A Fuzzy Multicriteria Decision-Making Approach in Higher Education

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Abstract: Higher education has become a competitive service industry, with a booming number of institutes trying to answer the increasing demand for university graduates. While students search for the best, universities are working hard to recruit a larger number of them. It is hardly possible to identify the particular factor(s) that make students select a specific university. Because students select universities based on multiple factors of different weights, a multicriteria decision-making approach is required. Therefore, as a first attempt in the literature, this paper has employed Fuzzy TOPSIS to evaluate the performance of universities in implementing student-recruitment activities based on the selection criteria valued by applicants. Since the available information in such an area is incomplete, and especially because the higher education industry is people-based, Fuzzy TOPSIS enables both students and higher education authorities, as well as their marketing managers, to maximize the efficiency of their decisions. The proposed approach comprises three main steps: i) criteria are listed; ii) linguistic terms are allocated to criteria and alternatives (universities); iii) the fuzzy TOPSIS approach, represented by a numerical application, is applied. The proposed approach benefits practicality in generating the best decisions under uncertainty.

Keywords: Fuzzy theory, Fuzzy TOPSIS, Multicriteria decision-making, Higher education

1. INTRODUCTION

Globalization has penetrated every aspect of our life, even in education, and has created phenomenal repercussions, including new features in the global flow of students [1]. Students are exploring the 'best' destinations in search of institutes where they can receive a quality education. As suggested by Wilkins and Huisman [2], the search for the best higher education institute (HEI) by study-abroad applicants has boosted the competition among HEIs in recruiting more international students.

To progress, learning about the reasons that may lead to student recruitment is crucial. The commonly cited factors that impact students' university choices are listed in Table I. Higher education is 'people-based' and is currently considered an industry with all characteristics of a service industry [16]. The approach of 'student as a customer' [17], [18] is more valued than before; therefore, considering applicants' HEI choices has become one of the most critical requirements for higher education management teams. However, due to the complex nature of human decisions and the extensive number of elements considered by decision-makers, it is impossible to pinpoint specific factors they take into account while making a decision. In return, it is thus impossible to easily determine a particular alternative out of a number of potential ones.

TABLE I. Motivation to study-abroad factors

Factors	Authors
Quality of education (standard, recognition, reputation, accreditation)	[3], [4], [5], [6]
Influence of others (family, spouse, friends)	[7], [3], [8], [9]
Political/governmental policy (visa, residency permit)	[10], [8]
Geographical location / proximity	[7], [11], [9], [12]
University specific (medium of instruction, campus, safety, services)	[10], [7], [13], [12] [14]
Monetary (tuition fee, living expenses, accommodation)	[7], [15], [4], [9]
Safety (hosting city / community)	[15], [8], [13]

Therefore, scholars and researchers use multicriteria decision-making (MCDM) methods [19], [20], [21]. MCDM methods have been used to find a solution for the problems regarding sorting or ranking the potential alternatives as well as selecting the best alternative out of a group of possibilities [22]. One of the successful MCDM methods is TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) which was introduced by Hwang and Yoon [23]. TOPSIS has been widely used in many real-world issues and challenges due to its simplicity, comprehensive mathematical concept, and computational efficiency [22].

The methods of MCDA are improved and modified successfully by combining with fuzzy set theory [24], [25] to deal with and manage uncertainty and to address problems when knowledge is not complete [26], [27]. When holding comprehensive knowledge is impossible, fuzzy set theory is applied to describe complexity, uncertainty, and ambiguity valid to decision-making processes [28]. The combination with fuzzy set theory improves the TOPSIS to solve imprecise and uncertain issues [29]. A fuzzy TOPSIS has been efficiently employed in various fields, namely Design, Engineering, and Manufacturing Systems [30], [31], [32]; Supply Chain Management and Logistics [33], [34]; Health, Safety and Environment Management [35], [36], [37]; Business and Marketing Management [38], [39], [40], [41]; Energy Management[42]; Chemical Engineering [43], [44]; Human Resources Management [45], [46], [47]; and Water Resources Management [48], [49].

However, despite the complexity of decisions made by higher education applicants and authorities, no study has attempted to propose a systematic framework by employing fuzzy techniques. As shown in Table I, the number of elements respected by applicants in selecting a university is immense. In addition, the factors are varied in nature and are not weighted equally by the students. It is also impossible for university authorities to select specific elements to plan their student recruitment policies accordingly.

As a first attempt in the literature, this study thus proposes employing the fuzzy TOPSIS technique to assess the performance of higher education institutes in addressing the criteria respected by applicants to select a university among the list of possible alternatives. In other words, considering the number of factors involved, this study formulates the evaluation of HEIs as an MCDM problem.

The paper is structured into six sections. After the introduction, preliminaries are defined in Section 2. Section 3 explains the fuzzy TOPSIS method. Section 4 displays the application of the method to evaluate the performance of HEIs. Section 5 is devoted to the conclusion and discussion. The last section describes the limitations and provides recommendations.

2. Preliminaries

Definition 1: Let $\Omega = \{x_1, x_2, \ldots, x_n\}$ be the universal set. A fuzzy set $\tilde{A}$ is defined as follows:

$$\tilde{A} = \{(x, \mu_{\tilde{A}(x)}) | x \in \Omega\} \tag{1}$$
$$\mu_{\tilde{A}} : \Omega \longrightarrow [0, 1]$$

Definition 2: Membership function (MF) is a map that associates each element in Ω to a real number in $[0, 1]$. The "degree of membership" is the value of MF.

Definition 3: Let $\alpha = (\alpha_1, \alpha_2, \alpha_3)$ be a triangular fuzzy number (TFN), its MF is given by

$$\mu_{\tilde{\alpha}}(x) = \begin{cases} 0, & x \le \alpha_1, \\ \frac{x - \alpha_1}{\alpha_2 - \alpha_1}, & \alpha_1 \le x \le \alpha_2, \\ \frac{\alpha_3 - x}{\alpha_3 - \alpha_2}, & \alpha_2 \le x \le \alpha_3, \\ 0, & x > \alpha_3 \end{cases} \tag{2}$$

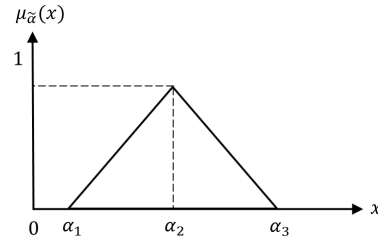Figure 1 demonstrates $\tilde{\alpha}$ and $\mu_{\tilde{\alpha}}(x)$.

Figure 1. Triangular fuzzy number $\tilde{\alpha}$

Definition 4: Assume $\tilde{\alpha} = (\alpha_1, \alpha_2, \alpha_3)$ and $\tilde{\beta} = (\beta_1, \beta_2, \beta_3)$ are two TFNs. We can have the following operations: Multiplication:
$\tilde{\alpha} \times \tilde{\beta} = (\alpha_1 \times \beta_1, \alpha_2 \times \beta_2, \alpha_3 \times \beta_3)$
$q\tilde{\alpha} = (q\alpha_1, q\alpha_2, q\alpha_3); \quad q \in \mathbb{R}, q \ge 0$
Addition:
$\tilde{\alpha} + \tilde{\beta} = (\alpha_1 + \beta_1, \alpha_2 + \beta_2, \alpha_3 + \beta_3)$
Subtraction:
$\tilde{\alpha} - \tilde{\beta} = (\alpha_1 - \beta_1, \alpha_2 - \beta_2, \alpha_3 - \beta_3)$
Distance between $\tilde{\alpha}$ and $\tilde{\beta}$:
$d(\tilde{\alpha}, \tilde{\beta}) = \sqrt{\frac{1}{3}[(\alpha_1 - \beta_1)^2 + (\alpha_2 - \beta_2)^2 + (\alpha_3 - \beta_3)^2]}$
Division:
$\tilde{\alpha}/\tilde{\beta} = (\alpha_1/\beta_1, \alpha_2/\beta_2, \alpha_3/\beta_3)$
$\tilde{\alpha}/q = (\alpha_1/q, \alpha_2/q, \alpha_3/q); \quad q \in \mathbb{R}, q \ge 0$
$q/\tilde{\alpha} = (q/\alpha_1, q/\alpha_2, q/\alpha_3); \quad q \in \mathbb{R}, q \ge 0$

Definition 5: A matrix with at least one fuzzy number element is referred to as a fuzzy matrix.

Definition 6: Values of linguistic variables are determined by linguistic terms. The linguistic terms are converted into fuzzy numbers using conversion scales.

3. Fuzzy TOPSIS

In a fuzzy TOPSIS approach, fuzzy evaluations of alternatives and criteria are used. Considering the difficulty of measuring an alternative's performance precisely, employing a fuzzy approach allows one to assign relative importance to attributes for real-world situations [50], [51]. Chen proposed the Fuzzy TOPSIS approach for solving multicriteria decision-making issues under uncertainty [52].

Fuzzy TOPSIS distinguishes between two criteria categories, such as "Benefit" and "Cost" factors, then picks alternatives close to positive ideal solutions and distant from negative ones. In this approach, n decision-makers D_k $(k = 1, 2, \ldots, n)$ employ linguistic variables to assess alternatives under each criterion.

The fuzzy TOPSIS takes the following 9 steps:

Step 1: Ratings are assigned to the alternatives and criteria.

Let $A = \{A_1, A_2, \ldots, A_j\}$, $(j = 1, 2, \ldots, n)$ be the set of alternatives and $C = \{Cra_1, Cra_2, \ldots, Cra_m\}$ be the set of criteria. The weights of the Cra_i are indicated by w_i, $i = 1, 2, \ldots, m$. Decision-makers (D_k) rate the performance of each (A_j) with respect to (Cra_i) indicated by $\tilde{R}_k = \tilde{x}_{ijk}$ with MF $\mu_{\tilde{R}_k}(x)$.

Step 2: The weight of criteria is Aggregated.

Let $\tilde{R}_k = (a_k, b_k, c_k)$ be the transformed ratings given by the decision-makers team (D_k) to TFNs. We have $\tilde{R} = (a, b, c)$ as aggregated fuzzy rating and define as follows:

$$a = \min_k\{a_k\}, \ b = \frac{1}{K}\sum_{k=1}^{K} b_k,$$
$$c = \max_k\{c_k\}, \ k = 1, 2, \ldots, K \quad (3)$$

Assume $\tilde{x}_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk})$ is the fuzzy rating and $\tilde{w}_{ijk}$ is the importance weight of the kth decision-makers where $\tilde{w}_{ijk} = (w_{jk1}, w_{jk2}, w_{jk3})$. We have $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ as aggregated fuzzy ratings of alternatives (A_j) for each criterion (Cra_i) and define as follows:

$$a_{ij} = \min_k\{a_{ijk}\}, \ b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ijk}, \ c_{ij} = \max_k\{c_{ijk}\} \quad (4)$$

Let $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ be the aggregated fuzzy weights of each (Cra_i). The $\tilde{w}_j$ are found as follows:

$$w_{j1} = \min_k\{w_{jk1}\}, \ w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{jk2}, \ w_{j3} = \max_k\{w_{jk3}\} \quad (5)$$

Step 3: The fuzzy decision matrix is computed.

The construction of the matrix $(\tilde{D})$ which is for the alternatives is as follows:

$$\tilde{D} = \begin{pmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \ldots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \ldots & \tilde{x}_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \ldots & \tilde{x}_{mn} \end{pmatrix} \ i, j = 1, 2, \ldots, m, n \quad (6)$$

The matrix $(\tilde{W})$ for the criteria is formed by:

$$\tilde{W} = (\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n). \quad (7)$$

Step 4: The fuzzy decision matrix is normalized.

The matrix $\tilde{R}$ is defined as follows:

$$\tilde{R} = [\tilde{r}_{ij}]_{m \times n}, \quad i, j = 1, 2, \ldots, m, n; \quad (8)$$

Based on the category of the criteria, which can be "Benefit" or "Cost", the calculation of $\tilde{r}_{ij}$ is done with a different formula. When the criteria is in the "Benefit" category, $\tilde{r}_{ij}$ calculates as:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), \quad c_j^* = \max_i c_{ij} \quad (9)$$

When the criteria is in the "Cost" category, $\tilde{r}_{ij}$ calculates

as:

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), \quad a_j^- = \min_i a_{ij} \quad (10)$$

Step 5: The weighted normalized matrix is computed.

The matrix $\tilde{V}$ for criteria is defined as follows:

$$\tilde{V} = [\tilde{v}_{ij}]_{m \times n}, \quad i, j = 1, 2, \ldots, m, n \quad (11)$$

To calculate $\tilde{v}_{ij}$ we have the following:

$$\tilde{v}_{ij} = \tilde{r}_{ij}(.)\tilde{w}_j, \quad (12)$$

Step 6: The fuzzy positive ideal solution (FPIS, A^*) and fuzzy negative ideal solution (FNIS, A^-) are computed.

(FPIS, A^*) is computed by:

$$(\text{FPIS}, A^*) = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*) \quad (13)$$

In the Eqn. (13), $\tilde{v}_j^*$ is given by

$$\tilde{v}_j^* = \max_i\{v_{ij3}\} \quad i, j = 1, 2, \ldots, m, n$$

(FNIS, A^-) is computed by:

$$(\text{FNIS}, A^-) = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-) \quad (14)$$

In the Eqn. (14), $\tilde{v}_j^-$ is given by

$$\tilde{v}_j^- = \min_i\{v_{ij1}\} \quad i, j = 1, 2, \ldots, m, n$$

Step 7: The distance of each alternative from (FPIS, A^*) and (FNIS, A^-) are computed.

(d_i^*) is given by:

$$d_i^* = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^*), \quad i = 1, 2, \ldots, m \quad (15)$$

(d_i^-) is given by:

$$d_i^- = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^-), \quad i = 1, 2, \ldots, m \quad (16)$$

Step 8: A closeness coefficient is calculated.

The closeness coefficient represented by (CC_i) shows the distances to the (FPIS, A^*) and (FNIS, A^-) for each alternative. The value of CC_i is computed as follows:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \quad i = 1, 2, \ldots, m. \quad (17)$$

Step 9: The ranking of the alternatives is determined.

In the last step, the potential alternatives are ranked based on their value of CC_i.

4. Fuzzy TOPSIS in Evaluating the Performance of HEIs

In this paper, to assess the efficiency of HEIs, a fuzzy TOPSIS method was developed. Four potential alternatives (HEIs) were assessed against different criteria. The

TABLE II. Criteria for selecting HEIs

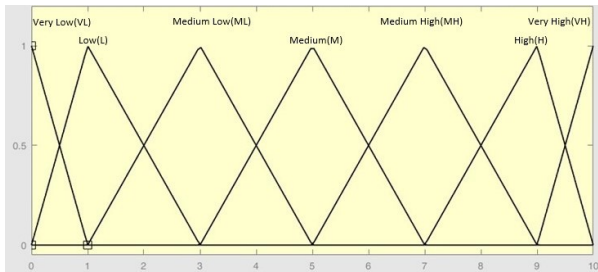| Criteria	Definition	Category
Cra_1: University reputation	Academic reputation of faculty members	+
Cra_2: Admission criteria	The required documents and acceptance rate	+
Cra_3: Education offered	Variety of available programs	+
Cra_4: Affordability	Life expenses and/or fees	-
Cra_5: Trust gaining Policy	Information accessible to candidates to reduce decision making risk and anxiety	+
Cra_6: Employability rate	Reputation of the university in employability during/after studies	+
Cra_7: Life Quality during the education	Extra curricular activities	+
Cra_8: Influence of others	Influence of parents, family, and friends	+
Cra_9: Safety	The safety (health and crime rate) of the university and its hosting city/society	+
Cra_{10}: Location	The geographical proximity of the HEI	+
Cra_{11}: Credibility	Recognitions, Accreditations, and Rankings	+
Cra_{12}: Ease of communication	Variety of Communication channels and their user-friendliness	+
Cra_{13}: Promotion Policy	Promotion strategy and materials	+
Cra_{14}: Internationality	Number of international students/staff	+
Cra_{15}: Medium of Instruction	Official language of the university	+
Cra_{16}: Accommodation Options	Accessible accommodation, their types and cost	-
Cra_{17}: Scholarship and fund	Variety of scholarships and funds offered by the university	+
Cra_{18}: Transportation	The quality and variety of vehicles accessible to students for on-campus and/or in city transportation	+
Cra_{19}: Campus	The size, greenness, and services provided on the campus	+
Cra_{20}: Quality of Education	The quality of education offered by the HEI	+
Cra_{21}: Covid related measures	The measures universities have employed against the COVID-19 pandemic	+

Benefit: "+"
Cost : "-"
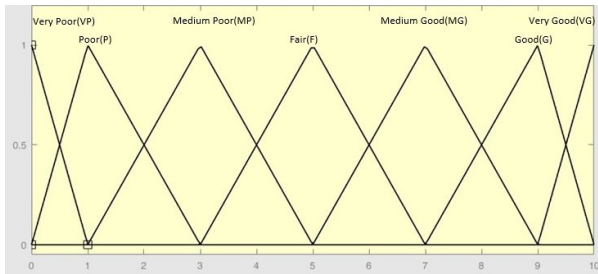

Figure 2. Rating scale for alternatives

Figure 3. Rating scale for criteria

assessment was carried out in accordance with linguistic terms given by decision-makers. The decision-makers were experts in HEIs. The rating scale and linguistic terms for the alternatives and criteria are demonstrated in Figures 2 and 3, respectively.

Asking the opinion of experts and with reference to the current literature, twenty-one factors have been chosen to form the list of criteria. It needs to be highlighted that considering the COVID-19 outbreak, the measures HEIs have taken against this pandemic are also included in the list of criteria. The criteria are classified into "Benefit" and "Cost" categories.

A. Numerical Example

In the proposed approach for evaluating the performance of HEIs in recruiting students, three decision-makers (D_1, D_2, D_3) from the field used linguistic terms presented in Figure 2, to rate alternatives against each criterion (Table III). The alternatives are represented as A_1, A_2, A_3, and A_4.

The criteria are represented as Cra_1, Cra_2, Cra_3, ..., Cra_{21} and are listed in Table II. By using the linguistic terms in Figure 3, the decision-makers assessed the significance of each criterion (Table IV). To create a fuzzy decision matrix (Table V), linguistic variables were converted into TFNs. The next step was to find each criterion's $\tilde{w}_j$ using Eqn. (5). For instance, for the first criterion (Cra_1), we have

$$w_{j1} = \min_k(7,5,7), \qquad w_{j2} = \frac{1}{3}\sum_{k=1}^{3}(9+7+9),$$

$$w_{j3} = \max_k(10,9,10)$$

Therefore, $\tilde{w}_j = (5, 8.33, 10)$.

In the same way, $\tilde{w}_j$ is calculated for the rest of the criteria (Cra_2 to Cra_{21}) as illustrated in Table V.

Then, using Eqn. (4), the aggregate fuzzy weights ($\tilde{x}_{ij}$) of the alternatives (A_j) were calculated. For instance, the aggregate rating for the first HEI (A_1) against criterion (Cra_1) was calculated as follows:

$$a_{ij} = \min_k(9,5,7)$$

$$b_{ij} = \frac{1}{3}\sum_{k=1}^{3}(10+7+9)$$

$$c_{ij} = \max_k(10,9,10)$$

TABLE III. Linguistic evaluations for HEIs

Criteria	HEIs											
	A_1			A_2			A_3			A_4		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
Cra_1	(V-G)	(M-G)	(G)	(F)	(F)	(P)	(M-G)	(F)	(F)	(F)	(F)	(F)
Cra_2	(G)	(G)	(V-G)	(P)	(V-G)	(M-G)	(P)	(V-G)	(G)	(M-G)	(G)	(G)
Cra_3	(G)	(G)	(G)	(M-P)	(P)	(P)	(M-P)	(F)	(P)	(M-G)	(M-G)	(F)
Cra_4	(F)	(F)	(M-G)	(V-G)	(G)	(G)	(G)	(G)	(G)	(M-G)	(M-G)	(M-G)
Cra_5	(V-G)	(G)	(M-G)	(M-P)	(F)	(F)	(M-P)	(F)	(F)	(M-G)	(F)	(M-G)
Cra_6	(M-G)	(M-G)	(G)	(P)	(P)	(P)	(P)	(M-P)	(M-P)	(F)	(F)	(F)
Cra_7	(V-G)	(M-G)	(G)	(F)	(F)	(P)	(F)	(M-G)	(M-G)	(F)	(F)	(F)
Cra_8	(G)	(F)	(G)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)
Cra_9	(G)	(G)	(V-G)	(M-G)	(F)	(M-P)	(M-G)	(M-G)	(M-G)	(G)	(G)	(G)
Cra_{10}	(G)	(G)	(V-G)	(F)	(F)	(F)	(G)	(G)	(G)	(F)	(F)	(F)
Cra_{11}	(V-G)	(G)	(G)	(F)	(M-P)	(M-P)	(F)	(F)	(F)	(M-G)	(M-G)	(M-G)
Cra_{12}	(V-G)	(V-G)	(G)	(G)	(M-G)	(M-G)	(M-G)	(F)	(M-G)	(F)	(F)	(F)
Cra_{13}	(G)	(G)	(M-G)	(M-G)	(F)	(M-G)	(M-G)	(F)	(F)	(M-P)	(F)	(F)
Cra_{14}	(V-G)	(G)	(G)	(G)	(M-G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)
Cra_{15}	(V-G)	(G)	(V-G)	(G)	(G)	(F)	(G)	(G)	(F)	(G)	(G)	(G)
Cra_{16}	(V-G)	(V-G)	(V-G)	(F)	(F)	(F)	(G)	(M-G)	(F)	(G)	(M-G)	(M-G)
Cra_{17}	(M-G)	(G)	(M-G)	(G)	(G)	(V-G)	(G)	(G)	(G)	(M-G)	(G)	(G)
Cra_{18}	(G)	(G)	(G)	(G)	(F)	(P)	(M-G)	(M-G)	(M-G)	(F)	(F)	(F)
Cra_{19}	(V-G)	(V-G)	(V-G)	(M-G)	(M-G)	(G)	(M-G)	(M-G)	(M-G)	(M-G)	(M-G)	(M-G)
Cra_{20}	(G)	(V-G)	(V-G)	(M-G)	(M-P)	(P)	(F)	(F)	(P)	(M-G)	(G)	(G)
Cra_{21}	(V-G)	(V-G)	(G)	(M-G)	(F)	(P)	(F)	(M-G)	(P)	(F)	(M-G)	(M-G)

TABLE IV. Linguistic evaluations for criteria

Criteria	D_k		
	D_1	D_2	D_3
Cra_1	(H)	(M-H)	(H)
Cra_2	(H)	(H)	(V-H)
Cra_3	(V-H)	(H)	(H)
Cra_4	(V-H)	(V-H)	(H)
Cra_5	(V-H)	(V-H)	(M-H)
Cra_6	(V-H)	(M)	(M)
Cra_7	(M-H)	(M)	(M)
Cra_8	(M-H)	(M)	(H)
Cra_9	(H)	(M)	(H)
Cra_{10}	(H)	(M)	(M)
Cra_{11}	(M-H)	(M-H)	(H)
Cra_{12}	(M-H)	(H)	(H)
Cra_{13}	(M)	(M-H)	(M-H)
Cra_{14}	(M)	(H)	(H)
Cra_{15}	(H)	(H)	(H)
Cra_{16}	(M-H)	(H)	(V-H)
Cra_{17}	(H)	(H)	(V-H)
Cra_{18}	(L)	(M)	(H)
Cra_{19}	(M)	(M-H)	(V-H)
Cra_{20}	(M-H)	(H)	(H)
Cra_{21}	(L-M)	(M)	(H)

TABLE V. Aggregate fuzzy criteria weight

Criteria	D_k			$\tilde{w}_j$
	D_1	D_2	D_3	
Cra_1	(7,9,10)	(5,7,9)	(7,9,10)	(5,8.33,10)
Cra_2	(7,9,10)	(7,9,10)	(9,10,10)	(7,9.33,10)
Cra_3	(9,10,10)	(7,9,10)	(7,9,10)	(7,9.33,10)
Cra_4	(9,10,10)	(9,10,10)	(7,9,10)	(7,9.67,10)
Cra_5	(9,10,10)	(9,10,10)	(5,7,9)	(5,9,10)
Cra_6	(9,10,10)	(3,5,7)	(3,5,7)	(3,6.67,10)
Cra_7	(5,7,9)	(3,5,7)	(3,5,7)	(3,5.67,9)
Cra_8	(5,7,9)	(3,5,7)	(7,9,10)	(3,7,10)
Cra_9	(7,9,10)	(3,5,7)	(7,9,10)	(3,7.67,10)
Cra_{10}	(7,9,10)	(3,5,7)	(3,5,7)	(3,6.33,10)
Cra_{11}	(5,7,9)	(5,7,9)	(7,9,10)	(5,7.67,10)
Cra_{12}	(5,7,9)	(7,9,10)	(7,9,10)	(5,8.33,10)
Cra_{13}	(3,5,7)	(5,7,9)	(5,7,9)	(3,6.33,9)
Cra_{14}	(3,5,7)	(7,9,10)	(7,9,10)	(3,7.67,10)
Cra_{15}	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)
Cra_{16}	(5,7,9)	(7,9,10)	(9,10,10)	(5,8.67,10)
Cra_{17}	(7,9,10)	(7,9,10)	(9,10,10)	(7,9.33,10)
Cra_{18}	(0,1,3)	(3,5,7)	(7,9,10)	(0,5,10)
Cra_{19}	(3,5,7)	(5,7,9)	(9,10,10)	(3,7.33,10)
Cra_{20}	(5,7,9)	(7,9,10)	(7,9,10)	(5,8.33,10)
Cra_{21}	(1,3,5)	(3,5,7)	(7,9,10)	(1,5.67,10)

Therefore, $\tilde{x}_{ij} = (5, 8.667, 10)$. In the same way, $\tilde{x}_{ij}$ were found for all alternatives (A_j) with respect to all criteria (Cra_i) (Table VI).

The next step was to normalize $\tilde{D}$ using Eqns. (8), (9), and (10). For instance, the calculation of the normalized rating for (A_1) against criterion (Cra_1) was:

$$a_j^- = \min_i(5, 0, 3, 3) = 0$$

$$c_j^* = \max_i(10, 7, 9, 7) = 10$$

Considering the category of the (Cra_1) which is the "Benefit", the Eq. (9) was used:

$$\tilde{r}_{ij} = (\frac{5}{10}, \frac{8.667}{10}, \frac{10}{10}) = (0.5, 0.867, 1)$$

In the same way, the values of $\tilde{r}_{ij}$ of all the alternatives for each criterion were calculated (Table VII). To construct the

TABLE VI. Aggregate fuzzy decision matrix for HEIs

Criteria	HEIs			
	A_1	A_2	A_3	A_4
Cra_1	(5,8.667,10)	(0,3.667,7)	(3,5.667,9)	(3,5,7)
Cra_2	(7,9.333,10)	(0,6,10)	(0,6.667,10)	(5,8.333,10)
Cra_3	(7,9,10)	(0,1.667,5)	(0,3,7)	(3,6.333,9)
Cra_4	(3,5.667,9)	(7,9.333,10)	(7,9,10)	(5,7,9)
Cra_5	(5,8.667,10)	(1,4.333,7)	(1,4.333,7)	(3,6.333,9)
Cra_6	(5,7.667,10)	(0,1,3)	(0,2.333,5)	(3,5,7)
Cra_7	(5,8.667,10)	(0,3.667,7)	(1,5,9)	(3,5,7)
Cra_8	(3,7.667,10)	(3,5,7)	(3,5,7)	(3,5,7)
Cra_9	(7,9.333,10)	(1,5,9)	(5,7,9)	(7,9,10)
Cra_{10}	(7,9.333,10)	(3,5,7)	(7,9,10)	(3,5,7)
Cra_{11}	(7,9.333,10)	(1,3.667,7)	(3,5,7)	(5,7,9)
Cra_{12}	(7,9.667,10)	(5,7.667,10)	(3,6.333,9)	(3,5,7)
Cra_{13}	(5,8.333,10)	(3,6.333,9)	(3,5.667,9)	(1,4.333,7)
Cra_{14}	(7,9.333,10)	(5,8.333,10)	(7,9,10)	(7,9,10)
Cra_{15}	(7,9.667,10)	(3,7.667,10)	(3,7.667,10)	(7,9,10)
Cra_{16}	(9,10,10)	(3,5,7)	(3,7,10)	(5,7.667,10)
Cra_{17}	(5,7.667,10)	(7,9.333,10)	(7,9,10)	(5,8.333,10)
Cra_{18}	(7,9,10)	(0,5,10)	(5,7,9)	(3,5,7)
Cra_{19}	(9,10,10)	(5,7.667,10)	(5,7,9)	(5,7,9)
Cra_{20}	(7,9.667,10)	(0,3.667,9)	(0,3.667,7)	(5,8.33310)
Cra_{21}	(7,9.667,10)	(0,4.333,9)	(0,4.333,9)	(3,6.3339)

TABLE VII. Normalized fuzzy decision matrix for HEIs

Criteria	HEIs			
	A_1	A_2	A_3	A_4
Cra_1	(0.5,0.867,1)	(0,0.367,0.7)	(0.3,0.567,0.9)	(0.3,0.5,0.7)
Cra_2	(0.7,0.933,1)	(0,0.6,1)	(0,0.667,1)	(0.5,0.833,1)
Cra_3	(0.7,0.9,1)	(0,0.167,0.5)	(0,0.3,0.7)	(0.3,0.633,0.9)
Cra_4	(0.333,0.529,1)	(0.3,0.321,0.429)	(0.3,0.333,0.429)	(0.333,0.429,0.6)
Cra_5	(0.5,0.867,1)	(0.1,0.433,0.7)	(0.1,0.433,0.7)	(0.3,0.633,0.9)
Cra_6	(0.5,0.767,1)	(0,0.1,0.3)	(0,0.233,0.5)	(0.3,0.5,0.7)
Cra_7	(0.5,0.867,1)	(0,0.367,0.7)	(0.1,0.5,0.9)	(0.3,0.5,0.7)
Cra_8	(0.3,0.767,1)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
Cra_9	(0.7,0.933,1)	(0.1,0.5,0.9)	(0.5,0.7,0.9)	(0.7,0.9,1)
Cra_{10}	(0.7,0.933,1)	(0.3,0.5,0.7)	(0.7,0.9,1)	(0.3,0.5,0.7)
Cra_{11}	(0.7,0.933,1)	(0.1,0.367,0.7)	(0.3,0.5,0.7)	(0.5,0.7,0.9)
Cra_{12}	(0.7,0.967,1)	(0.5,0.767,1)	(0.3,0.633,0.9)	(0.3,0.5,0.7)
Cra_{13}	(0.5,0.833,1)	(0.3,0.633,0.9)	(0.3,0.567,0.9)	(0.1,0.433,0.7)
Cra_{14}	(0.7,0.933,1)	(0.5,0.833,1)	(0.7,0.9,1)	(0.7,0.9,1)
Cra_{15}	(0.7,0.967,1)	(0.3,0.767,1)	(0.3,0.767,1)	(0.7,0.9,1)
Cra_{16}	(0.3,0.3,0.333)	(0.429,0.6,1)	(0.3,0.424,1)	(0.3,0.391,0.6)
Cra_{17}	(0.5,0.767,1)	(0.7,0.933,1)	(0.7,0.9,1)	(0.5,0.833,1)
Cra_{18}	(0.7,0.9,1)	(0,0.5,1)	(0.5,0.7,0.9)	(0.3,0.5,0.7)
Cra_{19}	(0.9,1,1)	(0.5,0.767,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)
Cra_{20}	(0.7,0.967,1)	(0,0.367,0.9)	(0,0.367,0.7)	(0.5,0.833,1)
Cra_{21}	(0.7,0.967,1)	(0,0.433,0.9)	(0,0.433,0.9)	(0.3,0.633,0.9)

$\tilde{v}_{ij}$ for the alternatives using Eqn. (11), the $\tilde{w}_j$ values from the last column of Table V and $\tilde{r}_{ij}$ values from Table VII were used. For instance, for alternative (A_1), the $\tilde{v}_{ij}$ for the first criterion (Cra_1) was calculated as:

$$\tilde{v}_{ij} = (5, 8.33, 10) \ (.) \ (0.5, 0.867, 1) = (2.5, 7.222, 10)$$

In the same way, $\tilde{v}_{ij}$ of all alternatives for the twenty-one criteria were calculated (Table VIII). The next step was calculating (FPIS, A^*) and (FNIS, A^-) using Eqns. (13) and (14) for all alternatives. For instance, for criterion (Cra_1), (FPIS, A^*)=(10, 10, 10, 10) and (FNIS, A^-)=(0, 0, 0, 0). In the same way, (FPIS, A^*) and (FNIS, A^-) were found for the remaining criteria (last two columns of Table VIII).

The next step was calculating $d_v(.)$ of each alternative from (FPIS, A^*) and (FNIS, A^-) using Eqns. (15) and (16). For instance, for alternative (A_1) and criterion (Cra_1), we have the followings:

$$d_v(A_1, A^*) = \sqrt{\frac{1}{3}[(2.5 - 10)^2 + (7.222 - 10)^2 + (10 - 10)^2]}$$
$$= 4.618$$
$$d_v(A_1, A^-) = \sqrt{\frac{1}{3}[(2.5 - 0)^2 + (7.222 - 0)^2 + (10 - 0)^2]}$$
$$= 7.268$$

In the same way, the distances $d_v(A_j, A^*)$ and $d_v(A_j, A^-)$ were calculated (Table IX). Then, d_i^* and d_i^- were calculated

TABLE VIII. Weighted normalized fuzzy decision matrix, (FNIS, A^-) and (FPIS, A^*)

Criteria	HEIs				(FNIS, A^-)	(FPIS, A^*)
	A_1	A_2	A_3	A_4		
Cra$_1$	(2.5,7.222,10)	(0,3.056,7)	(1.5,4.722,9)	(1.5,4.167,7)	(0,0,0,0)	(10,10,10,10)
Cra$_2$	(4.9,8.711,10)	(0,5.6,10)	(0,6.222,10)	(3.5,7.778,7)	(0,0,0,0)	(10,10,10,10)
Cra$_3$	(4.9,8.4,10)	(0,1.556,5)	(0,2.8,7)	(2.1,5.911,9)	(0,0,0,0)	(10,10,10,10))
Cra$_4$	(2.333,5.118,10)	(2.1,3.107,4.286)	(2.1,3.222,4.286)	(2.333,4.143,6)	(2.1,2.1,2.1,2.1)	(10,10,10,10)
Cra$_5$	(2.5,7.8,10)	(0.5,3.9,7)	(0.5,3.9,7)	(1.5,5.7,9)	(0.5,0.5,0.5,0.5)	(10,10,10,10)
Cra$_6$	(1.5,5.111,10)	(0,0.667,3)	(0,1.556,5)	(0.9,3.333,7)	(0,0,0,0)	(10,10,10,10)
Cra$_7$	(1.5,4.911,9)	(0,2.078,6.3)	(0.3,2.833,8.1)	(0.9,2.833,6.3)	(0,0,0,0)	(9,9,9,9)
Cra$_8$	(0.9,5.367,10)	(0.9,3.5,7)	(0.9,3.5,7)	(0.9,3.5,7)	(0.9,0.9,0.9,0.9)	(10,10,10,10)
Cra$_9$	(2.1,7.156,10)	(0.3,3.833,9)	(1.5,5.367,9)	(2.1,6.9,10)	(0.3,0.3,0.3,0.3)	(10,10,10,10)
Cra$_{10}$	(2.1,5.911,10)	(0.9,3.167,7)	(2.1,5.7,10)	(0.9,3.167,7)	(0.9,0.9,0.9,0.9)	(10,10,10,10)
Cra$_{11}$	(3.5,7.156,10)	(0.5,2.811,7)	(1.5,3.833,7)	(2.5,5.367,9)	(0.5,0.5,0.5,0.5)	(10,10,10,10)
Cra$_{12}$	(3.5,8.056,10)	(2.5,6.389,10)	(1.5,5.278,9)	(1.5,4.167,7)	(1.5,1.5,1.5,1.5)	(10,10,10,10)
Cra$_{13}$	(1.5,5.278,9)	(0.9,4.011,8.1)	(0.9,3.589,8.1)	(0.3,2.744,6.3)	(0.3,0.3,0.3,0.3)	(9,9,9,9)
Cra$_{14}$	(2.1,7.156,10)	(1.5,6.389,10)	(2.1,6.9,10)	(2.1,6.9,10)	(1.5,1.5,1.5,1.5)	(10,10,10,10)
Cra$_{15}$	(4.9,8.7,10)	(2.1,6.9,10)	(2.1,6.9,10)	(4.9,8.1,10)	(2.1,2.1,2.1,2.1)	(10,10,10,10)
Cra$_{16}$	(1.5,2.6,3.333)	(2.143,5.2,10)	(1.5,3.714,10)	(1.5,3.391,6)	(1.5,1.5,1.5,1.5)	(10,10,10,10)
Cra$_{17}$	(3.5,7.156,10)	(4.9,8.711,10)	(4.9,8.4,10)	(3.5,7.778,10)	(3.5,3.5,3.5,3.5)	(10,10,10,10)
Cra$_{18}$	(0,4.5,10)	(0,2.5,10)	(0,3.5,9)	(0,2.5,7)	(0,0,0,0)	(10,10,10,10)
Cra$_{19}$	(2.7,7.333,10)	(1.5,5.622,10)	(1.5,5.133,9)	(1.5,5.133,9)	(1.5,1.5,1.5,1.5)	(10,10,10,10)
Cra$_{20}$	(3.5,8.056,10)	(0,3.056,9)	(0,3.056,7)	(2.5,6.944,10)	(0,0,0,0)	(10,10,10,10)
Cra$_{21}$	(0.7,5.478,10)	(0,2.456,9)	(0,2.456,9)	(0.3,3.589,9)	(0,0,0,0)	(10,10,10,10)

TABLE IX. Distance $d_v(A_j, A^-)$ and $d_v(A_j, A^*)$

criteria	$d_v(A_j, A^-)$				$d_v(A_j, A^*)$			
	A_1	A_2	A_3	A_4	A_1	A_2	A_3	A_4
Cra$_1$	7.267	4.410	5.932	4.782	4.618	7.239	5.805	6.199
Cra$_2$	8.163	6.617	6.800	7.588	3.037	6.308	6.172	3.966
Cra$_3$	8.053	3.023	4.353	6.334	3.086	8.089	7.322	5.168
Cra$_4$	4.884	1.389	1.419	2.545	5.248	6.894	6.856	6.030
Cra$_5$	7.013	4.235	4.235	5.782	4.513	6.744	6.744	5.530
Cra$_6$	6.541	1.774	3.023	4.506	5.661	8.872	8.089	6.739
Cra$_7$	5.982	3.830	4.957	4.022	4.932	6.738	6.179	6.081
Cra$_8$	5.853	3.828	3.828	3.828	5.896	6.685	6.685	6.685
Cra$_9$	6.936	5.421	5.854	6.853	4.848	6.661	5.619	4.900
Cra$_{10}$	6.038	3.757	5.980	3.757	5.136	6.795	5.193	6.795
Cra$_{11}$	6.917	3.983	4.257	5.772	4.096	7.093	6.305	5.122
Cra$_{12}$	6.304	5.691	4.848	3.529	3.917	4.806	5.644	6.199
Cra$_{13}$	5.828	4.999	4.900	3.741	4.834	5.517	5.648	6.380
Cra$_{14}$	5.905	5.661	5.824	5.824	4.848	5.332	4.900	4.900
Cra$_{15}$	6.159	5.337	5.337	5.951	3.039	4.900	4.900	3.142
Cra$_{16}$	1.234	5.365	5.071	2.818	7.560	5.316	6.104	6.631
Cra$_{17}$	4.306	4.877	4.769	4.493	4.096	3.037	3.086	3.966
Cra$_{18}$	6.331	5.951	5.575	4.291	6.589	7.217	6.910	7.422
Cra$_{19}$	5.992	5.454	4.811	4.811	4.487	5.520	5.684	5.684
Cra$_{20}$	7.684	5.487	4.410	7.176	3.917	7.053	7.239	4.676
Cra$_{21}$	6.595	5.386	5.386	5.597	5.970	7.255	7.255	6.738
Sum	129.985	96.478	101.570	104.001	100.327	134.070	128.339	118.952

using Eqns. (15) and (16). For instance, for alternative (A_1), the distances d_i^- and d_i^* were calculated as:

$$d_i^- = \sqrt{\frac{1}{3}[(2.5-0)^2 + (7.222-0)^2 + (10-0)^2]}$$

$$+ \sqrt{\frac{1}{3}[(4.9-0)^2 + (8.711-0)^2 + (10-0)^2]}$$

$$+ \sqrt{\frac{1}{3}[(4.9-0)^2 + (8.4-0)^2 + (10-0)^2]}$$

$$+ \ldots + \sqrt{\frac{1}{3}[(0.7-0)^2 + (5.478-0)^2 + (10-0)^2]}$$

$$= 129.985$$

$$d_i^* = \sqrt{\frac{1}{3}[(2.5-10)^2 + (7.222-10)^2 + (10-10)^2]}$$

$$+ \sqrt{\frac{1}{3}[(4.9-10)^2 + (8.711-10)^2 + (10-10)^2]}$$

$$+ \sqrt{\frac{1}{3}[(4.9-10)^2 + (8.4-10)^2 + (10-10)^2]}$$

$$+ \ldots + \sqrt{\frac{1}{3}[(0.7-10)^2 + (5.478-10)^2 + (10-10)^2]}$$

$$= 100.327$$

In the same way, d_i^- and d_i^* were calculated for the
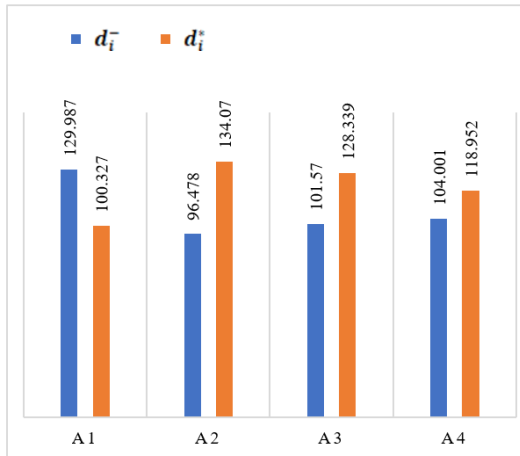
Figure 4. The value of d_i^- and d_i^* for each alternative
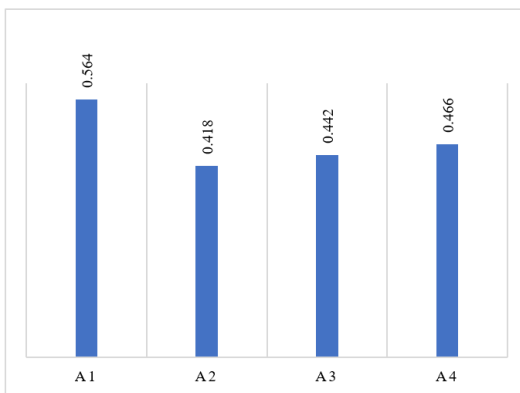

Figure 5. The value of CC_i for each alternative

rest of the alternatives. Figure 4 demonstrates the results. Then, using Eqn. (17), the closeness coefficient (CC_i) was computed. For instance, (CC_1) for alternative (A_1) was computed as follows:

$$CC_1 = d_i^-/(d_i^* + d_i^-) = 129.985/(129.985 + 100.327)$$
$$= 0.564$$

In the same way, CC_i were calculated for the remaining alternatives. Figure 5 exhibits the results. According to the result demonstrated in Figure 5, A_1 with the corresponding value of $CC_1 = 0.564$ is placed on top, followed by $A_4 > A_3 > A_2$. Therefore, it can be concluded that higher education institute (A_1) has the best performance among other potential alternatives.

5. Conclusion and Discussion

Higher education as a service industry is people-based, in which universities and higher education institutes provide educational services to the people, but it is the people who make decisions about what services and which institutes they prefer. Determining what factors lead to a student's selection of a university over other alternatives is a necessity

but hardly possible. It can be deduced that it is impossible to thoroughly judge the efficacy of HEIs' performances in answering the demands of all students through their student recruitment activities. As a result, this decision-making issue should be assessed and well-addressed by adopting some techniques. Therefore, by employing fuzzy TOPSIS, this paper shows a scientific framework to evaluate overall performance and rate the higher education industries.

In the first step, four potential HEIs were selected, then, with reference to the literature as well as collecting experts' opinions, a list of criteria valued by students, consisting of twenty-one items, was formed. In the next step, the experts gave linguistic variables to criteria and alternatives, which were converted to fuzzy numbers. In the last step, the fuzzy TOPSIS approach was applied to analyze the four universities' performance in addressing the criteria.

It was found that alternative A_1, compared to other alternatives, showed the best performance in meeting the decision criteria. Based on the values of the closeness coefficient (CC_i), there is a possibility not only to find the ranking order but to determine the evaluation status of other potential alternatives, which shows the flexibility of the method. Therefore, the suggested method could offer more objective information while selecting and evaluating the higher education institute.

These conclusions prove that the proposed technique might interest educational consultants and higher education policymakers. HEIs policymakers may also use TOPSIS to better understand how their applicants value different criteria while selecting their favorite institute. As a result, they can enhance the efficiency of their policies and use their financial resources more purposefully to attract a larger number of students to their institutes.

6. Limitations and Recommendations

Due to the novelty of this study as a first attempt at using fuzzy TOPSIS in the higher education sector, it was impossible to find similar studies or compare the findings with other papers. In addition, there was no readily accessible list of criteria that higher education applicants respect in selecting a university. Therefore, to find what elements are valued by students, the researcher triangulated the factors mentioned in the literature with the factors considered important by a team of experts.

Considering these limitations, the researcher recommends that other interested scholars employ the proposed technique in similar situations and contexts to enhance the literature. Scholars may use other MCDM techniques else than TOPSIS in higher education contexts to compare their results with the findings of this paper and analyze whether TOPSIS is an optimum technique to evaluate the complexity of decisions students make.

The concept of students as customers has been considered important in the higher education industry; as a

result, marketing departments and their authorities in HEIs are always searching for ways to improve their strategies' efficiency. They may use the proposed approach to evaluate the performance of their marketing activities and customize their marketing strategies according to the values students allocate to different elements and enhance the success and efficiency of their activities.

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