$$

Phase 2: Then calculate the weights of criteria.

- Compute the average of row

$$P_a = \frac{\sum_{x=1}^{a} (M_{xb})}{a}; x = 1,2,3, \dots \dots . a; b = 1,2,3, \dots \dots c \quad \textbf{(14)}$$

- The following equation is used to compute crisp value normalization**.**

$$P_a^X = \frac{P_a}{\sum_{a=1}^{x} P_a}; x = 1,2,3, \dots \dots . a \quad \textbf{(15)}$$

4.2 The MULTIMOORA Approach

Phase 3: Forming the decision matrix M is the first stage in the MULTIMOORA technique.

- In which M_{xb} presents the performance index of bth alternative respecting $\boldsymbol{x}$ th attribute x = 1, 2, …a and b = 1, 2, …c , and

$$M = [M_{xb}]_{ac} \quad \textbf{(17)}$$

- In the MULTIMOORA approach, to make performance indices comparable, these parameters should be dimensionless. As a result, the choice matrix is a normalized ratio of comparison between each alternative's response to criteria as a numerator and a denominator that represents all alternative performances on that attribute as a denominator.

$$N_{xb}^{*} = \frac{M_{xb}}{\sqrt[2]{\sum_{x=1}^{a} M_{xb}^{2}}}$$

(18)

where, N_{xb}^{*} denotes the normalized performance index of $\boldsymbol{b}$th alternative respecting $\boldsymbol{x}$ th attribute x = 1, 2, …a and b = 1, 2, …c and M_{xb} The performance index is displayed..

- Determine the total assessment

$$y_{x}^{*} = \sum_{b=1}^{g} P_{b}^{c} N_{xb}^{*} - \sum_{b=g+1}^{c} P_{b}^{c} N_{xb}^{*} \quad \textbf{(19)}$$

y_{x}^{*} denotes the total assessment of alternative $\boldsymbol{b}$th for subjective importance coefficients of all attributes **x**th, where **g** indicates the objectives to be maximized and (n-g) indicates the objectives to be minimized

- An ordinal ordering of the y_{x}^{*} with the highest assessment value is the best option based on the ratio system :

$$Z_{ac}^{*} = \left\{ Z_{b} \mid \max_{b} M_{b}^{*} \right\} \quad \textbf{(20)}$$

- The MULTIMOORA approach's second stage is built on the foundation of the ratio scheme displayed in eq. (20). In the procedure, a maximum objective reference point is also established in this form :

$$u_{a} = \begin{cases} \max_{m} M_{ac}^{*} & \text{in case of maximization} \\ \max_{m} M_{ac}^{*} & \text{in case of minimization} \end{cases} \quad \textbf{(21)}$$

Where u_{a} is the maximal objective reference point vector's $\boldsymbol{a}$th co-ordinate.

- A performance index's deviation from the reference point u_{l} can be represented as $(u_{a} - M_{ac}^{*})$. The greatest value of the deviation for each alternative t_{a} may then be computed using subjective significance coefficients for all criterion V_{l}^{j} and as follows:

$$t_a^* = \max_l \left| \left(P_b^g u_b - P_b^g M_{ac}^* \right) \right| \quad \textbf{(22)}$$

The best option is determined using the reference point approach, which involves determining the smallest number in prior calculations. Equation **(22)**. Demonstrated shown as:

$$Z_{ac}^* = \left\{ Z_a \mid \min_a t_a^* \right\} \quad \textbf{(23)}$$

The MULTIMOORA approach's third stage is proposed by Brauers and Zavadskas in 2010 is based on an idea from economic mathematics. As seen in this Equation, the formula for the full multiplicative form may well be calculated as demonstrated.

$$W_a' = \frac{\prod_{c=1}^{g} (M_{ac})^{P_c^g}}{\prod_{c=g+1}^{b} (M_{ac})^{P_c^g}} \quad \textbf{(24)}$$

where g refers to the maximized objectives and (b-g) refers to the minimized objectives. The product of performance indices of **a**th alternative related to advantageous attributes is the numerator of Eq. (23). The product of performance indices of **m**th alternative responding to non-beneficial features respects subjective importance coefficients of each attribute $\boldsymbol{P_c^g}$ is the denominator of Eq. (23). In the MULTIMOORA method, to keep all elements of the computations in harmony. Equation (23). Presents the whole multiplicative form in its normalized form. It is based on the search for the maximum among all assessment values of W_a^* similar to the ratio system calculation of the best alternative.

$$Z_{ac}^* = \left\{ Z_a \mid \max_a W_a^* \right\} \quad \textbf{(25)}$$

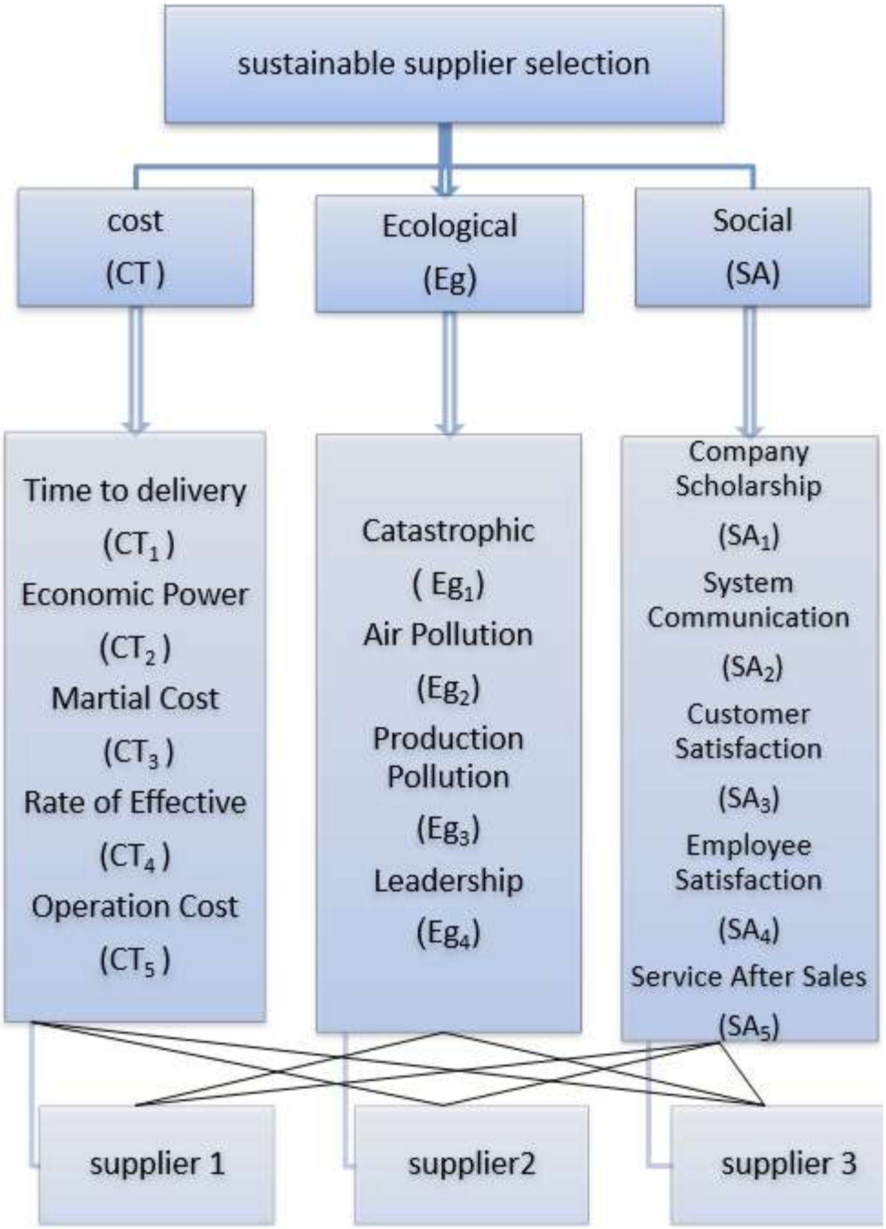

Figure 2. The hierarchical structure of SSS

5. Case Study

The proposed framework in this paper was applied for sustainable supplier selection (SSS) in an Egyptian pharmaceutical manufacturing company. The company makes and develops a variety of pharmaceuticals and tries to deal with various regulations relating to drug production, and drug marketing. This company's logistics section is in charge of supplying raw materials and chemicals. One of the company objectives is to create a framework for analyzing and finding top sustainable suppliers to improve efficiency and stay competitive. It is critical to choose the proper specialists while making decisions. We employ the integrated neutrosophic AHP-MULTIMOORA technique to choose the best one.

5.1 Results and Discussion

In this subsection, we discuss the results of the case study by using three experts to evaluate twenty criteria and three alternatives. The collected twenty criteria from the previous studies. Figure. 2 shows the hierarchical structure of sustainable supplier selection**.** We use the Single Valued Neutrosophic Scale for this study[42]. First steps, let decision-makers assess the criteria to build the comparison matrix. Then replace the linguistic terms with the Single Valued Neutrosophic Numbers. Then apply the score function to obtain the crisp value. Then aggregate the opinions of three experts into one matrix. Then compute the weights of main and sub-criteria. The weights of criteria show as CT1 =0.017554, CT2= 0.015736, CT3 =0.037136, CT4= 0. 035797, CT5=0.056704, Eg1 =0.039392, Eg2=0.074838, Eg3=0.105902, Eg4=0.09291, SA1 = 0.053527, SA2 =0.095759, SA3=0.088025, SA4=0.097024, SA5=0.189697. Figure 3. Show the weights of criteria.

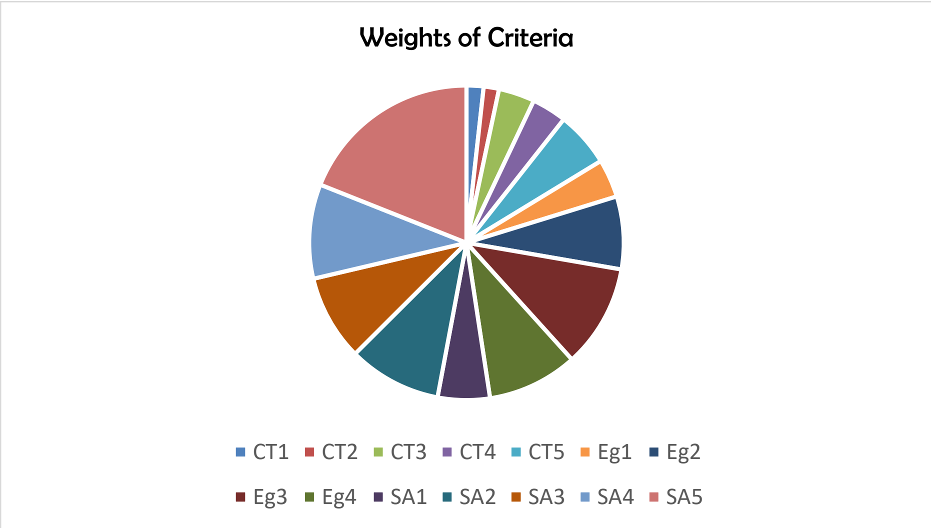

Figure 3. The Weights of Criteria

In the MULTIMOORA method, we let decision-makers evaluate the criteria and alternatives to obtain three decision matrices. Then convert these linguistic terms to neutrosophic numbers. Then convert these neutrosophic numbers into a crisp value. Then aggregate three decision matrices into one matrix in Table 1. Then compute the normalized decision matrix. Then compute the weighted normalized decision matrix by multiplying the normalized decision matrix by the weights of criteria in Table 2. Then compute the deviation references of the decision matrix in Table 3. Then compute the full multiplicative decision matrix in Table 4. Then rank the ratio system, reference point, and full multiplicative form in Table 5. From Table 7 we found that S2 is the best supplier and S1 is the worst Supplier in the ratio system. In the Reference point, we found that S2 is the best supplier and S3 is the worst supplier. But in the full multiplicative form, we found that S1 is the best supplier and S3 is the worst supplier. In the final rank, we conclude that S2 is the best supplier and s1 is the worst supplier. Figure 4 shows the rank of the supplier.

Table 1. The Combined Opinions of Three Experts.

Criteria/ Suppliers	CT_1	CT_2	CT_3	CT_4	CT_5	Eg_1	Eg_2	Eg_3	Eg_4	SA_1	SA_2	SA_3	SA_4	SA_5
S_1(Alternative)	0.62776	0.69443	0.8833	0.47223	0.6611	0.47223	0.4389	0.84996	0.37223	0.62776	0.37223	0.57223	0.59443	0.81663
S_2(Alternative)	0.72776	0.4389	0.4389	0.84996	0.59443	0.5611	0.4167	0.3389	0.3167	0.84996	0.3167	0.56043	0.8833	0.69443
S_3(Alternative)	0.7833	0.47223	0.81663	0.5611	0.2167	0.4167	0.33892	0.84996	0.72776	0.84996	0.4167	0.5389	0.5711	0.59443

Table 2. The Weighted Normalized of Decision matrix

Criteria/ Suppliers	CT_1	CT_2	CT_3	CT_4	CT_5	Eg_1	Eg_2	Eg_3	Eg_4	SA_1	SA_2	SA_3	SA_4	SA_5
S_1	0.3746	0.1323	0.1276	0.2276	0.0740	0.1659	0.1673	0.1099	0.0927	0.1224	0.0617	0.0626	0.0319	0.0263
S_2	0.3231	0.2094	0.2568	0.1264	0.0823	0.1396	0.1762	0.2757	0.1090	0.0904	0.0725	0.0639	0.0215	0.0309
S_3	0.3002	0.1946	0.1380	0.1915	0.2260	0.1880	0.2167	0.1099	0.0474	0.0904	0.0551	0.0665	0.0332	0.0361

Table 3. The Deviation References of Decision matrix.

Criteria/ Suppliers	CT_1	CT_2	CT_3	CT_4	CT_5	Eg_1	Eg_2	Eg_3	Eg_4	SA_1	SA_2	SA_3	SA_4	SA_5
S_1	0	0.0770	0.1292	0	0.1519	0.0221	0.0493	0.1658	0.0162	0	0.0108	0.0038	0.0013	0.0098
S_2	0.0514	0	0	0.1011	0.1436	0.0484	0.0404	0	0	0.0320	0	0.0025	0.0117	0.0052
S_3	0.0743	0.0147	0.1187	0.0360	0	0	0	0.1658	0.0615	0.0320	0.0174		0	0

Table 4. The Full Multiplicative Form

Criteria/ Suppliers	CT_1	CT_2	CT_3	CT_4	CT_5	Eg_1	Eg_2	Eg_3	Eg_4	SA_1	SA_2	SA_3	SA_4	SA_5
S_1	0.6277	0.6944	0.8833	0.4722	0.6611	0.4722	0.4389	0.8499	0.3722	0.6277	0.3722	0.5722	0.5944	0.8166
S_2	0.7277	0.4389	0.4389	0.8499	0.5944	0.5611	0.4167	0.3389	0.3167	0.8499	0.3167	0.5604	0.8833	0.6944
S_3	0.7833	0.4722	0.8166	0.5611	0.2167	0.4167	0.3389	0.8499	0.7277	0.8499	0.4167	0.5389	0.5711	0.5944

Table 5. Rank of MULTIMOORA Approach

Suppliers	Ratio System	Reference Point	Multiplicative Form	Final Rank
S_1	3	2	1	3
S_2	1	1	3	1
S_3	2	3	2	2

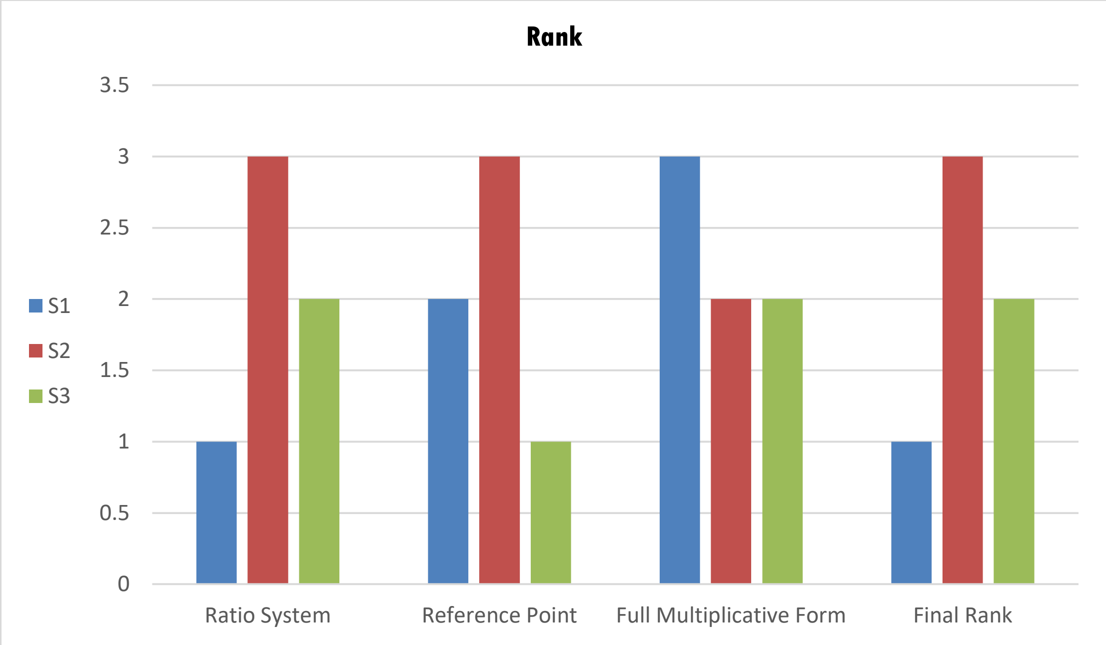

Figure 4. Rank of alternatives by the MULTIMOORA approach

6. Conclusions

Recently decision-making issues contain imprecision, vagueness, ambiguity, inconsistency, incompleteness, and indeterminacy, Neutrosophic set and logic are gaining traction as solutions and has been used to solve the various problem as a critical path problem.

Neutrosophic set helped to deal with ambiguous details, imprecise understanding, missing information, and linguistic imprecision through the neutrosophic environment. three membership degrees include the truth, indeterminacy, and falsity degrees, which are the main parts of a neutrosophic set. This feature is critical in a variety of applications including helping experts and decision-makers understand the information in an uncertain environment and make more precisely expressing their judgments to select the best supplier in supply chain management. NS is employed to evaluate and enhance supply chain management. The proposed study integrates neutrosophic analytical hierarchy process (AHP) and MULTIMOORA technique to suitable supplier selection. The AHP is used to calculate the weight of criteria and sub-criteria. The MULTIMOORA rank in different criteria. A case study is applied to a pharmaceutical manufacturing company demonstrates the efficacy of the suggested method and offers the final judgment to choose the best-qualified applicant for company success. The future work aims to use multiple multi-criteria decision-making strategies and display them in a neutrosophic environment utilizing the DEMETAL with MULTIMOORA method to solve the sustainable supplier selection problem.

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