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Improving the Quality of Education in Water Resources Engineering: A Hybrid Fuzzy-AHP-TOPSIS Method

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Abstract. Improving the quality of education in universities can play a prominent role in the development of countries. The purpose of this study is to develop a methodology for assessing the quality of education in Water Resources Engineering, one of the sub-disciplines of Civil Engineering, based on Klein's learning model and using the hybrid fuzzy-AHP-TOPSIS method. Four out of the top ten universities in Iran, including Iran University of Science and Technology (IUST), Amirkabir University of Technology (AUT), Shiraz University (SU), and Khajeh Nasir al-Din Toosi University of Technology (KUT) are considered as case studies. First, the weight coefficients were determined by surveying the students in the fuzzy environment using the AHP method, and then these coefficients were transferred to the TOPSIS environment. Finally, the relative closeness of universities (CC) as a performance evaluation criterion in the form of CC (IUST) = 0.54, CC (AUT) = 0.49, CC (SU) = 0.45, and CC (KUT) = 0.39 were obtained. The sensitivity analysis was performed based on the number and type of Klein's qualitative criteria on the model, and Fourier series expansion curves were used to observe the exact behavior of the model and better compare the results. This model of evaluation can have a considerable influence on the education methods improvement in Civil Engineering departments and related fields.

1 Introduction

Civil Engineering departments have been described as living laboratories or actual testing grounds where novel solutions are created, developed, and evaluated for efficacy before being implemented in full at the level of the community (Awuzie et al., 2021). Among several branches of Civil Engineering, Water Resources Engineering (WRE), mostly dealing with hydrology related courses, is taught in numerous engineering universities around the world because water is an essential resource for humans, ecosystems and economic growth (Fischer and Tatomir, 2022; Ghorbani et al., 2021b; Cullis et al., 2018).

The planning and management of water resources as well as the design and implementation of water projects are only a few of the many areas that WRE addresses. One of the primary factors in raising the standard of WRE instruction in colleges and universities may be the availability of challenges in the field(Kinar, 2021). For instance, in response to the expansion of technology and population, have universities embraced and put into practice effective strategies for managing water resources or maximizing the use of already-existing waters? How to address challenges due to an uneven distribution of water resources across the globe, where some countries have severe water shortages while others experience major flooding? Such queries highlight the need for the establishment of high-quality scientific environments, particularly in the area of WRE. It is believed that top-level education offers a variety of general benefits, including ads and reality, consistency between goals and actions, personal and professional improvement for the student, and changes in behavior (Pond, 2002).

Naveed et al. (2019) identified the most significant success elements in the case of remote learning in Saudi higher education institutions. They validated these characteristics using the combined Content Validity Analysis and Reliability Analysis (CVARA) technique. These components are divided into five groups: student, instructor, design and content, system and technology, and institutional management services.

Makki et al. (2022) planned the enrolment of university students using Goal Programming (GP). They discovered that this technique may be used for various parts of university management, such as human resource planning, teaching load planning, faculty-to-student ratio, accreditation, quality requirements, lab capacity planning, equipment procurement, and financial planning. Many studies have been undertaken on the subject of the efficiency of engineering education, especially Civil Engineering, to solve some of the challenges in universities (Diao and Shih, 2019; Chi et al., 2013). Paul (2015) developed SecondLife, a web-based virtual reality tool for civil and environmental engineering students. This emphasizes the importance of these technical students developing their employment skills from the start of the academic year, concurrent with university instruction, thereby strengthening the university's engagement with industry. Ahammed and Smith (2019) employed SPSS statistical tests to predict students' performance in a three-year course on creating WRE systems at the University of South Australia. They investigated the link between student learn-online engagement and academic success.

Multi-Criteria Decision-Making (MCDM) approach is a prominent way of decision-making in several fields. As one of the MCDM methods, Analytical Hierarchy Process (AHP) is a powerful and straightforward tool that relies on the application of pairwise comparison options of alternatives based on expert assessments to separate and distinguish the problem elements through weighting (Bozorg-Haddad et al., 2021; Piya et al., 2022a; Ghorbani and Hamidifar, 2022). The AHP technique has been employed by Tsinidou et al. (2010)_to determine the relative importance of qualitative elements influencing student satisfaction.

The Technique for Order of Preference to Similarity to Ideal Solution, or simply the TOPSIS method, is another well-known MCDM method employed by many researchers(Shahba et al., 2017; Sirisawat and Kiatcharoenpol, 2018; Piya et al., 2022b). When combined with AHP, the resulting AHP-TOPSIS hybrid approach, gives a robust tool that has gained popularity

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among academics in recent years. To reach that, the AHP model first determines the weights of the given problem criteria, which are then employed in the TOPSIS model to rank the alternatives. İnce and Hakan Isik (2017) employed the AHP-TOPSIS combination to choose learning objects from a variety of objects in web-based educational systems, including texts, data, figures, tables, and so on. Alqahtani and Rajkhan (2020) employed AHP and TOPSIS methods to determine the most beneficial aspects of e-learning during the COVID-19 pandemic.

Fuzzy set theory is a powerful mathematical tool that is widely employed in science. When the data is qualitative, the number of data points is insufficient, the data is insufficiently accurate, or the data is derived from unknown sources, fuzzy ideas can be ideal to find optimal solutions (Ghorbani et al., 2021a). In addition, fuzzy ideas are commonly employed to quantify approximation, experimental, and non-classical events (Hasanzadeh et al., 2020). Because people's emotions are engaged in decision-making in MCDM problems, various levels of vagueness arise in solutions; thus, it is advised that fuzzy concepts should be employed in these problems (Prakash et al., 2015).

Some academics employ MCDM techniques in fuzzy environments to solve engineering challenges, especially in Civil Engineering (Abdel-malak et al., 2017). Although the MCDM approach and its combinations assist decision-makers in ranking and selecting the best alternatives in a variety of situations (Naseem et al., 2021), few studies have been undertaken to use the hybrid fuzzy combination of these methods to address university educational challenges. In other words, in general, fuzzy approaches or MCDM methods have sporadically or inefficiently been used for the quantitative and qualitative evaluation of the teaching and learning of students (Muhammad et al., 2020; Niu et al., 2019).

In this study, the Fuzzy-AHP-TOPSIS approach is employed as a powerful MCDM tool for evaluating the initial data, in which both the weighting of criteria and the ranking of alternatives are obtained via mathematical calculations, and therefore the certainty of solutions in the fuzzy environment is improved. The Klein model (Klein, 1991) is employed to analyze the qualitative components of education and learning. The proposed methodology can be a comprehensive approach to the quality evaluation of teaching and learning in universities in various specialized fields such as WRE. This approach includes diversity in the number and type of criteria, flexibility and high capability in evaluating the criteria, as well as appropriate comprehensiveness. The model was implemented in four famous universities in Iran, and the results were evaluated by changing the number and type of quality criteria for eighteen specific cases. Finally, the results have been analyzed and investigated using the Fourier series expansion. Such analyzes can significantly contribute to better planning and improving the quality of education.

2 Methodology

Based on Klein's learning pattern, nine influential components of learning in educational settings were identified and investigated in this study. These components include aims and objectives, content, learning activities, teacher role, materials and resources, grouping, location, time, and assessment (Klein, 1991; Van den Akker et al., 2006), all of which were easily

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differentiated by students. These elements were researched for four well-known universities in Iran, namely the Iran University of Science and Technology (IUST), the Shiraz University (SU), the Amirkabir University of Technology (AUT), and the Khajeh Nasir al-Din Toosi University of Technology (KUT). All these four universities are on the list of top ten universities in Iran. This study's population consists of WRE students from these four institutions, and referred to the academic year 2020. Questionnaires and interviews were used to collect data. WRE students were asked to complete associated surveys to express their opinions on university quality based on the nine criteria.

2.1 Fuzzy-AHP method

As illustrated in Figure 1, multiple steps are taken to address the problem using the Fuzzy AHP method:

Step 1. First, questionnaires are designed and distributed to specialists based on the problem's criteria and alternatives. The questions should perform well when comparing all the criteria in a separate pairwise way, while keeping the problem's aims in mind. The triangular fuzzy matrix corresponding to the experts' response is then constructed using Chang's development analysis (Chang, 1996), a traditional method like the classical AHP method. The guidelines for constructing this pairwise comparison matrix must be followed (Chang, 1996).

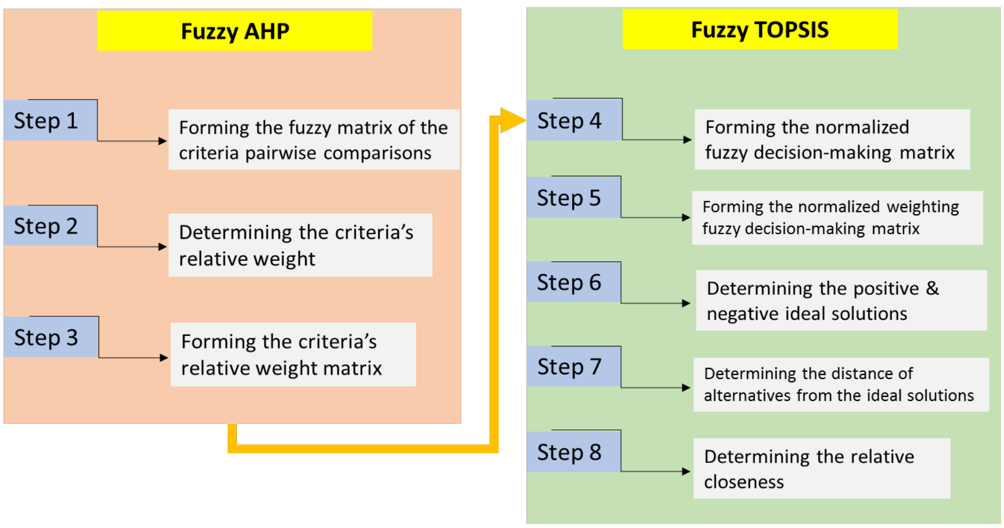

Figure 1. The flowchart of implementing the hybrid Fuzzy AHP-TOPSIS method step by step.

Step 2: Using the fuzzy expansion relationships, calculate the relative weight of the criteria in this step (Naseem et al., 2021).

Step 3: Based on the findings of the previous step, a relative weight matrix of criteria that adhere to the fuzzy rules is created, and this matrix is used in the following phases (Naseem et al., 2021). This matrix has one row and as many columns as there are criteria in the problem.

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2.2 Fuzzy-TOPSIS method

The typical TOPSIS technique attempts to select solutions with the smallest distance from the ideal positive solutions and the greatest distance from the ideal negative solutions at the same time. The ideal positive solutions increase the project's benefit criteria while minimizing its cost criteria, whereas the ideal negative solutions accomplish the opposite. The TOPSIS approach makes full use of provided data and produces a numerical rating of options (Chen and Hwang, 1992).

Step 4: In this step, the same experts who completed the first questionnaire will be given another questionnaire, and they will be asked to score, using numbers between 1 and 9, the quality of education in their university. The description of these numbers can be based on the description supplied in the AHP method's pairwise comparison table. A non-fuzzy decision-making matrix is created after compiling the questionnaire responses. Data normalization techniques and linguistic variable interpretation may be required in particular cases (Chen, 2000).

Step 5. The normalized weighted fuzzy decision matrix is formed in this step using the normalized fuzzy decision matrix from step 4 as well as the fuzzy weight matrix of problem criteria from step 2 (Sirisawat and Kiatcharoenpol, 2018).

Step 6. Fuzzy positive ideal solution ($\widetilde{A}^*$) and fuzzy negative ideal solution ($\widetilde{A}^-$) are calculated.

Step 7. The sum of the distances of the i^{th} alternative from the positive ideal solution in the j^{th} criteria, i.e., d_i^*, and the sum of the distances of the i^{th} alternative from the negative ideal solution in the j^{th} criteria, i.e., d_i^-, are calculated.

Step 8. The relative closeness coefficient (CC_i), that represents the distances to the fuzzy positive-ideal solution (d_i^*) and the fuzzy negative-ideal solution (d_i^-) simultaneously by taking the relative closeness to the fuzzy positive-ideal solution, is calculated based on the following relationship (Alqahtani and Rajkhan, 2020):

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

where CC_i has a value between 0 and 1 according to the above equation. In general, the value of relative closeness will be closer to one if an alternative is closer to the positive ideal solution. Furthermore, one choice with a higher CC_i value is superior to another.

Figure 2 specifies the problem's purpose, qualitative educational criteria based on Klein's model, the alternatives or universities involved in the study, and the instruments required to address the problem using the fuzzy AHP-TOPSIS approach.

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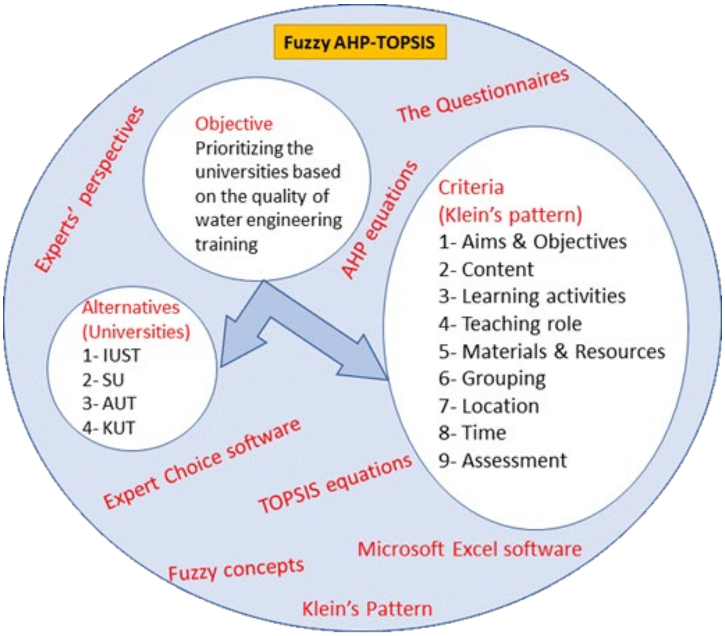

Figure 2. Objective, criteria and alternatives, and needed tools for Fuzzy AHP-TOPSIS method

3 Results and Discussion

Table 1 shows a pairwise comparison of matrix criteria for the AHP method in a triangular fuzzy environment. The mean values were calculated in a defined range limited to 1 to 3.5 in the fuzzy environment. However, in a pairwise comparison using the AHP approach, the numerical values of preferences for crisps often range between 1 and 9 (Piya et al., 2022a). The rules for forming this matrix must be followed precisely; for example, the values on the matrix's main diameter must be (1, 1, 1), the fuzzy triple values of each matrix array must be reversed, and the position of these values relative to each other must be adjusted, and so on. More information on the creation of this matrix may be found elsewhere (for example: Alyamani and Long, 2020; Zavadskas et al., 2020). Table 1 also displays the relative weighted coefficients of criteria for the Fuzzy-AHP approach based on the preceding steps 2 and 3.

Table 2 depicts a decision matrix created in step 4 to be used in the Fuzzy-TOPSIS approach. Initially, the questionnaire was described in crisp terms and on a scale of 1 to 9 based on nine qualitative educational characteristics. Then, it was completed by students from the four universities. After that, the data was entered into this table using statistical procedures such as averaging and bounding the crisp definitive values in a definable fuzzy range (Chen, 2000). Table 2 depicts also the normalized weighted fuzzy decision matrix generated by the fuzzy TOPSIS algorithm in step 5. The values in this table are derived from equations fully defined by previous researchers (Chen, 2000; Sirisawat and Kiatcharoenpol, 2018).

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Table 1 Pairwise comparison matrix and weighting coefficients of criteria in the Fuzzy environment

Criteria	C1 Aims and Objectives	C2 Content	C3 Learning activities	C4 Teaching role	C5 Materials and Resources	C6 Grouping	C7 Location	C8 Time	C9 Assessment
C1	(1, 1, 1)	(1/2, 1, 3/2)	(2, 5/2, 3)	(2/3, 1, 2)	(3/2, 2, 5/2)	(3/2, 2, 5/2)	(2, 5/2, 3)	(1, 3/2, 2)	(1/3, 2/5, 1/2)
C2	(2/3, 1, 2)	(1, 1, 1)	(2/5, 1/2, 2/3)	(2, 5/2, 3)	(3/2, 2, 5/2)	(5/2, 3, 7/2)	(2/3, 1, 2)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)
C3	(1/3, 2/5, 1/2)	(3/2, 2, 5/2)	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/3, 1, 2)	(3/2, 2, 5/2)	(3/2, 2, 5/2)	(2, 5/2, 3)	(1, 3/2, 2)
C4	(1/2, 1, 3/2)	(1/3, 2/5, 1/2)	(3/2, 2, 5/2)	(1, 1, 1)	(3/2, 2, 5/2)	(2, 5/2, 3)	(1/3, 2/5, 1/2)	(2/3, 1, 2)	(3/2, 2, 5/2)
C5	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)	(1/2, 1, 3/2)	(2/5, 1/2, 2/3)	(1, 1, 1)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1, 3/2, 2)	(3/2, 2, 5/2)
C6	(2/5, 1/2, 2/3)	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(1, 3/2, 2)	(1, 1, 1)	(2/3, 1, 2)	(3/2, 2, 5/2)	(2/3, 1, 2)
C7	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(2/5, 1/2, 2/3)	(2, 5/2, 3)	(3/2, 2, 5/2)	(1/2, 1, 3/2)	(1, 1, 1)	(1/2, 2/3, 1)	(3/2, 2, 5/2)
C8	(1/2, 2/3, 1)	(3/2, 2, 5/2)	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1, 3/2, 2)	(1, 1, 1)	(2, 5/2, 3)
C9	(2, 5/2, 3)	(1, 3/2, 2)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)	(1/2, 1, 3/2)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(1, 1, 1)
Weighting coefficients ($\times 10^{-4}$)	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
	(899, 1564, 2653)	(743, 1227, 2167)	(763, 1301, 2211)	(719, 1241, 2122)	(470, 823, 1415)	(482, 831, 1556)	(635, 1116, 1879)	(596, 1032, 1747)	(504, 864, 1459)

Table 2 Decision matrix based on the expert's perspectives for fuzzy TOPSIS method and normalized weighting

	Decision matrix based on the expert's perspectives for Fuzzy TOPSIS method in different universities				Normalized weighting Fuzzy decision-making matrix in different universities			
Criteria	SU	KUT	AUT	IUST	SU	KUT	AUT	IUST
C1	(0, 0.1, 0.3)	(0.1, 0.2, 0.4)	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0, 156, 796)	(90, 313, 1061)	(0, 156, 796)	(90, 469, 1327)
C2	(0, 0.1, 0.2)	(0.1, 0.2, 0.4)	(0.1, 0.2, 0.4)	(0.1, 0.3, 0.5)	(0, 123, 433)	(74, 245, 867)	(74, 245, 867)	(74, 368, 1083)
C3	(0.3, 0.5, 0.7)	(0, 0.1, 0.3)	(0, 0.1, 0.3)	(0.1, 0.2, 0.4)	(229, 651, 1548)	(0, 130, 663)	(0, 130, 663)	(76, 260, 884)
C4	(0.1, 0.2, 0.4)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.4, 0.6, 0.8)	(72, 248, 849)	(216, 620, 1486)	(216, 620, 1486)	(288, 744, 1698)
C5	(0, 0.1, 0.3)	(0, 0.1, 0.2)	(0.2, 0.4, 0.6)	(0.1, 0.2, 0.4)	(0, 82, 424)	(0, 82, 283)	(94, 330, 849)	(47, 165, 566)
C6	(0.1, 0.2, 0.4)	(0.3, 0.5, 0.7)	(0, 0.1, 0.2)	(0, 0.1, 0.3)	(48, 166, 623)	(144, 415, 1090)	(0, 83, 311)	(0, 83, 467)
C7	(0.3, 0.5, 0.7)	(0, 0.1, 0.3)	(0.5, 0.7, 0.9)	(0.1, 0.3, 0.5)	(190, 558, 1315)	(0, 111, 563)	(317, 781, 1691)	(63, 335, 940)
C8	(0.4, 0.6, 0.8)	(0.1, 0.3, 0.5)	(0.1, 0.2, 0.4)	(0.3, 0.5, 0.7)	(238, 619, 1397)	(053, 309, 0875)	(60, 206, 699)	(179, 516, 1223)
C9	(0.2, 0.4, 0.6)	(0.3, 0.5, 0.7)	(0.4, 0.6, 0.8)	(0.1, 0.3, 0.5)	(101, 346, 876)	(151, 432, 1021)	(201, 518, 1167)	(50, 259, 730)

To create a fuzzy AHP-TOPSIS problem, the relative weight coefficients of the problem's criteria generated by the fuzzy AHP technique are combined with the fuzzy matrix values of the fuzzy TOPSIS method via mathematical procedures. The weighted coefficients of the relevance of the criteria and the grading of the importance of universities are thus established statistically, rather than qualitatively, depending on the desired criteria.

Following step 6, the ideal positive and negative solutions to the issue are derived in columns 2 and 3 of Table 3. In addition, the distance of alternatives from these ideal positive and negative values is calculated in columns 4-11 based on qualitative education criteria (Sirisawat and Kiatcharoenpol, 2018; Naseem et al., 2021).

Finally, the relative closeness coefficients for the four universities analyzed are CC(IUST)=0.54, CC(AUT)=0.49, CC(SU)=0.45, and CC(KUT)=0.39. The value of CC is always between 0 and 1. The closer the alternative is to the positive ideal, the closer the relative closeness to 1. As a result, the ranking of universities in terms of qualitative WRE education is IUST>AUT>SU>KUT, with IUST having a higher relative performance.

Following the preceding steps, the proposed problem was calculated for 18 specific situations, and the relative closeness for the criterion and four institutions is shown in Tables 4 and 5. These tables can provide many conclusions, but some of the most significant ones are the following:

- Table 4 shows that while SU University has seen significant quality growth and performs very well with the addition of criterion number 3, it has experienced a loss in quality status based on the relative closeness coefficient with the addition of criterion numbers 4, 5, 6, and 7. Furthermore, when the data in rows 2 and 3 of the table are compared, it is clear that SU university is the only one whose relative proximity has increased with the addition of criterion number 3. In other words, when compared to the other three institutions, the quality status of criterion number three, i.e., Learning activities, has been determined to be very important and effective. This issue is also noticeable in rows 3 and 7 of Table 2.

-The KUT university has the lowest relative closeness for 9 quality criteria, as shown by the last two rows of Table 4. To prevent further decreases in relative closeness, it is advised that this university tighten its requirements for numbers 8, time, and 9, assessment. Other quality criteria should also be taken into account.

-As previously mentioned, the superiority of one alternative over others increases for a given set of criteria as the relative closeness approaches one. In Table 5, the maximum relative closeness is 0.58, while the minimum is 0.30. It is determined that, in the respondents' opinion, university conditions have gotten worse and that all institutions, even prestigious ones, should make plans and try to raise educational standards.

-According to Table 5, the standard deviation of the values for relative proximity is somewhat greater than 0.1 for rows 6 and 9, almost equal to 0.05 (the minimum value) for rows 2 and 5, and ranges from 0.1 to 0.05 in the remaining cases. Accordingly, it can be claimed that eliminating quality criteria 2 and 5 and adding quality criteria 6 and 9 causes the least change in the relative closeness values for each of the four universities. In other words, of the nine quality criteria considered, these four quality characteristics had the most influence on the superiority of institutions over one another based on the relative closeness coefficient.

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Table 3 Fuzzy positive ($\tilde{A}^{*}$) and negative ideal solution ($\tilde{A}^{-}$), and the sum of the distances from the positive (d^{*}) and negative (d^{-}) ideal solution (×10^{-4})

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11
Criteria	$\tilde{A}^{*}$	$\tilde{A}^{-}$	d^{*}(SU)	d^{-} (SU)	d^{*}(KUT)	d^{-} (KUT)	d^{*}(AUT)	d^{-} (AUT)	d^{*}(IUST)	d^{-}(IUST)
C1	(90, 469, 1327)	(0, 156, 796)	359	0	178	185	359	0	0	359
C2	(74, 368, 1083)	(0, 123, 433)	403	0	144	264	144	263	0	403
C3	(229, 651, 1547)	(0, 130, 663)	0	607	607	0	607	0	452	155
C4	(288, 744, 1698)	(72, 248, 849)	581	0	148	434	148	434	0	581
C5	(94, 330, 849)	(0, 82, 283)	289	82	361	0	0	361	191	172
C6	(145, 415, 1090)	(0, 83, 311)	311	188	0	496	496	0	416	90
C7	(317, 781, 1691)	(0, 112, 564)	263	517	779	0	0	779	526	255
C8	(238, 619, 1397)	(60, 206, 699)	0	480	366	117	480	0	122	358
C9	(201, 518, 1167)	(50, 259, 730)	204	102	102	204	0	306	306	0
Sum			2410	1975	2685	1700	2233	2143	2014	2374

-The standard deviation of relative proximity values fluctuates in most rows of Table 5 within a relatively small range of 0.1 to 0.05, indicating that there is intense competition among the four universities for the best academic programs. The probability of changing the preferred universities' rankings and domination over the others in subsequent years is very high. According to the data in this table, institutions are highly competitive, and their relative proximity to one another is changing.

-The IUST university has the lowest and highest values of standard deviation of the data in each column, respectively, of 0.04 and 0.09, according to Table 5 and simple calculations. For the other universities, the standard deviation is roughly 0.05. It can be inferred that IUST University's integrated management for the concurrent control and promotion of the 9 quality criteria is reasonably good and that each of the quality criteria has been thoroughly taken into account. namely, the values assessed for this university's quality criteria are not significantly different, and eliminating each of the quality criteria has no significant impact on this university's superiority over the other three universities. In contrast, some quality standards of AUT University are substantially higher than at other universities, while others are significantly lower.

-When the data in Tables 4 and 5 are compared, it is clear that IUST University is closer to the positive ideal than the other three universities, except for row 4 of Table 5, where SU University has the best performance with a relative closeness of 0.52. This demonstrates that the values chosen for criterion 4, the teaching role, at IUST University are high and significant from the perspective of the competent persons who submitted the surveys. AUT University is in direct competition with IUST University, according to rows 1, 3, and 7 of Table 5.

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Table 4 Final results of model implementation by determining the relative closeness for all 4 universities, when one or more criteria are removed

considered criteria number	The relative closeness of the universities			
	SU	KUT	AUT	IUST
1	0	0.55	0	1
1 and 2	0	0.60	0.40	1
1, 2 and 3	0.44	0.32	0.17	0.67
1, 2, 3 and 4	0.26	0.48	0.38	0.81
1, 2, 3, 4 and 5	0.25	0.42	0.48	0.76
1, 2, 3, 4, 5 and 6	0.27	0.50	0.41	0.68
1, 2, 3, 4, 5, 6 and 7	0.38	0.39	0.52	0.58
1, 2, 3, 4, 5, 6, 7 and 8	0.50	0.30	0.38	0.54
1, 2, 3, 4, 5, 6, 7, 8 and 9	0.45	0.39	0.49	0.54

Table 5 Final results of model implementation by determining the relative closeness for all 4 universities, when only one of the criteria is removed

considered criteria number	The relative closeness of the universities			
	SU	KUT	AUT	IUST
All, except 1	0.50	0.36	0.52	0.50
All, except 2	0.48	0.37	0.48	0.50
All, except 3	0.37	0.45	0.57	0.58
All, except 4	0.52	0.34	0.43	0.46
All, except 5	0.48	0.42	0.44	0.55
All, except 6	0.47	0.30	0.55	0.58
All, except 7	0.46	0.39	0.31	0.53
All, except 8	0.39	0.42	0.54	0.55
All, except 9	0.50	0.30	0.38	0.54

Because relative comparison occurs in MCDM approaches, there is a periodic fluctuation in the results values caused by reducing or increasing one or more criteria. The relative-closeness coefficient is employed in this study for the AHP-TOPSIS approach, which analyzes and evaluates four universities. This characteristic of MCDM approaches allows for the application of Fourier series functions (Dyke, 2014) to determine the significance of criteria and evaluate the situation more clearly. A Fourier series is a periodic function extension in terms of an infinite algebraic sum of sines and cosines functions that forms a link between these two types of trigonometric functions.

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Figure 3 depicts the change in relative-closeness coefficients based on the number of quality criteria for the problem as well as the relative-closeness coefficients as shown in Table 4, except for its first row. It is worth noting that using only one criterion resulted in fitting curves falling down the horizontal axis.

Each curve in Figure 3 corresponds to one of the four chosen universities, hence only a sort of 3rd order Fourier series expansion with a high R-square (from 0.90 to 0.99) is fitted. These curves represent a regular pattern of activity, from which a vast variety of inferences can be inferred, which are briefly discussed below:

-For IUST University, as the number of quality criteria increased, the slope of the curve fell, indicating that the university's performance decreased. One of the reasons is that this university paid close attention to some criteria while paying little attention to others. Another reason for this behavior is the AHP-TOPSIS model's relative comparison of criteria.

-The behavior of the SU and KUT universities is in direct opposition to one another, as seen by this figure, which is also in agreement with Figure 3. That is, students might select one of these two universities based on the importance of their desired criteria.

-The most fluctuations, as shown in the previous figure, occur at AUT University. That is, changing the quantity and kind of quality criteria has a significant impact on the relative-closeness coefficient.

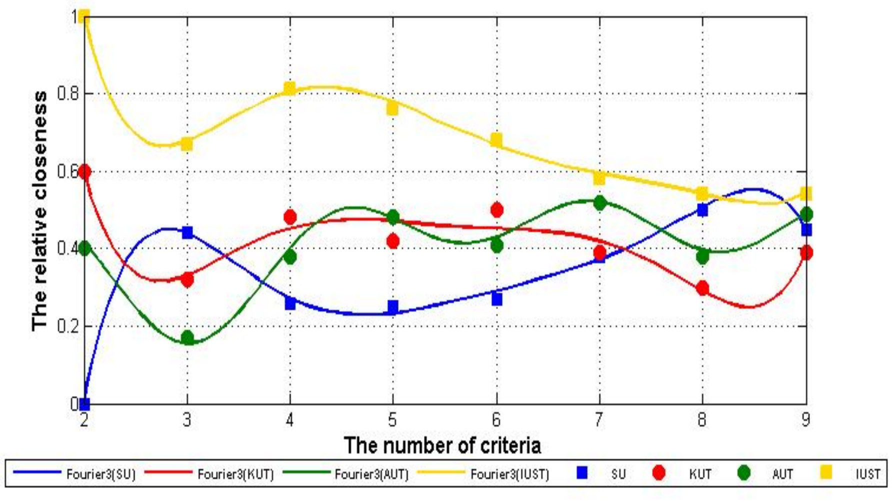

Figure 3. Examining the quality changes of education in four universities in terms of relative-closeness coefficients and the number of criteria considered, according to Table 4.

-The fluctuating trend of the relative-closeness coefficients at AUT University is regular, intense, and has a short-wave height. This ensures that, despite the high sensitivity of the quality criteria, quality control is carried out correctly and on time.

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-The fluctuating pattern of the relative-closeness coefficients is generally mild for SU and KUT universities, with multiple wavelengths but normal wave heights. This is because, practically, all criteria are taken into consideration, although this attention to the criterion is not particularly high. Furthermore, the shifting tendency at these two universities is diametrically opposed because specific criteria in one university receive more attention than in the other.

Figure 4 shows the changes in the relative-closeness coefficients for the removal of only one of the quality criteria (except the removal of criterion 1) for four universities. The curves shown were fitted by second-order Fourier series expansion with a high correlation coefficient between 0.85 and 0.97. This figure leads to the following findings:

-The values on the vertical axis in this figure range from 0.2 to 0.7, while those in Figure 3 range from 0 to 1. This indicates that, in general, the relative-closeness coefficients decrease as the number of criteria increases due to the relative nature of the comparisons and the systematic influence of the criteria on each other.

-The highest and lowest curves generally represent IUST and KUT universities, respectively, and as a result, they have the highest and lowest relative-closeness coefficients.

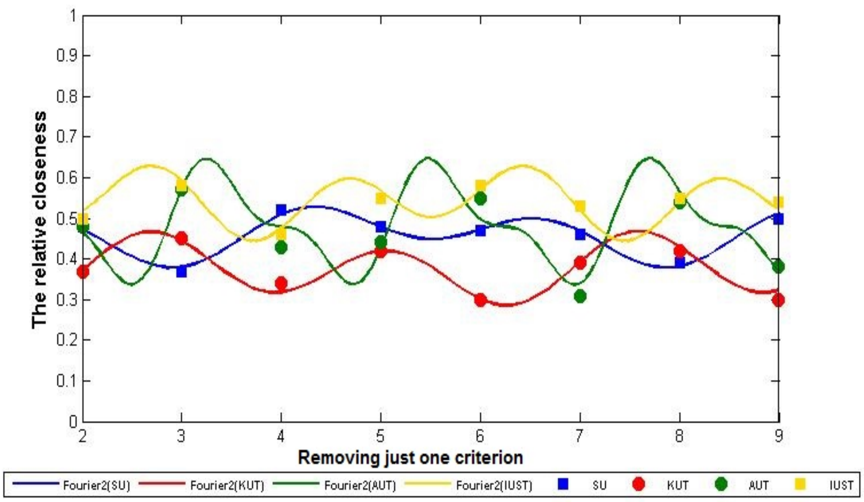

Figure 4. Line graphs for examining the quality changes of education in four universities in terms of relative-closeness coefficients and removing just one criterion, according to Table 5.

4 Conclusions

To compare and evaluate the quality of education in universities, the Fuzzy AHP-TOPSIS approach and Klein's learning model were employed in this study. These two methodologies, when combined, offer a comprehensive and powerful combination that may better evaluate the quality of education in universities from various perspectives. The fuzzy AHP-

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TOPSIS method in multi-criteria decision-making problems emphasizes weighting and fuzzifying criteria with the AHP technique, weighting criteria according to university type with the TOPSIS technique, and finally determining relative-closeness coefficients and prioritizing universities. The educational quality in the subject of Civil Engineering was investigated in four well-known Iranian universities. The study's final findings revealed that the ranking of universities in terms of Water Resources Engineering education quality from the perspective of students in this field in 2020 and for all nine quality parameters is IUST > AUT > SU > KUT. As a result, IUST has superior relative performance.

Furthermore, eighteen other specific situations were explored using different qualitative criteria, two tables, two graphs, and Fourier series expansion. The alternating behavior of the fitted functions indicates several remarkable features that might be investigated and evaluated. It is hoped that future research will look into the quality of education in universities in a broader sense, taking into account additional universities, faculty members, students, and academic subjects. The methodology presented here can be used to assess the quality of Civil Engineering education in various countries to improve the capabilities of graduates while also assisting universities in eliminating weak points and emphasizing good aspects.

Appendices

The questionnaires will be uploaded to an online repository accessible to all.

Data availability

The datasets generated during the current study are available from the corresponding author upon reasonable request.

Author contribution

MKG and NT designed the experiments and MS, SH and FR carried them out. MKG developed the model and performed the simulations. MKG, HH and MN prepared the manuscript with contributions from all co-authors.

Competing interests

The authors declare that they have no conflict of interest. The work of M.N. was supported by a subsidy from the Polish Ministry of Education and Science for the Institute of Geophysics, Polish Academy of Sciences.

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Ethical Statement

The work presented is original. It is in accordance with the ethical principles and the national norms and standards of research in Iran according to approval ID IR.US.PSYEDU.REC.1401.003 issued by the Research Ethics Committees of Shiraz University.

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