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Smart Assessment of Wheat Suppliers via MARCOS-based MCDM Modelling under a Neutrosophic Scenario

Reda M Hussien [1,*], Amr A. Abohany [2] , Karam M. Sallam [3] and Ahmed Salem [4]

[1] Faculty of Computers and Information, Kafrelsheikh University, Kafrelsheikh, 33511, Egypt; reda_mabrouk@fci.kfs.edu.eg
[2] Faculty of Computers and Information, Kafrelsheikh University, Kafrelsheikh, 33511, Egypt; amrabohany8@gmail.com
[3] School of IT and Systems, Faculty of Science and Technology, University of Canberra, Canberra, Australia; karam.sallam@canberra.edu.au
[4] College of Computing and Information Technology,Arab Academy for Science, Technology and Maritime Transport (AASTMT),Cairo,Egypt; a.salem@aast.edu
* Correspondence: reda_mabrouk@fci.kfs.edu.eg ;

Abstract: Wheat has had a substantial influence on the food security of a number of different nations. In addition, governments are grappling with a number of difficulties, such as fast population expansion, a lack of available water, growing urbanization, and a restricted amount of wheat production in agricultural settings. As a result, the majority of their wheat and wheat products come from outside sources. The purpose of this research is to discover the main wheat suppliers and rate them according to certain criteria by analyzing the different ways of supplier selection that are currently available. The type-2 neutrosophic numbers-Measurement of Alternatives and Ranking according to the Compromise Solution (T2NNs-MARCOS) methodology was used in order to evaluate, choose, and rank the most reliable wheat suppliers in the African and Middle Eastern regions. According to the data, Russia is the country that provides the highest quality wheat. Because of its proximity, its robust connections via official channels, and its adaptability, this provider is often regarded as being the most reliable and cost-effective option. Because wheat is a key commodity, importers, decision-makers, and anyone involved with wheat imports may find this research helpful in identifying and selecting suppliers.

Keywords: Wheat; Neutrosophic; Supplier; Supply chain; T2NNs; MARCOS.

1. Introduction

Wheat is a fundamental commodity in numerous nations, particularly in the regions of the Middle East and Africa, where dietary practices heavily rely on various wheat-based products. Wheat-based products such as bread, pasta, and sweets are commonly consumed as staple food items. Hence, wheat stands as the primary and fundamental commodity subject to governmental oversight, encompassing its importation, storage, and subsequent distribution. The quantity of tender is contingent upon factors such as the existing storage capacity, consumption rate, warehouse management practices, strategic plans for food security, and prevailing storage conditions. Hence, the tender encompasses the expenses associated with procurement, shipment, conveyance, handling, insurance, and additional charges and expenditures. The importation of wheat in the Middle East region exhibits a distinct process, wherein the relevant governmental authorities issue invitations to tender. Subsequently, applicants are required to select suppliers based on the specified conditions. This signifies that the government does not directly determine the supplier, but rather, the responsibility lies with the applicant or bidder to make the selection.

It is imperative to establish explicit terms and conditions for the tender process, encompassing various aspects such as specifications, quality requirements, timelines, supplier solvency, procedural requirements, contractual and financial considerations, as well as essential tests and acceptance criteria. After the tender has been awarded, it is imperative for the relevant authorities to adhere to the specified guidelines for the storage and distribution of wheat, in accordance with the established principles governing this process. Additionally, it is imperative to guarantee the presence of a strategic inventory of said product for specific timeframes, typically ranging from six months to a minimum of one year. The primary specifications for wheat encompass its origin, protein content, test weight, moisture level, purity, fall number, wet gluten content, presence of soft grain admixture, foreign matter, and grain admixture. The primary factors that determine the quality of processing are grain hardness, protein concentration and quality, and gluten strength.

Therefore, the primary objective of this study is to address this research gap by providing answers to the following research inquiries: The supplier selection process encompasses various approaches and stages. Which wheat suppliers offer high-quality products at the most competitive prices and provide flexible delivery options? What are the appropriate criteria for assessing suppliers? Based on the prevailing international environment and situation, an inquiry is made regarding the most reputable wheat suppliers in the Middle East.

One of the key challenges encountered in the process of decision-making is the identification and selection of the most optimal alternative, which necessitates the careful consideration of numerous selection criteria [1], [2]. Multi-criteria decision-making (MCDM) techniques are frequently employed to effectively manage a diverse range of decision-making criteria [3], [4]. The extensive utilization of these techniques in the supply chain domain can be attributed to their computational capabilities [5].

The primary purpose of this research was to determine the most important wheat suppliers in the Middle East and Africa via the use of MCDM methods and to rank those suppliers according to the features that were discovered. Wheat is an essential agricultural product across the nations that make up the Middle East, and the government is in charge of bringing it in, regulating it, and storing it. The purpose of this research was to investigate different wheat suppliers in light of established standards. This research gives a comprehensive framework for the selection of suppliers, which may be used to effectively find suppliers of wheat as well as other items, products, or materials and to reduce the risks associated with the selection process. The type-2 neutrosophic numbers-Measurement of Alternatives and Ranking according to the Compromise Solution (T2NNs-MARCOS) MCDM methodology was used throughout the evaluation, selection, and ranking of the most effective wheat providers [6], [7]. It was determined using a numerical case study which wheat suppliers were the most important, and then it was determined which wheat supplier was the best based on the features that were determined. The neutrosophic set applied in many applications like [8], [9][10]–[13]

The remainder parts of the research are planned as follows: Section 2 develops the applied approach for selecting a suitable supplier of wheat. Section 3 employs a real case study for applying the suggested methodology and analysis of the results. Section 5 concludes the research.

2. Methodology

In this section, the proposed methodology to solve the problem of selecting and determining the best wheat supplier is presented. The proposed methodology is based on the MARCOS method. The proposed methodology consists of several stages. The first stage presents the details of the study and the selection of experts. The second stage is related to determining the weights of the criteria used in the study. The third and final stage is related to the arrangement of the alternatives chosen in the study. Figure 1 provides details of the proposed methodology.

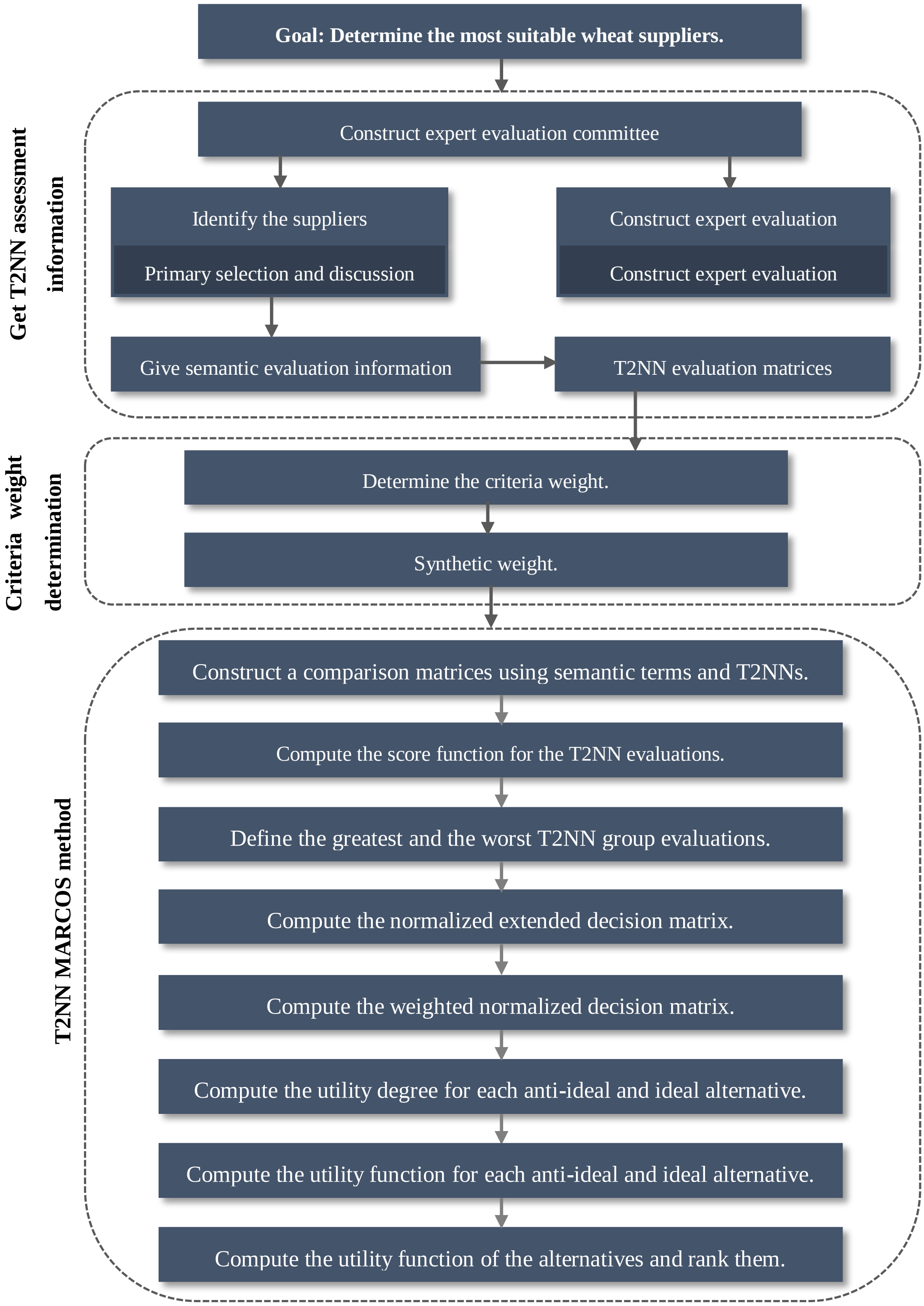

Figure 1. Details of the proposed methodology.

Step 1. The problem is studied in detail and the participating experts are identified as shown in Table 1. The participating experts give their opinions on the problem and define the criteria and available alternatives. Suppose a set of m alternatives is represented by $A = \{A_1, \dots, A_i, \dots\ A_m\}$ and a set of n criteria is denoted by $C = \{C_1, \dots, C_n, \dots, C_n\}$. Let experts $= \{E_1, \dots, E_e, \dots, E_k\}$ be a set of experts who offered their valuation report for each alternative $A_i (i = 1, 2 \dots m)$ against their criteria $C_j (j = 1, 2 \dots n)$. Let $w = (\mathrm{w}_1, \mathrm{w}_2, \dots, \mathrm{w}_\mathrm{e})^T$ be the weight vector for experts $E_e (e = 1, 2 \dots k)$ such that $\sum_{j=1}^{n} \mathrm{w}_l = 1$.

Table 1. Details on the participants of the panel of experts.

Expert	Experience	Occupation	Profession	Gender
$Expert_1$	5	Industry	Government policy maker	Male
$Expert_2$	12	Academia		Male
$Expert_3$	11	Industry		Male
$Expert_4$	8	Academia		Male

Step 2. A set of variables and their corresponding T2NNs are identified as shown in Table 2, for experts to use in evaluating the selected criteria and alternatives.

Table 2. T2NN semantic terms for weighing dimensions and alternatives.

Semantic terms	Abridgements	Type-2 neutrosophic number
Exceedingly little	EXC	$\langle(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.80, 0.70)\rangle$
Little	LLE	$\langle(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)\rangle$
Moderate little	MOL	$\langle(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.40, 0.60)\rangle$
Moderate	MOD	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0.45)\rangle$
Moderate high	MOH	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)\rangle$
High	HIG	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)\rangle$
Exceedingly high	EXH	$\langle(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)\rangle$

Step 3. Construct a preference matrix of criteria by experts to show their preferences to determine the criteria weights using the linguistic terms, then by using T2NNs.

Step 4. Compute the score function for the T2NN assessments according to Eq. (1) [14].

$$S(\tilde{X}_{ij}) = \frac{1}{12}\left\langle 8 + \left(T_{T_{\tilde{X}_{ij}}}(y) + 2\left(T_{I_{\tilde{X}_{ij}}}(y)\right) + T_{F_{\tilde{X}_{ij}}}(y)\right) - \left(I_{T_{\tilde{X}_{ij}}}(y) + 2\left(I_{I_{\tilde{X}_{ij}}}(y)\right) + I_{F_{\tilde{X}_{ij}}}(y)\right) - \left(F_{T_{\tilde{X}_{ij}}}(y) + 2\left(F_{I_{\tilde{X}_{ij}}}(y)\right) + F_{F_{\tilde{X}_{ij}}}(y)\right)\right\rangle, \; i = 1, \ldots, m; j = 1, \ldots, n. \quad (1)$$

Step 5. Determine the best and the worst T2NN assessments according to the extended T2NN decision matrix for denoting the ideal (AI) and anti-ideal (AAI) alternatives, respectively according to Eqs. (2) and (3).

The anti-ideal substitute $A_0 = \{X_{01}, \ldots, X_{0j}, \ldots, X_{0n}\}$

$$A_{0j} = \begin{cases} \max\limits_{1 \le i \le m} X_{ij} & |C_j \in C^- \\ \max\limits_{1 \le i \le m} X_{ij} & |C_j \in C^+ \end{cases}, j = 1, \ldots, n.$$

(2)

where A_{0j}(j = 1, ..., n) designates anti-ideal group estimations under each criterion.

The ideal substitute $A_{m+1} = \{X_{m+1\ 1}, \ldots, X_{m+1\ j}, \ldots, X_{m+1\ n}\}$

$$A_{m+1\ j} = \begin{cases} \max\limits_{1 \le i \le m} X_{ij} & |C_j \in C^- \\ \max\limits_{1 \le i \le m} X_{ij} & |C_j \in C^+ \end{cases}, j = 1, \ldots, n.$$

(3)

where $A_{m+1\ j}$(j = 1,..., n) indicates ideal group evaluations under each criterion.

Step 6. Calculate the normalized decision matrix according to Eq. (4).

$$R_{ij} = \begin{cases} \frac{x_{ij}}{x_{m+ij}} & |C_j \in C^+ \\ \frac{x_{m+ij}}{x_{ij}} & |C_j \in C^- \end{cases}, \text{ i = 0, ..., m + 1; j = 1, ..., n.} \quad (4)$$

Step 7. Calculate the weighted normalized decision matrix according to Eq. (5).

$$S_{ij} = w_j \ S_{ij}, \text{ i = 0, ..., m + 1; j = 1, ..., n.} \quad (5)$$

Step 8. Compute the utility degree for each anti-ideal substitute according to Eq. (6).Then, compute the utility degree for each ideal substitute according to Eq. (7).

$$U^-{}_i = \frac{\sum_{j=1}^{n} s_{ij}}{\sum_{j=1}^{n} s_{0j}}, \text{ i = 0, ..., m + 1.} \quad (6)$$

$$U^+{}_i = \frac{\sum_{j=1}^{n} s_{ij}}{\sum_{j=1}^{n} s_{m+1\ j}}, \text{ i = 0, ..., m + 1.} \quad (7)$$

Step 9. Compute the utility function for each anti-ideal alternative according to Eq. (8).Then, compute the utility function for each ideal substitute according to Eq. (9).

$$f(U^-) = \frac{U^+{}_0}{U^-{}_0 + U^+{}_0} \quad (8)$$

$$f(U^+) = \frac{U^-{}_{m+1}}{U^-{}_{m+1} + U^+{}_{m+1}} \quad (9)$$

Step 10. Compute the utility function of the substitutes and rank them by employing Eq. (10). The optimal substitute has the highest utility function.

$$f(U_i) = \frac{(U^-{}_i + U^+{}_i)[f(U^-) \times f(U^+)\ ]}{f(U^-) + f(U^+) - f(U^-) \times f(U^+)}, \text{ i = 1, ..., m.} \quad (10)$$

3. Application

3.1 Case Study

Most countries in the Middle East and Africa rely on wheat in their daily diet. Wheat, flour, and bread are staples that may be found on most people's dinner tables. The variety, quality, purchase prices from the source, transportation fees, loading and unloading charges, and other considerations such as delivery intervals all play a role in determining the source of wheat. Wheat production follows the cycles of the seasons, and storage capacity are often restricted or only enough for a range of time spans. Wheat prices fluctuate across the world based on the variety being purchased and the accepted level of quality. Wheat is normally divided into two categories: hard and soft. When choosing wheat suppliers for the Middle East and Africa, it is important to keep in mind that many nations in North America and Europe control the majority of the wheat supply chain. Wheat has been negatively affected by COVID-19 since it caused crop harvesting to be delayed, and the subsequent lockdown had an effect on both the supply chain and price. The extent to which wheat can be grown has a considerable bearing on the wheat supply chain's ability to continue operating profitably. As a result, the wheat supply chain has to commit to and actively engage in innovations that are sustainable via joint efforts. When doing an investigation to determine who the primary source of wheat is or how the various suppliers stack up against one another, each of these aspects should be taken into consideration. In addition, the identification and selection of the primary wheat suppliers in the Middle East and Africa may be impacted in the future by developments and risks that are both anticipated and unanticipated. In this study, we seek to assess four countries as suppliers of wheat. The four countries are Romania (A_1), Australia (A_2), Russia (A_3), and Ukraine (A_4).

3.2 Application of the proposed methodology

In this part, the steps of the proposed approach are applied to evaluate and select the most suitable country as a supplier of wheat for the countries of the Middle East and Africa.

Step 1. In the beginning, the problem and its main and subsidiary aspects were studied. In this regard, four experts were selected, as shown in Table 1, for the participation of the authors in expressing their views on the importance of the criteria, the arrangement of alternatives, and other matters related to the study.

Step 2. Seven semantic terms and their corresponding T2NNs were identified as in Table 2, to be used by experts in evaluating the criteria, determining their weights, and arranging the four selected alternatives.

Step 3. Seven criteria have been identified that have a direct impact on choosing the best country as a supplier of wheat. The seven selected criteria are Quality (C_1), Expenses (price and costs) (C_2), Delivery (time, place, and amount) (C_3), Origin (source country) (C_4), Flexibility (C_5), Communication (C_6), and Reliability/solvency of the importer (C_7). In addition, four alternatives were selected to be used in the evaluation process. The four alternatives selected are Romania (A_1), Australia (A_2), Russia (A_3), and Ukraine (A_4).

Step 4. An evaluation matrix was constructed by the four experts to show their preferences for the seven criteria using linguistic terms as in Table 3, then by using T2NNs as presented in Table 4.

Step 5. The T2NNs were converted to real values using Eq. (1), and the final weights for the seven criteria were determined as exhibited in Table 4 and Figure 2.

Table 3. Assessment matrix of criteria by the four experts using semantic terms.

Experts	Criteria						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
Expert_1	MOL	EXH	HIG	LLE	MOL	EXH	HIG
Expert_2	EXC	MOL	EXH	LLE	LLE	LLE	EXC
Expert_3	EXH	EXH	MOH	HIG	LLE	LLE	MOL
Expert_4	HIG	EXH	EXH	MOH	EXH	MOH	EXH

Table 4. Assessment matrix of criteria by the four experts using T2NNs.

Experts	Criteria	
	C_1	C_2
Expert_1	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.40, 0.60)⟩	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)⟩
Expert_2	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.80, 0.70)⟩	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.40, 0.60)⟩
Expert_3	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)⟩	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)⟩
Expert_4	⟨(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)⟩	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)⟩
Weight	0.139	0.185
Experts	C_3	C_4
Expert_1	⟨(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)⟩	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)⟩
Expert_2	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)⟩	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)⟩
Expert_3	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)⟩	⟨(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)⟩
Expert_4	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)⟩	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)⟩
Weight	0.192	0.122
Experts	C_5	C_6
Expert_1	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.40, 0.60)⟩	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)⟩
Expert_2	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)⟩	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)⟩
Expert_3	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)⟩	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)⟩
Expert_4	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)⟩	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)⟩
Weight	0.114	0.129
Experts	C_7	
Expert_1	⟨(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)⟩	
Expert_2	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.80, 0.70)⟩	
Expert_3	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.40, 0.60)⟩	
Expert_4	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0.45)⟩	
Weight	0.119	

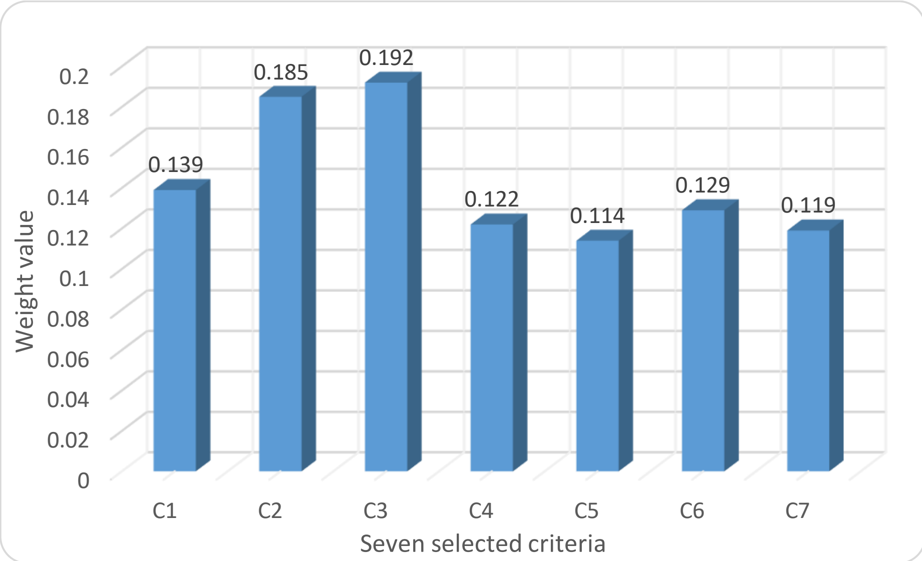

Figure 2. Weights of criteria.

Step 6. An evaluation matrix was constructed by the four experts to show their preferences for the four alternatives regarding the seven criteria using linguistic terms as in Table 5, then by using T2NNs as presented in Table 6.
Step 7. The T2NNs were converted to real values using Eq. (1).
Step 8. The best and the worst T2NN assessments according to the T2NN decision matrix were determined for denoting the AI and AAI substitutes, respectively according to Eqs. (2) and (3), as presented in Table 7.
Step 9. The normalized decision matrix was computed according to Eq. (4) as presented in Table 7.
Step 10. The weighted normalized decision matrix was computed according to Eq. (5) as presented in Table 8.
Step 11. The utility degree for each anti-ideal substitute was computed according to Eq. (6), as presented in Table 9. Then, the utility degree for each ideal substitute was computed according to Eq. (7), as presented in Table 9.
Step 12. The utility function for each anti-ideal alternative was computed according to Eq. (8), as presented in Table 9. Then, the utility function for each ideal substitute was computed according to Eq. (9), as presented in Table 9.
Step 13. The utility function of the substitutes was computed according to Eq. (10), as presented in Table 9. The alternatives were ranked as presented in Table 9 and shown in Figure 3.

Table 5. Assessment matrix of the four alternatives by the four experts using semantic terms.

Experts	Criteria						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	EXH	MOL	EXH	HIG	HIG	MOH	EXH
A_2	HIG	MOH	EXH	MOH	HIG	HIG	MOH
A_3	MOL	MOH	LLE	EXC	EXC	MOD	LLE
A_4	MOH	MOD	MOD	MOH	LLE	HIG	MOD

Table 6. Assessment matrix of the four alternatives by the four experts using T2NNs.

Alternatives	Criteria	
	C_1	C_2
A_1	$\langle(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)\rangle$	$\langle(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.40, 0.60)\rangle$
A_2	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)\rangle$	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)\rangle$

A_3	$\langle(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.40, 0.60)\rangle$	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)\rangle$
A_4	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)\rangle$	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0.45)\rangle$
Alternatives	**Criteria**	
	C_3	C_4
A_1	$\langle(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)\rangle$	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)\rangle$
A_2	$\langle(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)\rangle$	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)\rangle$
A_3	$\langle(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)\rangle$	$\langle(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.80, 0.70)\rangle$
A_4	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0.45)\rangle$	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)\rangle$
Alternatives	**Criteria**	
	C_5	C_6
A_1	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)\rangle$	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)\rangle$
A_2	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)\rangle$	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)\rangle$
A_3	$\langle(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.80, 0.70)\rangle$	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0.45)\rangle$
A_4	$\langle(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)\rangle$	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)\rangle$
Alternatives	**Criteria**	
	C_7	
A_1	$\langle(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)\rangle$	
A_2	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)\rangle$	
A_3	$\langle(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)\rangle$	
A_4	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0.45)\rangle$	

Table 7. Normalized matrix of the four alternatives according to all criteria.

Experts	Criteria						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
AAI	0.495	0.648	0.333	0.296	0.296	0.716	0.333
A_1	0.495	1.000	0.333	0.296	0.296	0.817	0.333
A_2	0.568	0.648	0.333	0.338	0.296	0.716	0.437
A_3	1.000	0.648	1.000	1.000	1.000	1.000	1.000
A_4	0.648	0.793	0.534	0.338	0.774	0.716	0.534
AI	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 8. Weighted normalized matrix of the four alternatives according to all criteria.

Experts	Criteria						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
AAI	0.069	0.120	0.064	0.036	0.034	0.092	0.040
A_1	0.069	0.185	0.064	0.036	0.034	0.105	0.040
A_2	0.079	0.120	0.064	0.041	0.034	0.092	0.052
A_3	0.139	0.120	0.192	0.122	0.114	0.129	0.119
A_4	0.090	0.147	0.103	0.041	0.088	0.092	0.064
AI	0.139	0.185	0.192	0.122	0.114	0.129	0.119

Table 9. Final ranking of the four alternatives.

Alternatives	O_i	U_i^-	U_i^+	$f(U^-)$	$f(U^-)$	$f(U_i)$	Rank
AAI	0.455						
A_1	0.533	1.172	0.533	0.313	0.687	0.466	3
A_2	0.482	1.061	0.482	0.313	0.687	0.422	4
A_3	0.935	2.057	0.935	0.313	0.687	0.819	1
A_4	0.625	1.375	0.625	0.313	0.687	0.547	2
AI	1.000						

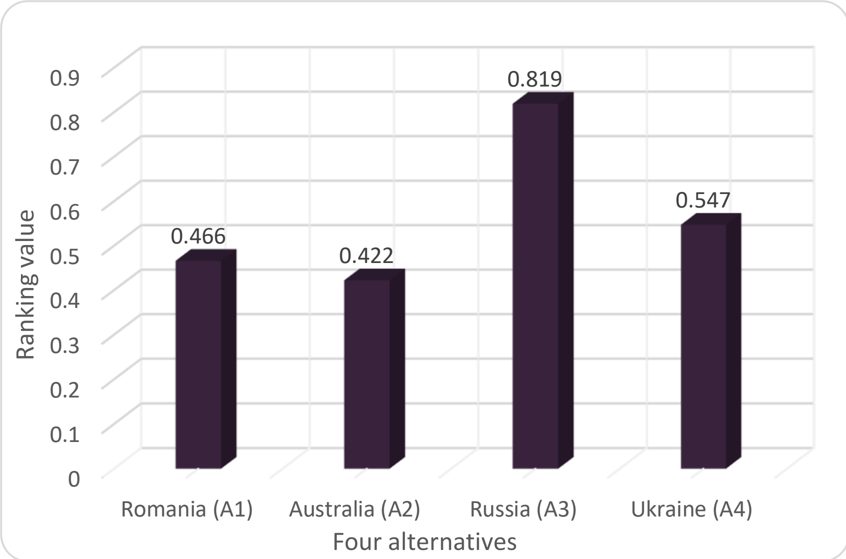

Figure 3. Final ranking of the four alternatives.

3.3 Results and discussion

In this part, the results obtained from the application of the proposed model to evaluate and determine the most suitable countries supplying wheat to the countries of the Middle East and Africa are discussed. The results are divided into two parts. The first part is concerned with evaluating the seven criteria and determining the weights. The seven criteria were evaluated through expert opinions as shown in Table 4. The results indicate that the Delivery criterion (time, place, and amount) (C_3), is the criterion with the highest weight by 0.192, followed by the Expenses criterion (price and costs) (C_2) with a weight of 0.185, while the Flexibility criterion (C_5) has the least weight by 0.114.

The second part is concerned with evaluating the four alternatives selected in the study. The four selected alternatives were arranged as shown in Table 9 and Figure 3. The results show that Russia (A_3) is the highest in the order, followed by Ukraine (A_4), while Australia (A_2) is the lowest in the order.

4. Conclusions

Wheat is a fundamental and significant product that is used in the majority of countries, including those in the Middle East and Africa, where derivatives of wheat are almost always present on dining tables. Because of this, the governments are able to maintain a consistent supply of wheat via the processes of importing, storing, and distributing it. The supply chain for wheat has a considerable influence not just on environmental sustainability but also on the safety of food supplies. In addition, nations are confronted with a number of issues, some of which include a fast-expanding population, considerable urbanization, a lack of water, and poor soil quality. Despite the ever-increasing need for food, agriculture is not a viable solution to the problem. In addition, the choice of supply is affected by a broad variety of variables, such as the price of the product at issue, the number of producers, the cost of inputs, technical advancements, the cost of alternative goods, and unpredictability in the form of the weather. This research addresses a knowledge gap regarding the ranking or selection of top wheat suppliers for the African area as well as the Middle Eastern region. This research examines alternatives to wheat suppliers based on recognized needs. This is important in light of the fact that wheat is seen as an essential food item in the Middle East. Given that governments are in charge of importing, managing, and storing wheat, this is of the utmost importance.

The main objective of the study is to identify and choose the most suitable wheat suppliers from the four countries used in the study. The four countries identified in the evaluation process are Russia, Romania, Ukraine, and Australia. Also, seven basic criteria were identified in selecting the most suitable suppliers. The evaluation process was conducted in a neutrosophic environment and by applying the MARCOS method to determine the most suitable countries for wheat supply.

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.

Conflict 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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