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Blending Uncertainty Theory Innovative into Decision Support Framework for Selecting Agricultural Machinery Suppliers

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Abstract

The rivalry among suppliers and stakeholders created pressure, making the selection of the best provider a crucial subject based on a set of criteria for the responsiveness of clients. Consequently, several criteria need to be considered to select the most suitable supplier. As a result, certain criteria may overlap and contradict one another. Multi-criteria decision-making (MCDM) techniques are widely used in many fields to address selection problems when there are numerous competing criteria and multiple alternatives. Hence, we are leveraging MCDM techniques in constructing a decision support framework (DSF) as MEthod based on the Removal Effects of Criteria (MEREC) and Multi-Attributive Border Approximation Area Comparison (MABAC). In our DSF, we harnessed the uncertainty theory of triangular neutrosophic sets (TrNSs) which is considered one of the advantages that DSF provides.TrNSs support experts in their judgments when facing problems such as imprecise judgments and insufficient data. As well, we applied the constructed DSF in a real case study for five suppliers for machinery agriculture and evaluated the suppliers based on ten criteria. The DSF's findings indicated that supplier 5 is the optimal one for machinery agriculture otherwise supplier 2 is the worst one. Also, we applied another ranker technique of MCDM technique entailed in the weighted sum model (WSM) and compared WSM results with MABAC under the authority of TrNSs.

Keywords: Multi Criteria Decision-Making; Triangular Neutrosophic Sets; Supplier Selection; Uncertainty.

1 | Introduction

The objective of this section is to illustrate the study's comprehensive vision, its motivations, and the contributions that the study provides. Moreover, this section is divided into a set of parts.

1.1 | Comprehensive Vision

Currently, the mechanization of traditional farming practices has resulted in a notable advancement in the agricultural area, as a result of the expanding population and concomitant growth in food consumption [1]. Nedeljković et al. [2] in turn, claimed that the use of suitable agricultural machinery ought to enable the most fertile production process. Thus, it is essential to modern agricultural production. From Sims's point of view

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[3], agricultural machinery is employed seasonally and under extremely challenging conditions due to the difficult nature of agricultural production. Accordingly, contemporary, and effective machinery in agriculture is inevitable due to several reasons where (1) farms' financial resources and requirements are intimately linked to the advancement of agricultural techniques [4]. (2) Also [5] indicated that a further indicator of agricultural economic growth is the degree of technology means equipped. Whereas [6] demonstrated that the time required for actual manufacturing is being reduced with the use of mechanical automation technologies. Hence, incorporating mechanical automation technologies may improve the quality of agricultural products advantageously.

Even so, [7] revealed that the operating and ownership expenses of farm machinery frequently account for over 30% of the overall expenditures associated with producing a crop, which has a significant impact on farm profitability.

All things considered, a wide variety of machinery and equipment are available for various agricultural activities, particularly for product harvesting. On the other hand, choosing the finest machinery while taking efficiency and other criteria into account may be quite difficult for farmers [7]. Hence, selecting the appropriate agricultural machinery supplier is a significant action.

1.2 | Contribution: Study Novelty

The selection of the optimal agricultural machinery supplier is important. Further prior studies treat with supplier selection (SS) problem by constructing a decision-support framework. MCDM techniques are the most popular and frequently used when constructing decision support frameworks. Even so [8] declared that the decision-making process suffers from several problems where the decision-maker (DM) can't use precise numerical values to convey their choices[9, 10]. Due to the majority of the information used by DMs for assessment being obscure or evasive[11]. Hence, fuzzy sets (FSs) and their extensions have been proposed in the decision-making of the selection process [12]. Albeit these techniques take into consideration membership and non-membership. Recently, the indeterminacy degree during the decision process was taken into consideration by leveraging the uncertainty theory of neutrosophic sets. Moreover, this theory became an effective technique for managing ambiguity and uncertainty in decision-making processes. Due to [13] its ability to handle uncertain, incomplete, and inconsistent information.

Overall, the study's contributions have been introduced through several points.

- We are determining the study's objectives and how these objectives have been achieved.
- In line with recent studies, we are leveraging the ability of MCDM techniques to treat conflicting attributes during the decision-making process toward SS.
- The method based on Removal Effects of Criteria (MEREC) is an objective weighing MCDM technique for the estimation of criteria weights. Another MCDM technique is MABAC (multi-attributive border approximation area comparison) where used for ranking estimation of the alternatives.
- As well the mentioned techniques have been bolstered by neutrosophic theory, especially triangular neutrosophic sets (TrNSs) in mysterious circumstances.
- The integration between MCDM and TrNSs is forming a decision support framework (DSF) to utilize in the problem of SS.
- Verifying the construction of DSF through implementing it into real case studies.

2 | Literary Surveys

Herein, we are exhibiting the techniques utilized in the SS problem. Also, we showcase the basic principles of utilized techniques in this study. Moreover, this section is divided into two sections.

2.1 | MCDM in Selection Process

We present some supplier selections from previous works. As supplier selection problems involve a set of contradicting alternatives it requires a robust method to solve it. According to the literature reviews, many researchers proposed methods based on MCDM and neutrosophic sets in the selection process. Badi et al [14] utilized COmbinative Distance-based ASsessment (CODAS) method for determining the most suitable alternative based on determining the Euclidean distance and the Taxicab distance. Cheraghalipour et al. [15] best worst method (BWM) is utilized for obtaining criteria weights where the generated weights have been harnessed in VIekriterijumsko KOmpromisno Rangiranje (VIKOR) to rank suppliers and obtain the optimal supplier. Dweiri et al.[16] Considered the example of the automobile sector in Pakistan as a case study, provides a decision support model for supplier selection based on the analytical hierarchy process (AHP). Sensitivity analysis is then carried out to verify the decision's resilience. The game theory-based ANP technique is suggested in [17] as an effective means of handling supplier management in an unpredictable setting where the subjective and objective weights of criteria, entropy weight, and analytical network process (ANP) are used. Keshavarz et al.[18]highlighted the need to select an all-inclusive, innovative index-based irrigation agriculture system that is sustainable where the authors utilized AHP for developing a unique eco-exergoenvironmental toxicity index to determine whether irrigation method surface irrigation or drip irrigation is the most sustainable for growing sunflowers in Kurdistan, Iran. Best-worst method (BWM) integrated with the alternative queuing method (AQM) in [19]within the interval-valued intuitionistic uncertain linguistic setting for selecting the most sustainable supplier. Three-phase supplier selection methodology in food supply chain are developed by J. Rezaei et al [20]. First and second phase, Conjunctive screening and BWM are used for pre-selection and selection phases.in third phase Material price and quantity are integrated with the decision at the third phase.

2.2 | Preliminaries

In this section, important definitions of neutrosophic sets, single-valued neutrosophic sets, triangular neutrosophic numbers, and operations of triangular neutrosophic numbers are illustrated clearly [21, 22].

Definition 1: Suppose S to be a space of points and s ∈ S. A neutrosophic set Z in S is defined by a truth-membership function $T_Z(s)$, indeterminacy-membership function $I_Z(s)$, and a falsity membership function $F_Z(s)$, where $T_Z(s)$, $I_Z(s)$, and $F_Z(s)$ are real standard or non-standard subset of $]^-0,1^+[$.also $T_Z(s)$;S $\to]^-0,1^+[$, $I_Z(s)$;S $\to]^-0,1^+[$ and $F_Z(s)$;S $\to]^-0,1^+[$. The sum of the three membership $T_Z(s)$, $I_Z(s)$, and $F_Z(s)$ has no restrictions, so $0^- \leq \sup T_Z(s) + I_Z(s) \sup + \sup F_Z(s) \leq 3^+$.

Definition 2: A single valued neutrosophic set across S taking the form = {⟨s, $T_Z(s)$, $I_Z(s)$, $F_Z(s)$⟩; s ∈ S} $T_Z(s)$, $I_Z(s)$, $F_Z(s)$; S→ [0, 1] with $0\leq T_Z(s)+ I_Z(s) +F_Z(s) \leq 3$ ∀ s ∈ S. The single-valued neutrosophic (SVN) number is shown by = (x, y, z) where x, y, z ∈[0,1] and x+y+z≤3.

Definition 3: **S**uppose $\alpha_{\bar{x}}$,$\theta_{\bar{x}}$,$\beta_{\bar{x}}^-$ ∈[0,1] and $\bar{x}1$, $\bar{x}2$, $\bar{x}3$ ∈ R and $\bar{x}1 \leq \bar{x}2 \leq \bar{x}3$. Then The single-valued triangular neutrosophic number $\bar{x}$=(($\bar{x}_1$, $\bar{x}2$, $\bar{x}3$) ; $\alpha_{\bar{x}}$,$\theta_{\bar{x}}$,$\beta_{\bar{x}}$) is a special neutrosophic set on the real line set R, whose three membership functions truth, indeterminacy, and falsity are computed as follows:

$$T_{\bar{x}}(x) = \begin{cases} \alpha_{\tilde{a}} \left(\frac{x-a_1}{a_2-a_1}\right) & a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}} & x = a_2 \\ \alpha_{\tilde{a}} \left(\frac{a_3-x}{a_3-a_2}\right) & a_2 \leq x \leq a_3 \\ 0 & otherwise \end{cases} \tag{1}$$

$$I_{\bar{x}}(x) = \begin{cases} \theta_{\tilde{a}}\left(\frac{a_2-x}{a_2-a_1}\right) & a_1 \le x \le a_2 \\ \theta_{\tilde{a}} & x = a_2 \\ \theta_{\tilde{a}}\left(\frac{x-a_3}{a_3-a_2}\right) & a_2 \le x \le a_3 \\ 1 & otherwise \end{cases} \tag{2}$$

$$F_{\bar{x}}(x) = \begin{cases} \beta_{\tilde{a}}\left(\frac{a_2-x}{a_2-a_1}\right) & a_1 \le x \le a_2 \\ \beta_{\tilde{a}} & x = a_2 \\ \beta_{\tilde{a}}\left(\frac{x-a_3}{a_3-a_2}\right) & a_1 \le x \le a_3 \\ 1 & otherwise \end{cases} \tag{3}$$

Definition 4: Suppose $\bar{x}$ and $\bar{y}$ are two single-valued triangular neutrosophic numbers and $\bar{x}$=(($\bar{x}_1$, $\bar{x}_2$, $\bar{x}_3$); $\alpha_{\bar{x}}$,$\theta_{\bar{x}}$,$\beta_{\bar{x}}$), $\bar{y}$=(($\bar{y}_1$, $\bar{y}_2$, $\bar{y}_3$) ; $\alpha_{\bar{y}}$,$\theta_{\bar{y}}$,$\beta_{\bar{y}}$) and $\gamma \neq 0$ be any real number.

- Two triangular neutrosophic numbers Addition

$$\bar{x}+\bar{y} = \langle(\bar{x}_1+\bar{y}_1, \bar{x}_2+\bar{y}_2, \bar{x}_3+\bar{y}_3); \alpha_{\bar{x}} \wedge \alpha_{\bar{y}}, \theta_{\bar{x}} \vee \theta_{\bar{y}}, \beta_{\bar{x}} \vee \beta_{\bar{y}}\rangle$$

- Two triangular neutrosophic number Subtraction

$$\bar{x}-\bar{y} = \langle(\bar{x}_1-\bar{y}_1, \bar{x}_2-\bar{y}_2, \bar{x}_3-\bar{y}_3); \alpha_{\bar{x}} \wedge \alpha_{\bar{y}}, \theta_{\bar{x}} \vee \theta_{\bar{y}}, \beta_{\bar{x}} \vee \beta_{\bar{y}}\rangle$$

- Triangular neutrosophic number Inverse

$$\bar{x}^{\ -1} = \left\langle\left(\frac{1}{\bar{x}_3}, \frac{1}{\bar{x}_2}, \frac{1}{\bar{x}_1}\right); \alpha_{\bar{x}}, \theta_{\bar{x}}, \beta_{\bar{x}}\right\rangle, \text{ where } (\bar{x} \neq 0)$$

- Triangular neutrosophic number Multiplication by the constant value

$$\gamma\bar{x} = \begin{cases} \langle(\gamma\bar{x}_1, \gamma\bar{x}_2, \gamma\bar{x}_3); \alpha_{\bar{x}}, \theta_{\bar{x}}, \beta_{\bar{x}}\rangle \text{ if } (\gamma > 0) \\ \langle(\gamma\bar{x}_3, \gamma\bar{x}_2, \gamma\bar{x}_1); \alpha_{\bar{x}}, \theta_{\bar{x}}, \beta_{\bar{x}}\rangle \text{ if } (\gamma < 0) \end{cases}$$

- Triangular neutrosophic number Division by constant value

$$\frac{\bar{x}}{\gamma} = \begin{cases} \left\langle\left(\frac{\bar{x}_1}{\gamma}, \frac{\bar{x}_2}{\gamma}, \frac{\bar{x}_3}{\gamma}\right); \alpha_{\bar{x}}, \theta_{\bar{x}}, \beta_{\bar{x}}\right\rangle \text{ if } (\gamma > 0) \\ \left\langle\left(\frac{\bar{x}_3}{\gamma}, \frac{\bar{x}_2}{\gamma}, \frac{\bar{x}_1}{\gamma}\right); \alpha_{\bar{x}}, \theta_{\bar{x}}, \beta_{\bar{x}}\right\rangle \text{ if } (\gamma < 0) \end{cases}$$

- Two triangular neutrosophic numbers Division

$$\frac{\bar{x}}{\bar{y}} =$$

$$\begin{matrix} \left(\left(\frac{\bar{x}_1}{\bar{y}_3}, \frac{\bar{x}_2}{\bar{y}_2}, \frac{\bar{x}_3}{\bar{y}_1}\right); \alpha_{\bar{x}} \wedge \alpha_{\bar{y}}, \theta_{\bar{x}} \vee \theta_{\bar{y}}, \beta_{\bar{x}} \vee \beta_{\bar{y}}\right) & \text{if } (\bar{x}_3 > 0, \bar{y}_3 > 0) \\ \left(\left(\frac{\bar{x}_3}{\bar{y}_3}, \frac{\bar{x}_2}{\bar{y}_2}, \frac{\bar{x}_1}{\bar{y}_1}\right); \alpha_{\bar{x}} \wedge \alpha_{\bar{y}}, \theta_{\bar{x}} \vee \theta_{\bar{y}}, \beta_{\bar{x}} \vee \beta_{\bar{y}}\right) & \text{if } (\bar{x}_3 < 0, \bar{y}_3 > 0) \\ \left(\left(\frac{\bar{x}_3}{\bar{y}_3}, \frac{\bar{x}_2}{\bar{y}_2}, \frac{\bar{x}_1}{\bar{y}_1}\right); \alpha_{\bar{x}} \wedge \alpha_{\bar{y}}, \theta_{\bar{x}} \vee \theta_{\bar{y}}, \beta_{\bar{x}} \vee \beta_{\bar{y}}\right) & \text{if } (\bar{x}_3 < 0, \bar{y}_3 < 0) \end{matrix}$$

- Multiplication of two triangular neutrosophic numbers

$$xy = \begin{cases} \langle(\bar{x}_1\bar{y}_1, \bar{x}_2\bar{y}_2, \bar{x}_3\bar{y}_3); \alpha_{\bar{x}} \wedge \alpha_{\bar{y}}, \theta_{\bar{x}} \vee \theta_{\bar{y}}, \beta_{\bar{x}} \vee \beta_{\bar{y}}\rangle \text{ if } (\bar{x}_3 > 0, \bar{y}_3 > 0) \\ \langle(\bar{x}_1\bar{y}_3, \bar{x}_2\bar{y}_2, \bar{x}_3\bar{y}_1); \alpha_{\bar{x}} \wedge \alpha_{\bar{y}}, \theta_{\bar{x}} \vee \theta_{\bar{y}}, \beta_{\bar{x}} \vee \beta_{\bar{y}}\rangle \text{ if } (\bar{x}_3 < 0, \bar{y}_3 > 0) \\ \langle(\bar{x}_3\bar{y}_3, \bar{x}_2\bar{y}_2, \bar{x}_1\bar{y}_1); \alpha_{\bar{x}} \wedge \alpha_{\bar{y}}, \theta_{\bar{x}} \vee \theta_{\bar{y}}, \beta_{\bar{x}} \vee \beta_{\bar{y}}\rangle \text{ if } (\bar{x}_3 < 0, \bar{y}_3 < 0) \end{cases}$$

3 | Proposed Decision Support Framework

The integration of MEREC-MABAC of MCDM techniques and the uncertainty theory of TrNSs resulted in generating DSF. This integration of these techniques for constructing DSF are exhibited in the following steps as mentioned in Figure 1.

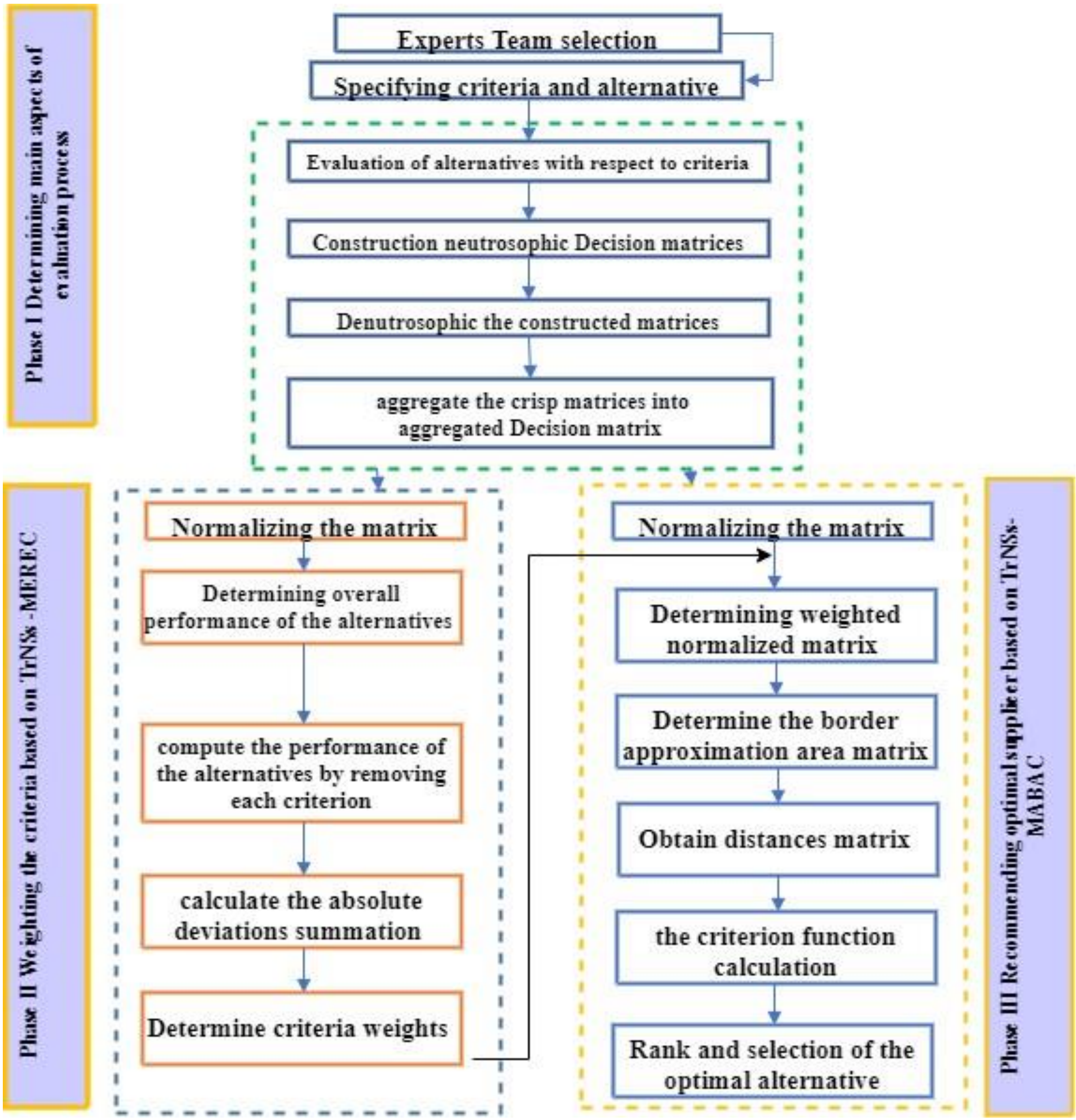

Figure 1. Proposed decision support framework schema.

3.1 | Determining Important Aspects for Conducting Supplier Evaluation

- The alternatives that contribute to the evaluation process. Also, influenced criteria in this process are determined for evaluating the alternatives based on it.
- The members of the expert panel for evaluating the candidates of suppliers are determined.

3.2 | TrNSs Based MEREC Approach

Ghorabaee et al. [23] proposed a novel objective weighting method called Method Based on the Removal Effects of Criteria (MEREC) to calculate criteria weights for the problems of multi-criteria decision-making. Whereas MEREC integrated with TrNSs to implement in uncertain environments of evaluation.

- The expert panel uses the neutrosophic scale of [24] which is presented in Table 1 to evaluate alternatives with respect to criteria.

- Construct the neutrosophic decision matrices as formed in Eq. (4).

$$\wp^e = \begin{pmatrix} x^e{}_{11} \cdots x^e{}_{1j} \cdots x^e{}_{1m} \\ \vdots \quad \ddots \quad \vdots \quad \ddots \quad \vdots \\ x^e{}_{i1} \cdots x^e{}_{ij} \cdots x^e{}_{im} \\ \vdots \quad \ddots \quad \vdots \quad \ddots \quad \vdots \\ x^e{}_{n1} \cdots x^e{}_{nj} \cdots x^e{}_{nm} \end{pmatrix} \tag{4}$$

Where $x^e{}_{ij}$ denote the evaluation of ith alternative with respect to jth criterion by the number of experts.

- Deneutrosophic the constructed matrices based on Eq. (5).

$$s(x_{ij}) = \frac{(l_{ij}+m_{ij}+u_{ij})}{9} * (2 + T - I - F) \tag{5}$$

Where m, u refer to the lower, middle, and upper values, and T, I, F refers to the truth, indeterminacy, and falsity values.

Table 1. Triangular neutrosophic scale.

Crisp Scale	Explanation	TrNSs Scale
1	Equally Essential	<<1,1,1>;0.5,0.5,0.5>>
2	Slightly Moderately	<<1,2,3>;0.4,0.6,0.65>>
3	slightly Essential	<<2,3,4>;0.3,0.75,0.7>>
4	Minor To Strong	<<3,4,5>;0.35,0.6,0.4>>
5	Mighty Essential	<<4,5,6>;0.8,0.15,0.2>>
6	Slightly Strong Essential	<<5,6,7>;0.7,0.25,0.3>>
7	High Strong Essential	<<6,7,8>;0.9,0.1,0.1>>
8	Very High Strong Essential	<<7,8,9>;0.85,0.1,0.15>>
9	Absolutely High Essential	<<9,9,9>;1.0,0.0,0.0>>

- Construct the aggregated decision matrix by considering all experts' evaluations in deneutrosophic matrices by utilizing Eq. (6).

$$ð_{ij} = \frac{\sum_{e=1}^{e} x_{ij}}{e} \tag{6}$$

Where e indicates to number of experts.

- Normalize the aggregated matrix by following Eq. (7):

$$Nor_{ij}^{ð} = \begin{cases} \frac{\min_a ð_{aj}}{ð_{ij}} & \text{if} \quad j \in B_c \\ \frac{ð_{ij}}{\max_a ð_{aj}} & \text{if} \quad j \in C_c \end{cases} \tag{7}$$

Where $ð_{ij}^{ð}$ denote the matrix normalized elements, B_c and C_c represent beneficial and non-beneficial criteria. a refers to alternatives.

- Calculate the overall performance of the alternatives (P_i). The following equation is used for this calculation:

$$P_i = \ln\left(1 + \left(\frac{1}{m}\sum_{j=1}^{m}\left|\ln\left(Nor_{ij}^{ð}\right)\right|\right)\right); j = 1,2, \cdots m \tag{8}$$

Where m is the number of criteria (decision variables).

- Compute the performance of the alternatives by removing each criterion separately (P'_{ij}):

$$P'_{ij} = \ln\left(1 + \left(\frac{1}{m}\sum_{e,e\neq j} |\ln(r^x_{ie})|\right)\right); e = 1,2,\cdots n \quad (9)$$

Where P'_{ij} denote the overall performance of ith alternative concerning the removal of jth criterion.

- Calculate the absolute deviations and sum to calculate(ER_j):

$$ER_j = \sum_i |P'_{ij} - P_i| \quad (10)$$

Where ER_j denote the effect of removing jth criterion.

- Determine criteria weights using the following formula:

$$w_j = \frac{ER_j}{\sum_e ER_e} \quad (11)$$

Where w_j denote the weight of jth criteria for all alternatives.

3.3 | Recommending Optimal Supplier: TrNSs Based MABAC

Multi-attributive border approximation area comparison was proposed by Pamucar et al. [25] to face the problems of MCDM. This method ranks the alternatives by determining the distance function for the criterion from the border approximation area. The integration between MABAC and TrSNs is stated below:

- Normalize the aggregated matrix by following Eq. (12):

$$r_{ij} = \begin{cases} \frac{ð_{ij} - ð^m_i}{ð^M_i - ð^m_i} & \text{if} \quad j \in B_c \\ \frac{ð_{ij} - ð^M_i}{ð^M_i - ð^m_i} & \text{if} \quad j \in C_c \end{cases} \quad (12)$$

Where $ð^M_i$ and $ð^m_i$ are the maximum and minimum values of the observed criterion in the decision matrix.

- The weighted normalized matrix is calculated as:

$$L = [l_{ij}]_{n\times m}; \ L_{ij} = w_j.(r^x_{ij} + 1) \quad (13)$$

- Determine the border approximation area matrix, (BAA) for each criterion using the following formula:

$$\mathfrak{H} = \left[\left(\prod_{j=1}^{n} l_{ij}\right)^{1/n}\right]_{1\times m} \quad (14)$$

- The distances matrix of the alternatives from the border approximation area is determined as the difference between the elements in the weighted matrix (L) and the value of the border approximation area (B) is calculated as:

$$Q = L - \mathfrak{H} \quad (15)$$

where L and G are the matrices defined in Steps 3 and 4.

- Calculate the criterion function as:

$$F_i = \sum_{j=1}^{n} q_{ij} \quad (16)$$

4 | Case Study

4.1 | Objective of Case Study

The proposed DSF has been applied in a real case study to verify the ability of the proposed framework to evaluate and select optimal suppliers. Herein the proposed framework is applied to firms working in the field of agriculture. Moreover, five possible alternative suppliers (S1, S2, S3, S4, S5) have been considered and a set of ten criteria as shown collected by interviewing five experts as **Error! Reference source not found.**, the evaluation of alternatives concerning criteria is done by the experts, and is of significant importance. A rigorous supplier selection was required for each item internally classified as critical for its impact in terms of the various criteria selected.

4.2 | Decision Support Framework Implementation

The preceding steps for the proposed DSF have been implemented herein for evaluating five suppliers based on ten criteria which are listed in Table 2.

4.2.1 | Five experts are volunteering to evaluate the suppliers over ten criteria for selecting the best supplier by using linguistic terms and their corresponding triangular neutrosophic scale in Table 1.

4.2.2 The neutrosophic decision matrices are constructed and Eq. (5) is utilized for transforming them into crisp matrices.

4.2.3 The crisp matrices are aggregated into a single decision matrix based on Eq. (6) as mentioned in Table 3.

Table 2. Determined criteria for the evaluation process.

Criteria	Code	Description
Price competitiveness	C1	it directly impacts the profitability of the agricultural operation. It is important to compare prices from different suppliers to ensure that you are getting a fair deal.
Communication and responsiveness	C2	Effective communication with suppliers is essential for maintaining a strong relationship and addressing any issues that may arise. Choose suppliers that are responsive to inquiries and provide timely updates on order status.
Sustainability practices	C3	Sustainability practices involve evaluating how environmentally friendly and socially responsible a supplier's operations are. Choosing suppliers that prioritize sustainability can help improve your company's reputation and reduce its environmental impact.
Reliability	C4	the supplier's ability to consistently deliver products on time and in the quantities requested. A reliable supplier helps ensure a steady supply chain and prevents disruptions in production.
Financial stability	C5	Assessing a supplier's financial stability is important to ensure they will be able to fulfill their obligations over the long term. A financially stable supplier is less likely to go out of business or experience disruptions in production.
Reputation	C6	Consider the reputation of potential suppliers within the industry, including feedback from other customers, reviews, and ratings. A supplier with a positive reputation is more likely to provide high-quality products and reliable service.
Geographic location	C7	The geographic location of a supplier can impact transportation costs and lead times. Choosing suppliers that are located close to your operation can help reduce shipping costs and improve efficiency.
Quality of products	C8	This criterion involves assessing the quality of the agricultural products provided by the supplier. It is important to ensure that the products meet industry standards and are free from defects.
Technical expertise	C9	Suppliers with technical expertise in agriculture can provide valuable insights and support for your operation. Look for suppliers who know best practices, new technologies, and industry trends.
Flexibility	C10	A flexible supplier can adapt to changing market conditions, production requirements, or other unforeseen circumstances. Choose suppliers that are willing to work with you to find solutions that meet your specific needs.

Table 3. Aggregated decision matrix.

Criteria Suppliers	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	2.755	16.624	31.537	2.294	5.771	4.755	8.361	9.229	5.445	12.076
S2	1.704	1.318	1.318	1.704	6.989	4.848	3.491	11.898	14.273	2.294
S3	13.100	2.294	26.201	14.642	3.629	18.135	26.201	5.291	2.755	1.693
S4	0.437	28.887	1.704	21.504	3.491	13.720	3.173	0.674	14.642	10.863
S5	15.004	26.323	0.674	1.318	9.009	9.694	13.785	14.937	17.600	12.480

4.2.4 The produced aggregated matrix in Table 3 is normalized by applying Eq. (7) for constructing a normalized matrix as in Table 4.

4.2.5 Eq.(8) helps in computing the performance of the alternatives. Also, Eq. (9) was used for Computing the performance of the alternatives by removing each criterion separately, and the results were recorded in Table 5.

4.2.6 The removable effect is calculated through Eq. (10) and listed in Table 6.

4.2.7 Eq. (11) was utilized for generating the final criteria's weights as illustrated in Figure 2. According to this Figure, we observed that product quality (C8) has the greatest weight while financial stability (C5) has the smallest weight.

Table 4. Normalized direct matrix.

Criteria Suppliers	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	0.183618	0.079283	0.021372	0.574542	0.604921	1	0.3795	0.073031	0.505969	0.140195
S2	0.11357	1	0.511381	0.773474	0.499499	0.980817	0.908909	0.056648	0.193022	0.738012
S3	0.873101	0.574542	0.025724	0.090015	0.961973	0.2622	0.121102	0.127386	1	1
S4	0.029126	0.045626	0.39554	0.061291	1	0.346574	1	1	0.188157	0.15585
S5	1	0.05007	1	1	0.387501	0.49051	0.230178	0.045123	0.156534	0.135657

Table 5. Performance of the alternatives by removing each criterion.

Criteria Suppliers	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	0.861582	0.825455	0.766316	0.908652	0.910726	0.930743	0.891794	0.821851	0.903516	0.850117
S2	0.504174	0.627622	0.591163	0.613814	0.58986	0.626588	0.62251	0.461254	0.535707	0.611271
S3	0.796216	0.777161	0.623086	0.688098	0.800578	0.740432	0.702896	0.705398	0.802318	0.802318
S4	0.760614	0.781376	0.875658	0.794797	0.913569	0.870137	0.913569	0.913569	0.844217	0.836086
S5	0.836124	0.697125	0.836124	0.836124	0.794169	0.804766	0.770346	0.691931	0.752339	0.74557

Table 6. Removable effect.

Criteria Suppliers	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	0.069161	0.105288	0.164427	0.022091	0.020017	0	0.038949	0.108892	0.027228	0.080626
S2	0.123448	0	0.036459	0.013808	0.037762	0.001035	0.005112	0.166368	0.091915	0.016351
S3	0.006102	0.025157	0.179232	0.11422	0.001739	0.061886	0.099422	0.09692	0	0
S4	0.152954	0.132192	0.037911	0.118772	0	0.043431	0	0	0.069351	0.077483
S5	0	0.138998	0	0	0.041955	0.031357	0.065777	0.144193	0.083785	0.090554

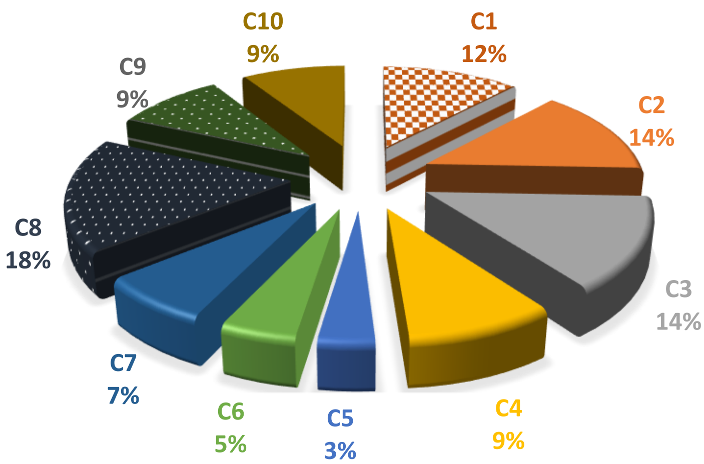

Figure 2. Final criteria weights.

4.2.8 MABAC based on TrNSs recommends optimal suppliers for machinery agricultural.

- The constructed aggregated matrix from the proceeding stage of mere-TrNSs has been harnessed for generating a normalized matrix through deploying Eq. (12) as in Table 7.
- Implement Eq. (13) for generating a weighted decision matrix as in Table 8.
- The border approximation area matrix (BAA) for each criterion is computed via Eq. (14) and the results are leveraged in Eq. (15) for generating the distance alternatives matrix as in Table 9.
- Eq. (16) is implemented on the distance matrix of Table 9 to rank the suppliers and recommend the optimal one according to the values of F_i of Eq. (16). Hence, Figure 3 summarized the rank of alternatives which indicated that S5 is optimal otherwise, S2 is the worst supplier.

Table 7. Normalized decision matrix.

Criteria Suppliers	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	0.840873	0.555189	1	0.04835	0.413193	0	0.225291	0.599804	0.181206	0.962548
S2	0.913023	0	0.020866	0.019122	0.633925	0.006951	0.013809	0.786931	0.775884	0.055715
S3	0.130706	0.035402	0.827107	0.660061	0.025009	1	1	0.323705	0	0
S4	1	1	0.033373	1	0	0.67003	0	0	0.800741	0.850097
S5	0	0.906997	0	0	1	0.369133	0.46083	1	1	1

Table 8. Weighted decision matrix.

Criteria Suppliers	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	0.22002	0.212287	0.284149	0.095806	0.048737	0.046803	0.087143	0.280763	0.109307	0.176765
S2	0.228643	0.136503	0.145039	0.093134	0.05635	0.047128	0.072102	0.313603	0.164338	0.095088
S3	0.135141	0.141335	0.259585	0.151708	0.03535	0.093606	0.142241	0.232308	0.092539	0.090069
S4	0.239039	0.273005	0.146816	0.182774	0.034487	0.078162	0.07112	0.175498	0.166638	0.166637
S5	0.119519	0.26031	0.142074	0.091387	0.068974	0.064079	0.103895	0.350997	0.185077	0.180139

Table 9. Distance alternatives matrix.

Criteria Suppliers	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	0.039026	0.016044	0.09806	-0.02192	0.001672	-0.01672	-0.00489	0.017692	-0.02936	0.041404
S2	0.04765	-0.05974	-0.04105	-0.02459	0.009285	-0.01639	-0.01993	0.050533	0.025673	-0.04027
S3	-0.04585	-0.05491	0.073496	0.033985	-0.01172	0.030085	0.050204	-0.03076	-0.04613	-0.04529
S4	0.058045	0.076762	-0.03927	0.065051	-0.01258	0.014642	-0.02092	-0.08757	0.027973	0.031275
S5	-0.06147	0.064067	-0.04401	-0.02634	0.02191	0.000559	0.011859	0.087926	0.046412	0.044777

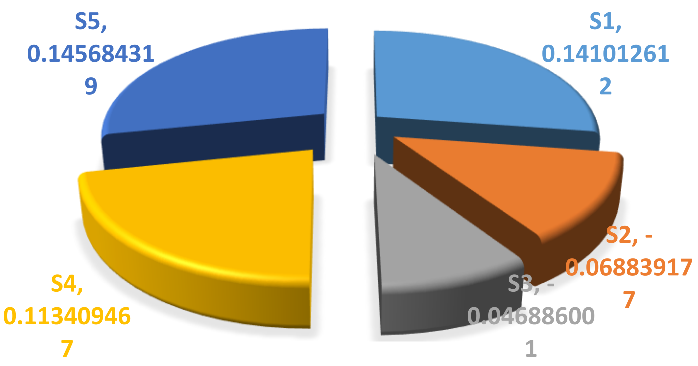

Figure 3. Supplier of machinery agriculture ranking based on Mabac-TrNSs.

5 | Comparative Analysis

Herein, we utilized the collected data and experts' priorities for five suppliers over ten criteria in another ranker MCDM technique Weighted Sum Method (WSM). Ditto, WSM merged with TrNSs to bolster the MCDM technique when facing uncertain judgments.

Generally speaking, there are several steps that have been implemented for deploying WSM-TrNSs for ranking five suppliers of machinery agriculture.

Step 1: Aggregated matrix generated from merec-TrNSs in Table 3 are utilized in Eqs. (17) and (19) for normalizing the constructed aggregated matrix as in Table 10.

$$\mathrm{Nor}_{\mathrm{Agg}} = \frac{ð_{ij}}{sum\,(ð_{ij})} \quad \text{, For Benficial criteria} \tag{17}$$

$$\mathrm{N} = \frac{1}{ð_{ij}} \tag{18}$$

$$\mathrm{Nor}_{\mathrm{Aggj}} = \frac{\mathrm{N}}{\mathrm{sum(N)}} \quad \text{, For Non} - \text{Benficial criteria} \tag{19}$$

Step 2: A weighted decision matrix is generated by deploying Eq. (20) in the normalized matrix of Table 10. the weighted matrix represented in Table 11.

$$\mathrm{weighted} - \mathrm{matrix}_{\mathrm{ij}} = w_j * \mathrm{Nor}_{\mathrm{Agg}} \tag{20}$$

Step 3: Global score calculated based on Eq. (21). Whereas suppliers are ranking based on $\mathrm{V}\left(\mathrm{weighted} - \mathrm{matrix}_{\mathrm{ij}}\right)$.

$$\mathrm{V}\left(\mathrm{weighted} - \mathrm{matrix}_{\mathrm{ij}}\right) = \sum_{\mathrm{j}=1}^{\mathrm{n}} \mathrm{Dec\_mat}_{\mathrm{ij}} \tag{21}$$

Where $V\left(\mathrm{weighted} - \mathrm{matrix}_{\mathrm{ij}}\right)$ is global score values.

Generally, the values of the global score are represented in Figure 4 where S4 is the optimal supplier whilst S2 is the worst.

According to the values of F_i in mabac-TrNSs and $\mathrm{V}\left(\mathrm{weighted} - \mathrm{matrix}_{\mathrm{ij}}\right)$ of WSM-TrNSs S1, S2, and S3 are similar and in the same rank where rank is 2, 5, 4 whilst S4 and S5 are different as in Figure 5.

Table 10. Normalized decision matrix.

Criteria Suppliers	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	0.107353	0.220343	0.513348	0.055328	0.199765	0.092958	0.151988	0.219586	0.099516	0.306451
S2	0.173567	0.017469	0.021454	0.041098	0.241926	0.094776	0.06346	0.28309	0.260861	0.058214
S3	0.022577	0.030406	0.42649	0.353143	0.125619	0.354532	0.476287	0.125889	0.050352	0.042963
S4	0.676791	0.382883	0.027737	0.518644	0.120842	0.26822	0.057679	0.016037	0.267605	0.275669
S5	0.019712	0.348899	0.010971	0.031788	0.311849	0.189514	0.250586	0.355397	0.321667	0.316703

Table 11. Weighted decision matrix.

Criteria Suppliers	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	0.012831	0.030077	0.072934	0.005056	0.006889	0.004351	0.010809	0.038537	0.009209	0.027602
S2	0.020745	0.002385	0.003048	0.003756	0.008343	0.004436	0.004513	0.049682	0.02414	0.005243
S3	0.002698	0.00415	0.060593	0.032273	0.004332	0.016593	0.033874	0.022093	0.004659	0.00387
S4	0.08089	0.052265	0.003941	0.047397	0.004168	0.012553	0.004102	0.002814	0.024764	0.024829
S5	0.002356	0.047626	0.001559	0.002905	0.010755	0.00887	0.017822	0.062372	0.029767	0.028525

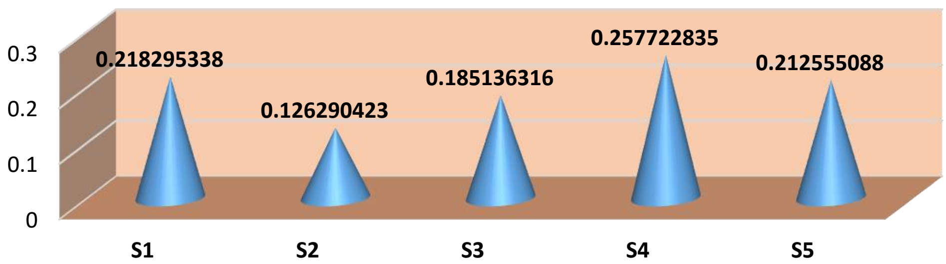

Figure 4. Supplier of machinery agriculture ranking based on WSM-TrNSs.

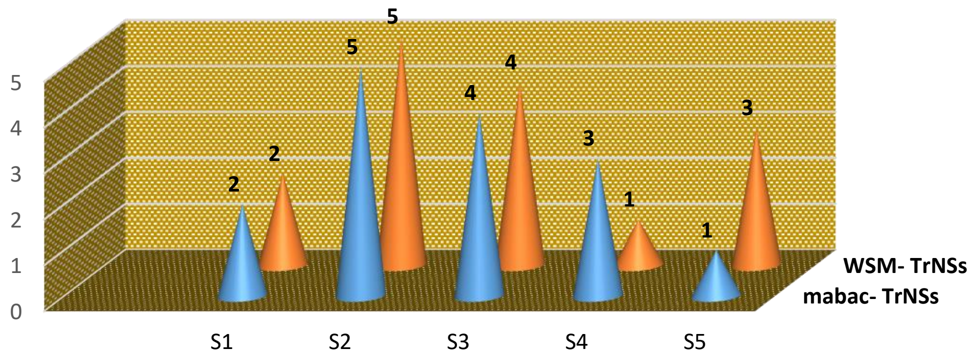

Figure 5. Comparative analysis of MABAC-TrNSs and WSM-TrNSs for ranking suppliers.

6 | Conclusion

Herein, we constructed DSF to solve the problem of selecting the optimal supplier for machinery agriculture. The selection process is conducted based on evaluating candidates of suppliers based on determining the most influenced criteria. As well the constructed DSF supported the experts who contributed to the evaluation process in ambiguous and hazy situations by deploying the notion of uncertainty theory in the utilized techniques of MCDM. Hence, each technique that contributes to constructing DSF has a vital role in the evaluation process to select the optimal supplier. Thereby, TrNSs-based merec is utilized for generating criteria's weights which are employed in MABAC based on TrNSs for analyzing the suppliers and recommending optimal and worst suppliers. In our study, five suppliers are volunteering in our DSF for the evaluation process. As well, the verifying process is also performed by applying our DSF to the real case study to confirm its validity. The DSF's findings indicated that supplier 5 is optimal, otherwise, supplier 2 is the worst.

Also, we conduct a comparison between MABAC-TrNSs and WSM-TrNSs as ranker techniques of MCDM. The findings of the comparison are exhibited in the comparative analysis section. Two ranker techniques are agreed that S1, S2, and S3 occupy second, fifth, and fourth rank nonetheless, the difference in ranking S4, S5 where S5 occupies rank 1 in MABAC-TrNSs and S4 occupies rank 1in WSM-TrNSs as in Figure 5.

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Author Contribution

All authors contributed equally to this work.

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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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