Neutrosophic Sets and Systems, Vol. 81, 2025

University of New Mexico

Clear Approach to Education Quality Evaluation of Multilingual Higher Education Internationalization under Probabilistic Simplified Neutrosophic Sets for Academic Improvement

Qing Li[1], Wenya Chen[2*]

[1.]School of Humanities, Zhuhai College of Science and Technology, Zhuhai, 519041, Guangdong, China (E-mail: liqing7@zcst.edu.cn)

[2.]School of Foreign Language, Zhuhai College of Science and Technology, Zhuhai, 519041, Guangdong, China

*Corresponding author, E-mail: chenwenyasci@126.com

Abstract: An integrated multi-criteria decision-making (MCDM) approach is used in this study to evaluate multilingual higher education internationalization. This study is the first to employ a novel combination technique that has not yet been used for corporate performance evaluation. It is based on root assessment method (RAM) and indifference threshold-based attribute ratio analysis (ITARA) methodologies. The weights of the criteria are determined using the ITARA approach, and the RAM method is used to rank the alternatives. these methods are used under the neutrosophic sets to deal with vague and uncertainty data. This study uses the Probabilistic Simplified Neutrosophic sets to overcome uncertainty issues. Three experts have evaluated the criteria and alternatives. We used seven criteria and ten alternatives to be evaluated and selected the best one.

Keywords: Probabilistic Simplified Neutrosophic sets; RAM Method; ITARA Method; Decision Making.

1. Introduction and Related Work

To assess multilingual higher education internationalization based on their criteria statements, several methodologies have been developed in the literature, including regression models, discriminant analysis, factor analysis, and multi-criteria decision-making (MCDM) techniques. To create a successful model for multilingual higher education internationalization analysis, several factors need to be considered. As a result, MCDM techniques, which are popular in multilingual higher education internationalization, can be utilized to handle such issues. Researchers favor MCDM approaches due to the intricate, multifaceted, and contradictory character of multilingual higher education internationalization performance. Furthermore, by combining data from multiple criteria into a single score, MCDM approaches simplify and make performance evaluation more straightforward[1], [2]. On the other hand, MCDM techniques use several criteria to rank options based on a mathematical foundation to aid in decision-making.

Many scholars use MCDMs for many domains. However, decision makers find it challenging to model issues when faced with ambiguous or insufficient information. Zadeh created fuzzy sets (FSs) to deal with this issue and model unclear information. The information about its members defines an FS. FSs are used as models for decision problems, pattern recognition, and approximation reasoning in several publications[3], [4]. However, the absence of information about uncertainty makes FSs inadequate for expressing some circumstances. Atanassov created the idea of intuition fuzzy sets (IFS) with this in mind. We have information about non-membership, and the total membership and non-membership is less than or equal to one, unlike FSs.

However, uncertainty in our lives can take many forms. When asked to consider a circumstance, for instance, an expert may state that the degree of truth membership is 0.5, the degree of indeterminacy membership is 0.3, and the degree of falsity membership is 0.7. The sets mentioned above are insufficient to explain this circumstance. Smarandache created neutrosophic logic and neutrosophic set (NS) based on this concept. Truth membership, indeterminacy membership, and falsity membership are the three memberships that define the NSs. None of these memberships add up to more than three[5], [6]. This is an extension of the standard unit interval where the membership degrees accept values in non-standard unit intervals.

Decision-makers may be reluctant to express their preferences during the decision-making process and may want information regarding the potential of each neutrosophic aspect. This issue is partially resolved by the possibility-induced simplified neutrosophic number (PISNN), which was recently presented by Şahin and Liu. The neutrosophic number is given a probability value by a PISNN. However, when decision makers voice their opinions about neutrosophic aspects, they could be hesitant to discuss each one[7], [8]. A new set theory is needed for this concept. In light of this, we provide some theoretical set attributes and define a new set known as the probabilistic simplified neutrosophic set. It is more efficient and trustworthy to define issues that are emerging in numerous fields when components and their potential are considered simultaneously.

For the first time, this study combines the ITARA and RAM methodologies, which is an innovative approach and contribution. The integration of the ITARA and RAM methodologies is further justified by the fact that they are recently introduced approaches with limited literature usage. Moreover, assessments of multilingual higher education internationalization performance have not used these two approaches[9], [10]. This study will add to the body of knowledge and assist scholars in assessing the multilingual higher education internationalization performance.

1.1 Related Work

PSNS is a useful tool for characterizing the ambiguity that exists in everyday life. Altun et al. [6] define a PSNS and go over some theoretical set operations in this study. They suggested the ideas of an inner product, a projection operator between two, and a module on. They present a PSNS in connection with this new collection. Truth membership degree, indeterminacy membership degree, and falsity membership degree are the three pieces that make up a PSNS. They provided a score function, an accurate function, and a few algebraic operational principles. They designed a way based on preference function to calculate the weight of each decision maker and use a fuzzy measure-based method to establish the weights of the criterion. For group decision problems, they offered an expanded PROMETHEE approach. To guarantee the stability of the suggested approach, they concluded by providing an example of a MCDM problem based on the extended PROMETHEE method.

The widespread use of computer networks has greatly facilitated people's lives and careers, but it has also resulted in information security issues. Performing well in the assessment of computer network security is crucial. In the face of complicated computer network applications, a security assessment approach with good operability and a larger application range is required. Conventional computer network security evaluation can be achieved with the aid of firewalls, antivirus software, etc. It is believed that the assessment of computer network security is a MCDM problem. An extended PSNN grey relational analysis approach is developed by Wang et al. [11] for assessing the security of computer networks. The PSNN-GRA technique combined with the significance of criteria. A numerical example for computer network security evaluation was used to demonstrate the feasibility of the recently proposed method and to compare it with other approaches, even though the CRITIC method was used to rank the optional alternatives in PSNS scenario. Their findings show that the method is straightforward, reliable, and easy to calculate.

Neutosophic sets are a kind of intuitionistic fuzzy set and fuzzy sets that are used to represent ambiguous, imprecise, inconsistent, and incomplete information found in the actual world. The primary goal of SNS is to solve problems involving a given set of numbers. However, there are certain issues with the way SNS now operate, as well as with their comparison techniques and aggregation operators. Thus, Peng et al. [5] established a comparison approach based on the related research of intuitionistic fuzzy numbers and specifies the innovative operations of SNNs.

There are five sections to this study. Section 2 shows some definitions of PSNS. A summary of the MCDM framework is provided in the third section. The steps of the ITARA approach, a semi-objective weighting procedure suggested to establish the criteria weights, are first described. The steps of the new MCDM technique, the RAM method, are then presented and described. By using the integrated MCDM approach to evaluate criteria, the fourth section Additionally, the conclusion is shown in Section 5.

2. Probabilistic simplified neutrosophic set (PSNS)

We introduce some basic definitions of the PSNSs in this paper[11], [12].

Definition 1

We can define the PSNS such as:

$$K = \left\{\left(z; T_k(z)\left(P_{Tk}(z)\right), I_k(x)\left(P_{Ik}(z)\right), F_k(x)\left(P_{Fk}(z)\right)\right); z \in Z\right\} \quad (1)$$

$$0 < P_{Tk}(z), P_{Ik}(z), P_{Fk}(z) \leq 1 \quad (2)$$

$$0 < T_k(x) + I_k(x) + F_k(x) \leq 3 \quad (3)$$

Definition 2.

Let two PSNS such as:

$$A_1 = \left\{\left(z; T_{k_{A_1}}(z)\left(P_{Tk_{A_1}}(z)\right), I_{k_{A_1}}(x)\left(P_{Ik_{A_1}}(z)\right), F_{k_{A_1}}(x)\left(P_{Fk_{A_1}}(z)\right)\right); z \in Z\right\}$$

$$A_2 = \left\{\left(z; T_{k_{A_2}}(z)\left(P_{Tk_{A_2}}(z)\right), I_{k_{A_2}}(x)\left(P_{Ik_{A_2}}(z)\right), F_{k_{A_2}}(x)\left(P_{Fk_{A_2}}(z)\right)\right); z \in Z\right\}$$

$$A_1 \sqsubseteq A_2 \leftrightarrow \begin{pmatrix} T_{k_{A_1}}(z) \le T_{k_{A_2}}(z), P_{Tk_{A_1}}(z) \le P_{Tk_{A_2}}(z); \\ I_{k_{A_1}}(x) \ge I_{k_{A_2}}(x), P_{Ik_{A_1}}(z) \ge P_{Ik_{A_2}}(z); \\ F_{k_{A_1}}(x) \ge F_{k_{A_2}}(x), P_{Fk_{A_1}}(z) \ge P_{Fk_{A_2}}(z) \end{pmatrix} \tag{4}$$

$$A_1^c = \left\{\begin{matrix} F_{k_{A_1}}(x)\left(P_{Fk_{A_1}}(z)\right), \\ \left(1 - I_{k_{A_1}}(x)\right)\left(1 - P_{Ik_{A_1}}(z)\right), \\ T_{k_{A_1}}(z)\left(P_{Tk_{A_1}}(z)\right) \end{matrix}\right\} \tag{5}$$

$$A_1 \cap A_2 = \left\{\begin{matrix} \min\left\{T_{k_{A_1}}(z), T_{k_{A_2}}(z)\right\}\left(\min\left\{P_{Tk_{A_1}}(z), P_{Tk_{A_2}}(z)\right\}\right), \\ \max\left\{I_{k_{A_1}}(x), I_{k_{A_2}}(x)\right\}, \left(\max\left\{P_{Ik_{A_1}}(z), P_{Ik_{A_2}}(z)\right\}\right), \\ \max\left\{F_{k_{A_1}}(x), F_{k_{A_2}}(x)\right\}, \left(\max\left\{P_{Fk_{A_1}}(z), P_{Fk_{A_2}}(z)\right\}\right) \end{matrix}\right\} \tag{6}$$

$$A_1 \cup A_2 = \left\{\begin{matrix} \max\left\{T_{k_{A_1}}(z), T_{k_{A_2}}(z)\right\}\left(\max\left\{P_{Tk_{A_1}}(z), P_{Tk_{A_2}}(z)\right\}\right), \\ \min\left\{I_{k_{A_1}}(x), I_{k_{A_2}}(x)\right\}, \left(\min\left\{P_{Ik_{A_1}}(z), P_{Ik_{A_2}}(z)\right\}\right), \\ \min\left\{F_{k_{A_1}}(x), F_{k_{A_2}}(x)\right\}, \left(\min\left\{P_{Fk_{A_1}}(z), P_{Fk_{A_2}}(z)\right\}\right) \end{matrix}\right\} \tag{7}$$

$$A_1 \oplus A_2 = \begin{pmatrix} T_{k_{A_1}}(z) + T_{k_{A_2}}(z) - \\ T_{k_{A_1}}(z) T_{k_{A_2}}(z)\left(2!\frac{P_{Tk_{A_1}}(z) P_{Tk_{A_2}}(z)}{P_{Tk_{A_1}}(z) + P_{Tk_{A_2}}(z)}\right), \\ I_{k_{A_1}}(x) I_{k_{A_2}}(x)\left(2!\frac{P_{Ik_{A_1}}(z) P_{Ik_{A_2}}(z)}{P_{Ik_{A_1}}(z) + P_{Ik_{A_2}}(z)}\right), \\ F_{k_{A_1}}(x) F_{k_{A_2}}(x)\left(2!\frac{P_{Fk_{A_1}}(z) P_{Fk_{A_2}}(z)}{P_{Fk_{A_1}}(z) + P_{Fk_{A_2}}(z)}\right) \end{pmatrix} \tag{8}$$

$$\gamma A_1 = \begin{pmatrix} 1 - \left(1 - T_{k_{A_1}}(z)\right)^{\gamma} P_{Tk_{A_1}}(z), \\ \left(I_{k_{A_1}}(z)\right)^{\gamma} P_{Ik_{A_1}}(z), \\ \left(F_{k_{A_1}}(z)\right)^{\gamma} P_{Fk_{A_1}}(z) \end{pmatrix} \tag{9}$$

$$A_1^{\gamma} = \begin{pmatrix} \left(T_{k_{A_1}}(z)\right)^{\gamma} P_{Tk_{A_1}}(z), \\ 1 - \left(1 - I_{k_{A_1}}(z)\right)^{\gamma} P_{Ik_{A_1}}(z), \\ 1 - \left(1 - F_{k_{A_1}}(z)\right)^{\gamma} P_{Fk_{A_1}}(z) \end{pmatrix} \tag{10}$$

Definition 3

We can compute the score function such as:

$$S(A) = \frac{TP_T + 1 - FP_I + 1 - FP_F}{3} \tag{11}$$

3. MCDM framework

The framework known as MCDM was created by combining several disciplines to help decision-makers by evaluating the issue they are trying to address from several angles. Another definition of MCDM is a procedure designed to manage decision-making in a transparent and consistent manner. For this procedure, more than 50 MCDM approaches have been proposed by researchers in literature, and the number of these methods is growing every day. It is clear from evaluating the suggested MCDM approaches for different choice issues that each approach has advantages and disadvantages; yet the literature analysis has shown that the MCDM approaches are not intrinsically better.

Determining the decision criteria, taking expert viewpoints into account, and performing a literature study are all part of the integrated method's initial step. The seven factors considered when evaluating the Multilingual Higher Education Internationalization are shown in Table 1. The criteria fall into one of two categories: cost or benefit. The benefit criterion is the one that is chosen to have greater values, while the cost criterion is the one that is favored to have lower values. Stated differently, the benefit criteria describe the circumstance in which greater values are more effective in reaching the goal.

Table 1. Criteria and alternatives considered in the evaluation of the MCDM issue.

Alternatives	Criteria
AI-Powered Translation Joint Degree Programs Cultural Integration Programs International Branch Campuses Open Education Resources Multilingual Degree Programs Faculty Exchange Programs Content and Language Integrated Learning Global Research Collaborations Hybrid Learning Platforms	Faculty Language Proficiency Technology-Enhanced Multilingual Learning International Student Support Multilingual Curriculum Design Global Research Collaboration Graduate Employability Cross-Cultural Communication

ITARA method

Hatefi devised the ITARA approach, a semi-objective weighting technique, to determine the criteria's weights[13], [14]. To establish criterion weights based on alternatives, it is predicated on the ideas of dispersion logic and indifference threshold (IT). Compared to the entropy approach, the ITARA method is more stable and simpler to apply. When there are more options, the ITARA approach has been used in literature.

The ITARA technique has been applied in the literature to establish the weights of criteria in several different domains.

Step 1. The decision matrix is built

$$X_{ij} = \begin{pmatrix} x_{11} & \cdots & x_{1j} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{pmatrix}_{m \times n} \quad (12)$$

Where n refers to the number of criteria and m refers to the number of alternatives. The experts can determine the IT.

Step 2. Normalize the decision matrix and normalize IT (NIT).

$$y_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (13)$$

$$NIT_j = \frac{IT_j}{\sum_{i=1}^{m} x_{ij}} \quad (14)$$

Step 3. Rank the normalized values and named them such as: $\delta_{ij}\ so\ that\ \delta_{ij} \leq \delta_{i+1j}$

Step 4. Compute the distance

$$d_{ij} = \delta_{i+1j} + \delta_{ij} \quad (15)$$

Step 5. Compute the distance between the ranked scores

$$y_{ij} = \begin{cases} d_{ij} - NIT_j & for\ d_{ij} > NIT_j \\ 0\ for\ d_{ij} \leq NIT_j \end{cases} \quad (16)$$

Step 6. Compute the criteria weights.

$$w_j = \frac{v_j}{\sum_{i=1}^{n} v_j} \quad (17)$$

$$v_j = \left(\sum_{i=1}^{m-1} y_{ij}^{p}\right)^{\frac{1}{p}} \quad (18)$$

Where p refers to the parameter model.

RAM Method

This part shows the steps of the RAM method to rank the alternatives[15], [16].

Step 1. Normalize the decision matrix

$$q_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (19)$$

Step 2. Compute the weighted decision matrix.

$$f_{ij} = w_j q_{ij} \quad (20)$$

Step 3. Compute the sum of weighted decision matrix for positive and negative criteria

$$T_{+i} = \sum_{j=1}^{n} f_{+ij} \quad (21)$$

$$T_{-i} = \sum_{j=1}^{n} f_{-ij} \quad (22)$$

Step 4. Compute the total score

$$L_i = \sqrt[2+T_{-i}]{2 + T_{+i}} \quad (23)$$

Step 5. Rank the alternatives.

4. Case Study

This section shows the results of the proposed approach to compute the criteria weights and rank the alternatives. We invited three experts to evaluate the criteria and alternatives. We gathered seven criteria and ten alternatives to be evaluated. We proposed ten solutions to Multilingual Higher Education Internationalization to select the best one.

Determination of criterion weights by the ITARA method

Eq. (12) is used to build the decision matrix. We used the neutrosophic numbers to evaluate the criteria and alternatives as shown in Tables 2-4. Then we applied the score function to obtain the crisp values. Then we used the average method to combine these values.

Table 2. Expert 1 values.

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

Table 3. Expert 2 values.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.8(0.9),0.2(0.7),0.3(1))	(0.7(1),0.2(1),0.2(0.7))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.8(1),0.3(0.8),0.5(0.7))	(0.8(0.9),0.2(0.7),0.3(1))
A_2	(0.8(1),0.3(0.8),0.5(0.7))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.8(1),0.3(0.8),0.5(0.7))	(0.8(0.9),0.2(0.7),0.3(1))	(0.7(1),0.2(1),0.2(0.7))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.6,(0.8),0.3(0.9),0.2(0.9))
A_3	(0.8(0.9),0.2(0.7),0.3(1))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.7(1),0.2(1),0.2(0.7))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.3(0.7),0.2(0.9),0.3(0.9))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.8(1),0.3(0.8),0.5(0.7))
A_4	(0.7(1),0.2(1),0.2(0.7))	(0.4(0.9),0.2(0.9),0.1(1))	(0.8(0.9),0.2(0.7),0.3(1))	(0.8(1),0.3(0.8),0.5(0.7))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.8(1),0.3(0.8),0.5(0.7))	(0.8(0.9),0.2(0.7),0.3(1))
A_5	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.8(1),0.3(0.8),0.5(0.7))	(0.8(0.9),0.2(0.7),0.3(1))	(0.7(1),0.2(1),0.2(0.7))
A_6	(0.8(0.9),0.2(0.7),0.3(1))	(0.8(1),0.3(0.8),0.5(0.7))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.8(1),0.3(0.8),0.5(0.7))	(0.8(0.9),0.2(0.7),0.3(1))	(0.7(1),0.2(1),0.2(0.7))	(0.5(0.9),0.3(0.9),0.5(0.8))
A_7	(0.8(1),0.3(0.8),0.5(0.7))	(0.8(0.9),0.2(0.7),0.3(1))	(0.8(1),0.3(0.8),0.5(0.7))	(0.8(0.9),0.2(0.7),0.3(1))	(0.7(1),0.2(1),0.2(0.7))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.8(1),0.3(0.8),0.5(0.7))
A_8	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.7(1),0.2(1),0.2(0.7))	(0.8(0.9),0.2(0.7),0.3(1))	(0.7(1),0.2(1),0.2(0.7))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.7(1),0.2(1),0.2(0.7))	(0.8(0.9),0.2(0.7),0.3(1))
A_9	(0.4(0.9),0.2(0.9),0.1(1))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.7(1),0.2(1),0.2(0.7))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.7(1),0.2(1),0.2(0.7))

A 10	(0.3(0.7),0.2(0.9),0.3(0.9))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.8(0.9),0.2(0.7),0.3(1))	(0.8(1),0.3(0.8),0.5(0.7))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.5(0.9),0.3(0.9),0.5(0.8))

Table 4. Expert 3 values.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A 1	(0.8(1),0.3(0.8),0.5(0.7))	(0.8(0.9),0.2(0.7),0.3(1))	(0.7(1),0.2(1),0.2(0.7))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.3(0.7),0.2(0.9),0.3(0.9))	(0.8(1),0.3(0.8),0.5(0.7))	(0.8(0.9),0.2(0.7),0.3(1))
A 2	(0.4(0.9),0.2(0.9),0.1(1))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.8(1),0.3(0.8),0.5(0.7))	(0.8(0.9),0.2(0.7),0.3(1))	(0.7(1),0.2(1),0.2(0.7))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.5(0.9),0.3(0.9),0.5(0.8))
A 3	(0.3(0.7),0.2(0.9),0.3(0.9))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.7(1),0.2(1),0.2(0.7))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.3(0.7),0.2(0.9),0.3(0.9))	(0.3(0.7),0.2(0.9),0.3(0.9))	(0.3(0.7),0.2(0.9),0.3(0.9))
A 4	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.4(0.9),0.2(0.9),0.1(1))	(0.8(0.9),0.2(0.7),0.3(1))	(0.8(1),0.3(0.8),0.5(0.7))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.4(0.9),0.2(0.9),0.1(1))	(0.5(0.9),0.3(0.9),0.5(0.8))
A 5	(0.7(1),0.2(1),0.2(0.7))	(0.3(0.7),0.2(0.9),0.3(0.9))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.8(1),0.3(0.8),0.5(0.7))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.4(0.9),0.2(0.9),0.1(1))
A 6	(0.8(0.9),0.2(0.7),0.3(1))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.7(1),0.2(1),0.2(0.7))	(0.4(0.9),0.2(0.9),0.1(1))	(0.8(1),0.3(0.8),0.5(0.7))	(0.8(1),0.3(0.8),0.5(0.7))	(0.6,(0.8),0.3(0.9),0.2(0.9))
A 7	(0.8(1),0.3(0.8),0.5(0.7))	(0.7(1),0.2(1),0.2(0.7))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.3(0.7),0.2(0.9),0.3(0.9))	(0.8(0.9),0.2(0.7),0.3(1))	(0.8(0.9),0.2(0.7),0.3(1))	(0.8(1),0.3(0.8),0.5(0.7))
A 8	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.8(0.9),0.2(0.7),0.3(1))	(0.3(0.7),0.2(0.9),0.3(0.9))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.7(1),0.2(1),0.2(0.7))	(0.7(1),0.2(1),0.2(0.7))	(0.8(0.9),0.2(0.7),0.3(1))
A 9	(0.4(0.9),0.2(0.9),0.1(1))	(0.8(1),0.3(0.8),0.5(0.7))	(0.4(0.9),0.2(0.9),0.1(1))	(0.4(0.9),0.2(0.9),0.1(1))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.7(1),0.2(1),0.2(0.7))
A 10	(0.3(0.7),0.2(0.9),0.3(0.9))	(0.5(0.9),0.3(0.9),0.5(0.8))	(0.7(1),0.2(1),0.2(0.7))	(0.8(0.9),0.2(0.7),0.3(1))	(0.8(1),0.3(0.8),0.5(0.7))	(0.6,(0.8),0.3(0.9),0.2(0.9))	(0.5(0.9),0.3(0.9),0.5(0.8))

Eq. (13) is used to normalize the decision matrix between the criteria and alternatives as shown in Table 5. Then we ranked the normalization values. Then we compute the distance using the Eq. (15). Then we compute the distance between the ranked scores. Then we compute the criteria weights using Eq. (17). Then we ranked these criteria as shown in fig 1.

Table 5. The normalization matrix by the ITARA method.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.103831294	0.108969	0.109361	0.086004	0.088399	0.105506	0.100587
A_2	0.102543464	0.093038	0.10241	0.110163	0.112363	0.084978	0.09789
A_3	0.093367675	0.102278	0.109361	0.086004	0.092049	0.097868	0.099159
A_4	0.09529942	0.102597	0.09793	0.10678	0.099508	0.104551	0.099476
A_5	0.104636188	0.095587	0.091443	0.094057	0.098397	0.103756	0.103443
A_6	0.110109466	0.091923	0.103027	0.107103	0.108713	0.10105	0.088688
A_7	0.106728912	0.111518	0.095768	0.101788	0.109824	0.102164	0.107568
A_8	0.098036059	0.110244	0.089589	0.102271	0.100778	0.111394	0.10852
A_9	0.10045074	0.098773	0.100711	0.095668	0.084748	0.09182	0.109948
A_{10}	0.08499678	0.085072	0.100402	0.110163	0.105221	0.096913	0.084722

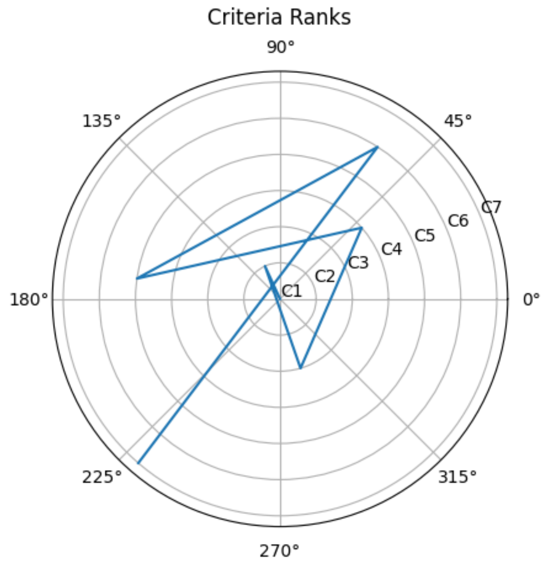

Fig 1. The rank of criteria.

Evaluation of alternatives with the RAM method

We used the criteria weights to rank the alternatives. Eq. (19) is used to normalize the decision matrix. Then we used Eq. (20) to compute the weighted decision matrix as shown in Table 6.

Then we compute the sum of weighted decision matrix for positive and negative criteria using Eqs. (21 and 22). Then we compute the total score using Eq. (23) as shown in Fig 2. Then we ranked the alternatives as shown in fig 3.

Table 6. The weighted normalization matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.029233	0.003468	0.022763	0.030575	0.002964	0.00253	0.006585
A_2	0.02887	0.002961	0.021316	0.039164	0.003767	0.002037	0.006409
A_3	0.026287	0.003255	0.022763	0.030575	0.003086	0.002347	0.006492
A_4	0.026831	0.003265	0.020384	0.037961	0.003336	0.002507	0.006513
A_5	0.029459	0.003042	0.019034	0.033438	0.003299	0.002488	0.006772
A_6	0.031	0.002926	0.021445	0.038076	0.003645	0.002423	0.005806
A_7	0.030048	0.003549	0.019934	0.036186	0.003682	0.00245	0.007042
A_8	0.027601	0.003509	0.018648	0.036358	0.003379	0.002671	0.007105
A_9	0.028281	0.003144	0.020963	0.034011	0.002842	0.002202	0.007198
A_{10}	0.02393	0.002708	0.020898	0.039164	0.003528	0.002324	0.005547

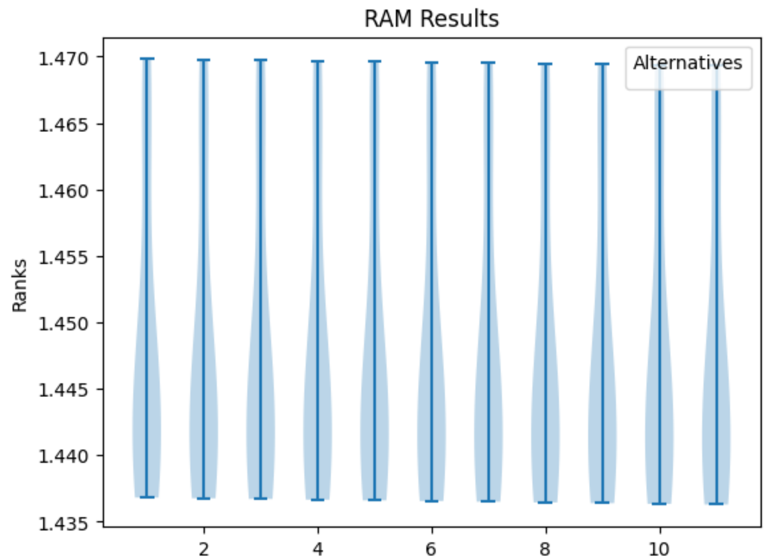

Fig 2. The total score by the RAM method.

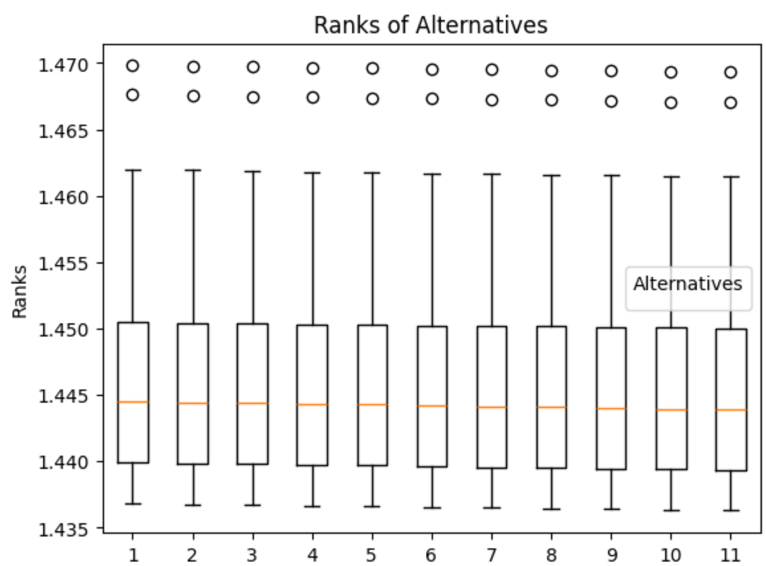

Fig 3. The rank of the alternatives.

Validation of the results

We validated the results of this proposed approach by conducting sensitivity analysis to show the different ranks of alternatives by different criteria weights. We proposed eight cases in the criteria weights. Fig 4. Show the different criteria weights. In each case we increase the criteria weights by the 28% weights and all other criteria have the same weights.

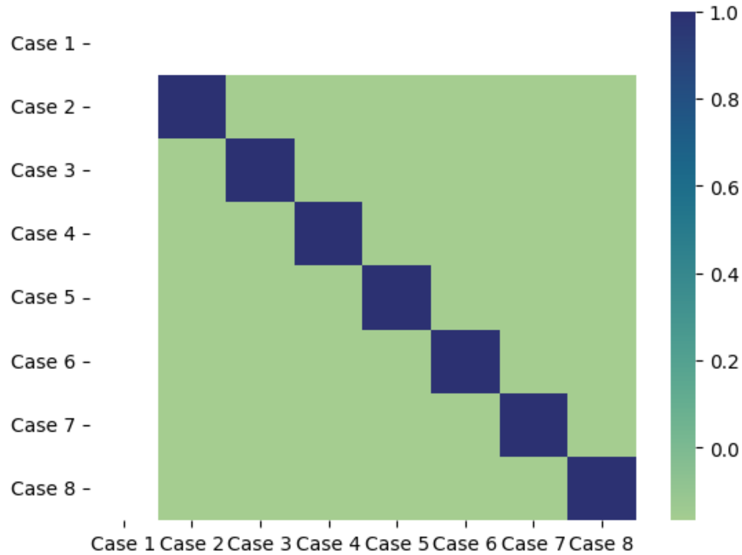

Fig 4. Different criteria weights.

Then we applied the RAM method under different criteria weights. In all cases we compute the rank of alternatives and compute the total score. The total scores of each alternatives with different criteria weights are shown in Fig 5. Then we ranked the alternatives under these criteria weights as shown in Fig 6. The results show the rank of alternatives are stable under different cases.

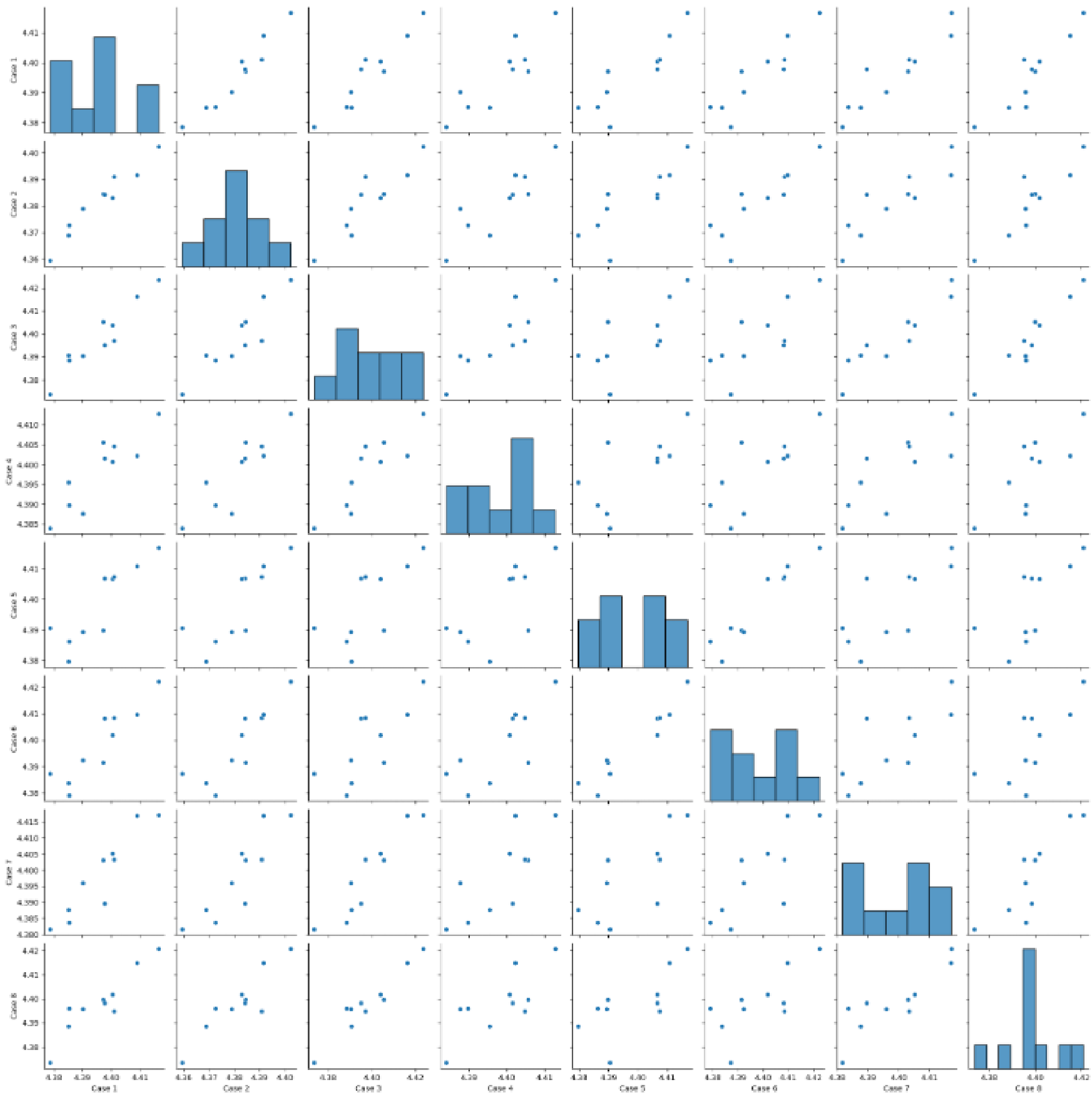

Fig 5. Different total scores of each alternative.

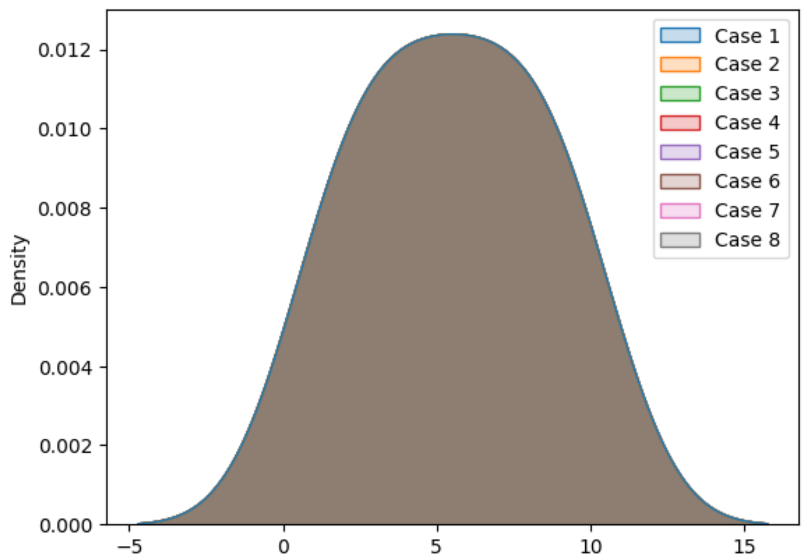

Fig 6. Different ranks of each alternative.

5. Conclusions

This study proposed the MCDM approach to compute the criteria weights and rank the alternatives of multilingual higher education internationalization. We used two methods, ITARA to compute the criteria weights and the RAM methodology to rank the alternatives. These two methods are used under the Probabilistic Simplified Neutrosophic sets to deal with uncertainty and vague information. We used seven criteria and ten alternatives to be evaluated in this study. Three experts evaluate these criteria and alternatives. The sensitivity analysis was conducted with eight cases to show the rank of alternatives. The results show the rank of alternatives is stable in different cases.

References

[1] S. S. Yildiz, "Spatial multi-criteria decision making approach for wind farm site selection: A case study in Balıkesir, Turkey," *Renew. Sustain. Energy Rev.*, vol. 192, p. 114158, 2024.

[2] G. Demir, P. Chatterjee, and D. Pamucar, "Sensitivity analysis in multi-criteria decision making: A state-of-the-art research perspective using bibliometric analysis," *Expert Syst. Appl.*, vol. 237, p. 121660, 2024.

[3] C. Kahraman, "Proportional picture fuzzy sets and their AHP extension: Application to waste disposal site selection," *Expert Syst. Appl.*, vol. 238, p. 122354, 2024.

[4] Y. M. Geremew, W.-J. Huang, and K. Hung, "Fuzzy-set qualitative comparative analysis as a mixed-method and analysis technique: a comprehensive systematic review," *J. Travel Res.*, vol. 63, no. 1, pp. 3–26, 2024.

[5] J. Peng, J. Wang, J. Wang, H. Zhang, and X. Chen, "Simplified neutrosophic sets and their applications in multi-criteria group decision-making problems," *Int. J. Syst. Sci.*, vol. 47, no. 10, pp. 2342–2358, 2016.

[6] F. Altun, R. Şahin, and C. Güler, "Multi-criteria decision making approach based on PROMETHEE with probabilistic simplified neutrosophic sets," *Soft Comput.*, vol. 24, no. 7, pp. 4899–4915, 2020.

[7] K. Gao and F. Yu, "An improved GRA algorithm for teaching quality evaluation of college physical education based on the probabilistic simplified neutrosophic sets," *J. Intell. Fuzzy Syst.*, vol. 45, no. 4, pp. 5199–5210, 2023.

[8] C. Liu, "GRA method for probabilistic simplified neutrosophic MADM and application to talent training quality evaluation of segmented education," *J. Intell. Fuzzy Syst.*, vol. 44, no. 5, pp. 8637–8647, 2023.

[9] A. Khan, U. Ahmad, and S. Shahzadi, "A new decision analysis based on 2-tuple linguistic q-rung picture fuzzy ITARA–VIKOR method," *Soft Comput.*, pp. 1–24, 2023.

[10] H.-W. Lo, C.-C. Hsu, C.-N. Huang, and J. J. H. Liou, "An ITARA-TOPSIS based integrated assessment model to identify potential product and system risks," *Mathematics*, vol. 9, no. 3, p. 239, 2021.

[11] H. Wang and G. Chen*, "Improving computer network security evaluation with grey relational analysis and probabilistic simplified neutrosophic sets," *Int. J. Knowledge-based Intell. Eng. Syst.*, vol. 27, no. 4, pp. 425–436, 2023.

[12] Q. Liu, "Lagrange-enhanced GRA method for probabilistic simplified neutrosophic MADM: Yaozhou porcelain decoration design quality evaluation," *Int. J. Knowledge-based Intell. Eng. Syst.*, vol. 27, no. 3, pp. 331–342, 2023.

[13] V. Simić, B. Milovanović, S. Pantelić, D. Pamučar, and E. B. Tirkolaee, "Sustainable route selection of petroleum transportation using a type-2 neutrosophic number based ITARA-EDAS model," *Inf. Sci. (Ny).*, vol. 622, pp. 732–754, 2023.

[14] P. Liu, Y. Wu, and Y. Li, "Probabilistic hesitant fuzzy taxonomy method based on best–worst-method (BWM) and indifference threshold-based attribute ratio analysis (ITARA) for multi-attributes decision-making," *Int. J. Fuzzy Syst.*, vol. 24, no. 3, pp. 1301–1317, 2022.

[15] A. Sotoudeh-Anvari, "Root Assessment Method (RAM): A novel multi-criteria decision making method and its applications in sustainability challenges," *J. Clean. Prod.*, vol. 423, p. 138695, 2023.

[16] I. M. Hezam, A. M. Ali, K. Sallam, I. A. Hameed, A. Foul, and M. Abdel-Basset, "An Extension of Root Assessment Method (RAM) Under Spherical Fuzzy Framework for Optimal Selection of Electricity Production Technologies Toward Sustainability: A Case Study," *Int. J. Energy Res.*, vol. 2024, no. 1, p. 7985867, 2024.

Received: Sep 3, 2024. Accepted: Feb 9, 2025