

APPLICATION OF FUZZY ANALYTICAL HIERARCHY PROCESS (FAHP) IN THE SELECTION OF STUDY SPACE

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Abstract: *A study space is a location or environment used by a person to carry out learning activities. It can include various places such as bedrooms, libraries, cafes, dormitories, or any place that is suitable for a person to focus on studies. A suitable study space can contribute to the effectiveness of the learning process. Choosing a suitable study space is very important, especially for university students who often face various challenges every semester such as assignments, exams, and presentations. This research introduces a Fuzzy Analytical Hierarchy Process (FAHP) approach to determine the most important criteria and rank four study spaces which are library, study lounges, outdoor study spot, and dormitory rooms among students in Universiti Teknologi MARA Kelantan Branch (UiTMCK). This study was rated for criteria and alternatives by five decision makers using a linguistic scale. The evaluation was conducted based on four main criteria and alternatives. Among the criteria, environmental conditions (C_1) have been identified as the most influential criterion. Meanwhile, the most preferred study space by students is Library (A_1). This research shows the importance of FAHP in resolving complex problems in decision making and supports the formation of a productive and consistent learning routine. For future study, the FAHP can be applied to other fields and combined with other uncertainty theories.*

Keywords: *Fuzzy Analytical Hierarchy Process (FAHP), Multi-Criteria Decision Making (MCDM), Study Space Selection, Higher Education, Learning Environment*

Introduction

A study space is a place where students study, complete assignments, and prepare for exams. A good study space should be quiet, comfortable, organized, and well-equipped with facilities such as internet, proper lighting, and suitable seating. It helps students stay focused, reduce distractions, and study effectively, especially during busy academic periods. A suitable study environment can improve productivity, time management, and the overall learning experience (Beckers et al., 2016; Harrop & Turpin, 2013).

For this reason, study space selection is considered a complex decision widely treated as a multi-criteria decision-making problem, where several alternatives are compared against a structured set of criteria and sub-criteria (Afolayan et al., 2020). According to Koksalan et al. (2013), Multi-Criteria Decision Making (MCDM) refers to the process of selecting the best alternatives based on many criteria. Mrinmoy and Majumder (2015) found that MCDM techniques can assist decision makers in making fair decisions and selecting the best options.

The Analytic Hierarchy Process (AHP) has been extensively used in such various problems because it organizes complex decisions into a hierarchy and derives priorities through pairwise comparison (Yan Liu et al., 2020). However, conventional AHP is based on crisp numerical judgments and is limited when expert opinions are imprecise, incomplete, or expressed linguistically rather than with exact values (Tripathi et al., 2021).

To address this limitation, the Fuzzy Analytical Hierarchy Process (FAHP) combines AHP with fuzzy set theory so that uncertainty and vagueness in human judgment can be represented explicitly during the decision process (Mahad et al., 2019). The FAHP is the method that will be used to identify interrelationships and to determine the important criteria and also to rank the alternatives. This method provides the FAHP employing the triangular fuzzy set in the MCDM technique. It can improve decision-making when experts are unclear or imprecise (Aliyev et al., 2020).

While Multi-Criteria Decision-Making (MCDM) tools like FAHP have been widely implemented in general facility and site selection, existing higher education literature predominantly focuses on formal library evaluations in isolation or traditional crisp AHP. There is a lack of empirical research examining group decision-making across diverse informal and formal campus learning environments (e.g., study lounges, outdoor spots, and dormitory rooms) under fuzzy cognitive uncertainty. This study contributes to the literature by establishing a comprehensive, multi-criteria FAHP framework specifically tailored to student learning space selection, offering actionable data-driven insights for university campus space planners and facility managers.

A triangular fuzzy number is commonly expressed as a triplet representing the lowest possible value, the most probable value, and the highest possible value of a judgment. This form is widely used because it is simple to interpret, computationally practical, and adequate for representing fuzzy linguistic variables in pairwise comparison matrices (Mahad et al., 2019). However, there is limited study used triangular fuzzy number and FAHP in solving selection of study space.

Therefore, this study aims to identify the key criteria influencing study space selection and rank the four alternatives based on those criteria. The application of FAHP in the selection of study spaces is well suited to decision settings where criteria are numerous, judgments are subjective, and precise measurement alone is insufficient. By grounding pairwise comparisons in fuzzy set theory and representing expert opinions with triangular fuzzy numbers, FAHP provides a systematic and transparent basis for identifying and prioritizing the most suitable study space for further analysis.

Literature Review

The selection of study spaces among university students is strongly influenced by amenities and facilities. Amenities like parking, recreational areas, and convenience services are major determinants in the success of public and recreational facilities. Berry et al. (2002) has described a sports center site selection study, arguing that service convenience, ease, and range of amenities is a key motivator for consumers. Helbich et al. (2018) found a strong positive correlation between the availability of amenities (for example, toilets, lighting) and both park satisfaction and use. In MCDM contexts, including amenity related criteria strongly influences decision outcomes, particularly for community-oriented facilities.

Moreover, one of the criteria in choosing a suitable study space is flexibility and availability. Flexibility refers to how well a facility can adapt to changing requirements over time (Castro et al., 2013). According to Read and Meath (2025), design flexibility enhances sustainability and supports future adaptation of healthcare facilities. In historic building management, flexibility is managed through adaptive furniture and future-proofing strategies that reduce structural constraints (Helbich et al., 2018). Similarly, facility management highlights that flexible configurations allow efficient reallocation of space and resources to support evolving functions.

The Analytic Hierarchy Process (AHP) was first introduced by Saaty (1980) and has become the technique most widely used for multi-criteria decision-making problems due to its simplicity, ease of use, great flexibility, and ability to be combined with other methods (Davies, 1994). AHP helps in decision-making by combining perceptions, feelings, judgments, and memories in a structured way (Saaty, 2004). However, traditional AHP is criticized for its inability to handle the inherent uncertainty and vagueness in human cognitive judgments.

To resolve this limitation, Fuzzy AHP is recommended (Chan et al., 2019). FAHP is used when there is a vague perception of making a decision, generalizing crisp theory over fuzzy techniques (Nguyen et al., 2021). FAHP ensures detailed analysis in a complicated and uncertain MCDM environment to improve the reliability of decisions. Lin (2010) addressed website quality evaluation by integrating Triangular Fuzzy Numbers with AHP to develop a fuzzy evaluation model, comparing perspectives of high- and low-experience users across four main criteria and sixteen sub-criteria. Wan Nordin et al. (2023) used FAHP to evaluate online food delivery services (Foodpanda, Grabfood, OdaMakan) based on criteria like Service, Cost, Time, and Quality. Pairwise comparisons from respondents in UiTM Kota Bharu Campus were analyzed using geometric mean, defuzzification, and normalization, ranking Grabfood as the preferred choice. Lastly, Alwedyan (2024) employed AHP to select optimal casual dining restaurant locations using seven criteria and twenty-five sub criteria, identifying costs, location, and traffic patterns as the most influential factors.

In conclusion, FAHP is an appropriate and robust method for evaluating and ranking the alternatives in this study, as it incorporates human judgment vagueness with structural mathematical consistency.

Research Methodology

Hierarchical Model for Study Area Selection

The hierarchical structure of this study consists of the top level, the second level, and the third level, which represent the goal, criteria, and alternatives, respectively. Figure 1 shows hierarchical structure in selection of study space. The first level of the hierarchy represents the overall goal to identify the most suitable study space. Followed by, the second level consists of the criteria used in the decision-making process. Four key criteria representing the primary dimensions of student's evaluation: Environmental Conditions (C_1), Amenities and Facilities (C_2), Capacity and Space Management (C_3), and Flexibility and Availability (C_4). All the criteria are based on studies by Read and Meath (2025), Helbich et al. (2018), Şahin and Yiğider (2014) and Castro et al. (2013). In addition, the third level comprises the alternatives, which are the four most well-known and frequently visited study spaces located in the UiTM Kelantan Branch. These alternatives were selected based on student preferences, popularity, and availability of relevant facilities such as Library (A_1), Study Lounges (A_2), Outdoor Study Spots (A_3), and Dormitory Rooms (A_4) (Beckers et al., 2016; Harrop & Turpin, 2013; Lau & Yang, 2009).

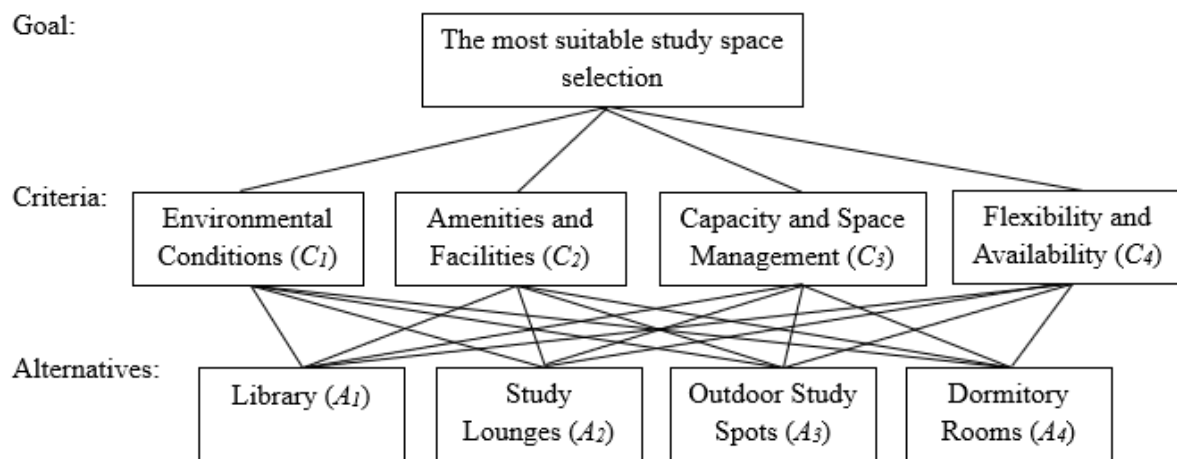


Figure 1: Hierarchical Structure in Selection of Study Area

Participants and Survey Instrument

The questionnaire was distributed to five student decision-makers (DM) from UiTM Kelantan Branch who actively utilize all four alternative study environments.

Fuzzy Analytical Hierarchy Process (FAHP) Mathematical Formulation

The evaluation and ranking of suitable study spaces are structured through eight sequential steps adapted from Biswas et al. (2025) as shown in Figure 2.

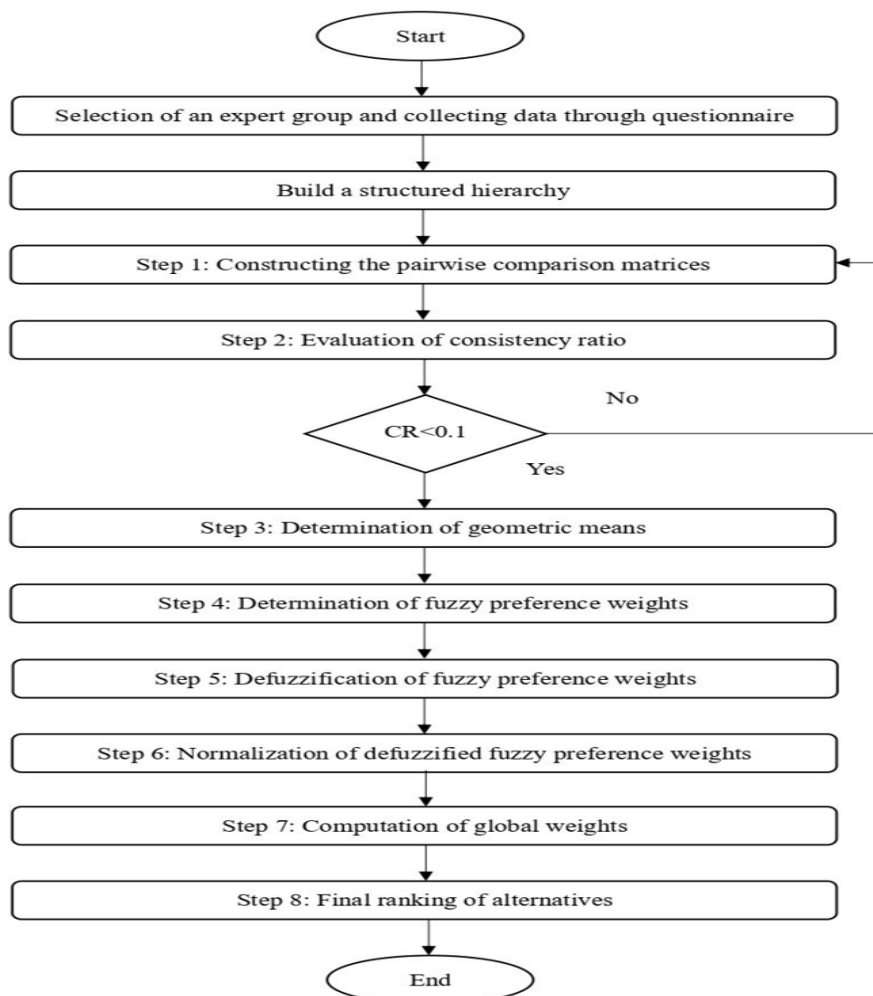


Figure 2: Structured Flowchart for Evaluating and Ranking Suitable Study Spaces

Source: Biswas et al. (2025)

Step 1: Constructing the pairwise comparison matrices.

The important of each criterion and alternatives will be determined by creating the fuzzy pairwise comparison matrix. Linguistic variables were used in this study to allow the decision makers to express their opinion and judgments fully. The matrix was an $n \times n$ real matrix, where n was the number of criteria. Each element of matrix denotes the importance of the i^{th} criterion over the j^{th} criterion.

The comparison of criterion measured according to the numerical scale 1-9 in the form of linguistic variables as shown in Table 1.

Table 1: Triangular Fuzzy Number Scale

Fuzzy Number	Definition	Triangular Scale	Reciprocal TFN
1	Equally Importance	(1,1,1)	(1,1,1)
2	Extremely Low Importance	(1,2,3)	(1/3,1/2,1)
3	Very Low Importance	(2,3,4)	(1/4,1/3,1/2)
4	Low Importance	(3,4,5)	(1/5,1/4,1/3)
5	Slightly Low Importance	(4,5,6)	(1/6,1/5,1/4)

6	Slightly More Importance	(5,6,7)	(1/7,1/6,1/5)
7	High Importance	(6,7,8)	(1/8,1/7,1/6)
8	Very High Importance	(8,8,9)	(1/9,1/8,1/8)
9	Extremely High Importance	(9,9,9)	(1/9,1/9,1/9)

Source: Sonmez Gumushan and Sonmez Cakir (2023)

The fuzzy pairwise comparison matrix, M which represents the relative importance of each member in a pair, is provided by Equation (1).

$$M = \begin{pmatrix} 1 & 1_{12} & \dots & 1_{1n} \\ 1_{12} & 1 & \dots & 1_{2n} \\ \dots & \dots & \dots & \dots \\ 1_{n1} & 1_{n2} & \dots & 1 \end{pmatrix} = \begin{pmatrix} 1 & 1_{12} & \dots & 1_{1n} \\ 1/1_{12} & 1 & \dots & 1_{2n} \\ \dots & \dots & \dots & \dots \\ 1/1_{n1} & 1/1_{n2} & \dots & 1 \end{pmatrix} \quad (1)$$

Step 2: Evaluation of consistency ratio.

The consistency ratio (CR) helps in measuring the consistency of a matrix. The difference between the maximum eigenvalue ($\lambda_{\max}$) and the matrix dimension (N) can be utilized as an indicator of inconsistency. The CR was defined as a ratio between the consistency of a given evaluation matrix and consistency of a random matrix where RI is a random index that depends on N . Table 2 shows the value of the Random Consistency Index (RI) adopted from Saaty (2005).

Table 2: Saaty's Random Consistency Index (RI)

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Saaty (2005)

The Consistency Index (CI) and CR are calculated by using Equation (2) and (3).

$$CI = \frac{\lambda_{\max} - N}{N - 1} \quad (2)$$

$$CR = \frac{CI}{RI} \quad (3)$$

If the value of CR is less than 0.1, it indicates that the pairwise comparisons' consistency is validated. However, if CR exceeds 0.1, it suggests that the matrix needs to be revised as it exhibits inconsistencies that may affect the reliability of the comparisons.

Step 3: Determination of Geometric Means

The fuzzy geometrical mean technique was used to define the fuzzy geometrical mean,

r_i of each criterion, which shown by Equation (4).

$$r_i = \left(\prod_{j=1}^n l_{ij} \right)^{1/n} \quad (4)$$

where l_{ij} represents the fuzzy comparison value from a group of decision makers.

Step 4: Determination of Fuzzy Preference Weights

By including the subs steps which finding the vector summation of each r_i as shown in Equation (5) and inverse of the summation vector. The fuzzy triangular was then replaced to make it in the form of increasing order. Define the fuzzy preference weight, w_i of each criterion, which is calculated by Equation (6).

$$\text{Vector summation} = \sum r_i \text{ such that } i = 1, 2, 3, \dots, n \quad (5)$$

$$w_i = r_i \otimes \left(r_1 (+) r_2 (+) \dots (+) r_n \right)^{-1} \quad (6)$$

Step 5: Defuzzification of Fuzzy Preference Weights

Defuzzification of the fuzzy weights is also known as average weight criteria. The fuzzy weights, w_i need to be defuzzified because it still in fuzzy triangular numbers form. The calculation of the defuzzification, G_i can be done using Equation (7).

$$G_i = \frac{l_i + m_i + u_i}{3} \quad (7)$$

Step 6: Normalization of The Defuzzified Fuzzy Preference Weights

The normalization of the defuzzified weight of criterion is required as G_i is a non-fuzzy number. Calculation of the normalized preference weight, H_i of each criterion which is presented in Equation (8).

$$H_i = \frac{G_i}{\sum_{i=1}^n G_i} \quad (8)$$

Step 7: Computation of Global Weights

Determining the global weight involves taking into consideration the weight vectors of each criterion and alternatives. The weight assigned to the main criteria, H_C is multiplied by the weights of alternatives, H_A to calculate the global weight. This global weight is then used to develop a selection scoring model.

$$\text{Global Weight} = H_{C_n} \times H_{A_n} \quad (9)$$

where C stands for criteria, A for alternatives and $n = 1, 2, 3, \dots$

Step 8: Final Ranking of Alternatives

The alternatives were ranked according to the global weight calculated in Step 7.

Implementation

This study applies the Fuzzy Analytic Hierarchy Process (FAHP) method to rank and determine the most preferable study area among university students based on multi-criteria decision-making (MCDM). To achieve realistic evaluation, five decision makers (DM) were selected from UiTM Kelantan Branch. These DM are experienced students familiar with all academic facilities on campus.

The evaluation framework consists of four alternatives evaluated against four criteria as defined in Table 3.

Table 3: Labels of Alternatives and Criteria

Alternatives	Labels	Criteria	Labels
Library	A_1	Environmental Conditions	C_1
Study Lounges	A_2	Amenities and Facilities	C_2
Outdoor Study Spot	A_3	Capacity and Space Management	C_3
Dormitory Rooms	A_4	Flexibility and Availability	C_4

Step 1: Constructing Pairwise Comparison Matrices

Linguistic comparisons gathered from the DM were replaced with Triangular Fuzzy Numbers (TFN) according to Saaty's 1–9 scale. For DM 1, if Criterion 2 (C_2) is moderately preferred over Criterion 3 (C_3), the fuzzy triangular scale (4,5,6) is applied, while its reciprocal (0.1667,0.2000,0.2500) is assigned to (C_3 , C_2). This process was systematically followed for all criteria and alternatives. The resulting pairwise comparison matrices are presented in Table 4.

Table 4: Pairwise Comparison Matrices for Criteria

Criteria				
DM 1	C_1	C_2	C_3	C_4
C_1	(1,1,1)	(1,1,1)	(2,3,4)	(5,6,7)
C_2	(1,1,1)	(1,1,1)	(4,5,6)	(3,4,5)
C_3	(0.2500,0.3333,0.5000)	(0.1667,0.2000,0.2500)	(1,1,1)	(4,5,6)
C_4	(0.1429,0.1667,0.2000)	(0.2000,0.2500,0.3333)	(0.1667,0.2000,0.2500)	(1,1,1)
DM 2	C_1	C_2	C_3	C_4
C_1	(1,1,1)	(8,8,9)	(2,3,4)	(5,6,7)
C_2	(0.1111, 0.1250, 0.1250)	(1,1,1)	(4,5,6)	(3,4,5)
C_3	(0.2500,0.3333,0.5000)	(0.1667,0.2000,0.2500)	(1,1,1)	(4,5,6)
C_4	(0.1429,0.1667,0.2000)	(0.2000,0.2500,0.3333)	(0.1667,0.2000,0.2500)	(1,1,1)
DM 3	C_1	C_2	C_3	C_4
C_1	(1,1,1)	(9,9,9)	(8,8,9)	(8,8,9)
C_2	(0.1111, 0.1111, 0.1111)	(1,1,1)	(6,7,8)	(5,6,7)
C_3	(0.1111,0.1250,0.1250)	(0.1250,0.1429,0.1667)	(1,1,1)	(6,7,8)

C_4	(0.1111,0.1250,0.1250)	(0.1429,0.1667,0.2000)	(0.1250,0.1429,0.1667)	(1,1,1)
DM 4	C_1	C_2	C_3	C_4
C_1	(1,1,1)	(1,2,3)	(2,3,4)	(1,1,1)
C_2	(0.3333, 0.5000, 1.0000)	(1,1,1)	(2,3,4)	(1,2,3)
C_3	(0.2500,0.3333,0.5000)	(0.2500,0.3333,0.5000)	(1,1,1)	(4,5,6)
C_4	(1,1,1)	(0.3333, 0.5000, 1.0000)	(0.1667,0.2000,0.2500)	(1,1,1)
DM 5	C_1	C_2	C_3	C_4
C_1	(1,1,1)	(5,6,7)	(4,5,6)	(2,3,4)
C_2	(0.1429,0.1667,0.2000)	(1,1,1)	(1,2,3)	(4,5,6)
C_3	(0.1667,0.2000,0.2500)	(0.3333, 0.5000, 1.0000)	(1,1,1)	(1,1,1)
C_4	(0.2500,0.3333,0.5000)	(0.1667,0.2000,0.2500)	(1,1,1)	(1,1,1)

The aggregated fuzzy evaluation matrix, which represents the combined opinions of the decision makers, is presented in Table 5 for the criteria and in Tables 6 for the alternatives. For examples in Table 6, to fill the cell of A_1 to A_2 for alternatives with respect to A_1 , we calculated the average of the pairwise comparisons by

$$\left(\frac{0.1111+0.1111+0.1250+0.1667+0.1667}{5}, \frac{0.1111+0.1250+0.1429+0.2000+0.2000}{5}, \frac{0.1111+0.1111+0.1667+0.2500+0.2500}{5} \right) \\ = (0.1361, 0.1336, 0.1556)$$

Then, followed the same process to determine the aggregated fuzzy numbers for all the criteria and alternatives.

Table 5: Aggregated Fuzzy Number for Criteria

C_1	C_2	C_3	C_4
C_1 (1,1,1)	(4.8000,5.2000,5.8000)	(3.6000,4.4000,5.4000)	(4.2000,4.8000,5.6000)
C_2 (0.3397,0.3806,0.4872)	(1,1,1)	(3.4000,4.4000,5.4000)	(3.2000,4.2000,5.2000)
C_3 (0.2056,0.2650,0.3750)	(0.2083,0.2752,0.4333)	(1,1,1)	(3.8000,4.6000,5.4000)
C_4 (0.3294,0.3583,0.4050)	(0.2086,0.2733,0.4233)	(0.3250,0.3486,0.3833)	(1,1,1)

Table 6: Aggregated Fuzzy Number for Alternative with Respect to C_1

A_1	A_2	A_3	A_4
A_1 (1,1,1)	(6.2000,6.8000,7.6000)	(4.2000,5.2000,6.2000)	(4.0000,4.6000,5.4000)
A_2 (0.1361,0.1336,0.1556)	(1,1,1)	(2.8000,3.6000,4.4000)	(5.2000,5.8000,6.8000)
A_3 (0.1733,0.2138,0.2833)	(0.3717,0.4286,0.5667)	(1,1,1)	(4.4000,5.0000,5.8000)
A_4 (0.3472,0.3936,0.5083)	(0.1630,0.2000,0.2511)	(0.2178,0.2972,0.5111)	(1,1,1)

Step 2: Evaluation of consistency ratio.

Consistency checks were executed using the eigenvalue approach. The Consistency Index (CI) and Consistency Ratio (CR) were computed using Equation (2) and (3). Using Saaty's Random Index (RI = 0.90 for $N = 4$), the calculations for DM 1 yields:

$$CI_{DM1} = \frac{4.0877 - 4}{4 - 1} = 0.0292$$

$$CR_{DM1} = \frac{0.0292}{0.90} = 0.0325$$

Table 7: Consistency Index and Consistency Ratio for Criteria

	λ_{max}	CI	CR
DM 1	4.0877	0.0292	0.0325
DM 2	4.160.3	0.0534	0.0594
DM 3	4.0389	0.0130	0.0144
DM 4	4.0799	0.0266	0.0296
DM 5	4.0778	0.0259	0.0288

Since all CR values remain below 0.10 as shown in Table 7, judgment consistency is fully validated.

Step 3: Determination of Geometric Means

The geometric mean of the fuzzy comparison values was calculated using Equation (4). For criterion 1 (C_1):

$$l = r_{C_1} = (1 \times 4.8000 \times 3.6000 \times 4.2000)^{\frac{1}{4}} = 2.9189$$

$$m = r_{C_1} = (1 \times 5.2000 \times 4.4000 \times 4.8000)^{\frac{1}{4}} = 3.2372$$

$$u = r_{C_1} = (1 \times 5.8000 \times 5.4000 \times 5.6000)^{\frac{1}{4}} = 3.6392$$

Table 8 and Table 9 list the fuzzy geometric mean vectors for criteria and alternative.

Table 8: Geometric Mean of Fuzzy Comparison Values for Criteria

Criteria	l	m	u
C_1	2.9189	3.2372	3.6392
C_2	1.3865	1.6285	1.9232
C_3	0.6351	0.7611	0.9679
C_4	0.3865	0.4299	0.5063
Total	5.3270	6.0566	7.0366
Inverse	0.1877	0.1651	0.1421
Increasing Order	0.1421	0.1651	0.1877

Table 9: Geometric Mean of Fuzzy Comparison Values for Alternatives for C_1

C_1	l	m	u
A_1	3.1947	3.5712	3.9939
A_2	1.1865	1.2923	1.4688
A_3	0.7297	0.8227	0.9823
A_4	0.3332	0.3911	0.5054
Total	5.4440	6.0773	6.9505
Inverse	0.1837	0.1645	0.1439
Increasing Order	0.1439	0.1645	0.1854

Step 4: Determination of Fuzzy Preference Weights

Fuzzy weights, w_i were derived by multiplying individual geometric values by the inverse of total summation vector (in increasing order) using Equation (6). For C_1 :

$$l = w_{C_1} = (2.9188 \times 0.1421) = 0.4148$$

$$m = w_{C_1} = (3.2372 \times 0.1651) = 0.5345$$

$$u = w_{C_1} = (3.6392 \times 0.1877) = 0.6831$$

Tables 10 displays the fuzzy weights for criteria and Table 11 displays the fuzzy weights for the alternative for C_1 .

Table 10: Fuzzy Preferences Weight for Criteria

Criteria	l	m	u
C_1	0.4148	0.5345	0.6831
C_2	0.1970	0.2689	0.3610
C_3	0.0903	0.1257	0.1817
C_4	0.0549	0.0710	0.0950

Table 11: Fuzzy Preferences Weight for Alternatives for C_1

C_1	l	m	u
$\tilde{w}_{A_1}$	0.4597	0.5875	0.7405
$\tilde{w}_{A_2}$	0.1707	0.2126	0.2723
$\tilde{w}_{A_3}$	0.1050	0.1353	0.1821
$\tilde{w}_{A_4}$	0.0479	0.0643	0.0937

Step 5 and Step 6: Defuzzification and Normalization of Fuzzy Preference Weights

The average of the criteria was calculated using Equation (7). The calculations for defuzzification for criteria are as follows:

$$G_{C_1} = \frac{(0.4148 + 0.5345 + 0.6831)}{3} = 0.5441$$

$$G_{C_2} = \frac{(0.1970 + 0.2689 + 0.3610)}{3} = 0.2756$$

$$G_{C_3} = \frac{(0.0903 + 0.1257 + 0.1817)}{3} = 0.1325$$

$$G_{C_4} = \frac{(0.0549 + 0.0710 + 0.0950)}{3} = 0.0736$$

$$\sum G_{C_i} = \left(G_{C_1} + G_{C_2} + G_{C_3} + G_{C_4} \right) = 1.0259$$

Then, the defuzzified weights (relative non-fuzzy weights) must be normalized before being computed using Equation (8). The calculations for normalized for criteria are as follows:

$$H_{C_1} = \frac{0.5441}{1.0259} = 0.5304$$

$$H_{C_2} = \frac{0.2756}{1.0259} = 0.2687$$

$$H_{C_3} = \frac{0.1325}{1.0259} = 0.1292$$

$$H_{C_4} = \frac{0.0736}{1.0259} = 0.0718$$

The calculations also being used to compute the defuzzification and normalization of fuzzy preference weights for alternatives. The results are shown in Table 12 and Table 13 below:

Table 12: Defuzzification and Normalized of Criteria

Criteria	Defuzzification	Normalization
C_1	0.5441	0.5304
C_2	0.2756	0.2687
C_3	0.1325	0.1292
C_4	0.0736	0.0718
Total	1.0259	1

Table 13: Defuzzification and Normalization of Alternatives for for C_1

C_1	Defuzzification	Normalization
A_1	0.5959	0.5820
A_2	0.2185	0.2134
A_3	0.1408	0.1375
A_4	0.0687	0.0671
Total	1.0239	1

Step 7: Computation of Global Weights

Global weights for each alternative across criteria were computed by multiplying the normalized criteria weight with the respective alternative weight using Equation (9). Table 14 shows the weight of criteria for each alternative that were use to find the global weight of criteria for each alternative as shown in Table 15.

Table 14: The Weight of Criteria for each Alternatives

Criteria/Alternatives	Weight	A_1	A_2	A_3	A_4
C_1	0.5304	0.5820	0.2134	0.1375	0.0671
C_2	0.2687	0.5757	0.2341	0.1339	0.0563
C_3	0.1292	0.5372	0.2453	0.1425	0.075
C_4	0.0718	0.5991	0.2284	0.1073	0.0652

Table 15: The Global Weight of Criteria for each Alternatives

Criteria/Alternatives	A_1	A_2	A_3	A_4
C_1	0.3094	0.1122	0.0731	0.0356
C_2	0.1547	0.0629	0.0360	0.0151
C_3	0.0694	0.0317	0.0184	0.0097
C_4	0.0430	0.0164	0.0077	0.0047

Step 8: Final Ranking of Alternatives

The ranking of all alternatives will be determined by adding the product of the normalized weight for each criterion and the normalized weight for each alternative as shown in Table 16. The summation of the global weight was calculated as below:

$$\sum A_1 = 0.3094 + 0.1547 + 0.0694 + 0.0430 = 0.5765$$

$$\sum A_2 = 0.1122 + 0.0629 + 0.0317 + 0.0164 = 0.2232$$

$$\sum A_3 = 0.0731 + 0.0360 + 0.0184 + 0.0077 = 0.1352$$

$$\sum A_4 = 0.0356 + 0.0151 + 0.0097 + 0.0047 = 0.0651$$

Table 16: Ranking of the alternatives

Criteria/Alternatives	A_1	A_2	A_3	A_4
C_1	0.3094	0.1122	0.0731	0.0356
C_2	0.1547	0.0629	0.0360	0.0151
C_3	0.0694	0.0317	0.0184	0.0097
C_4	0.0430	0.0164	0.0077	0.0047
Total	0.5765	0.2232	0.1352	0.0651
Ranking	1	2	3	4

Result and Discussion

Table 16 shows that the Library (A_1) was identified as the top study space for UiTM Kelantan students, with the highest score of 0.5765. It followed by Study Lounges (A_2) at 0.2232, Outdoor Study Spot (A_3) at 0.1352, and Dormitory Room (A_4) at 0.0651. Therefore, based on the findings, Library was identified as the preferred study space and the least preferred study space is Dormitory Rooms (A_4). Since CR values is below 0.10, it shows that the FAHP method gave reliable results.

Among the four selection criteria, environmental conditions (C_1) was the most important factor, with the highest weight of 0.5304, followed by amenities and facilities (C_2) at 0.2687, capacity and space management (C_3) at 0.1292, and flexibility and availability (C_4) at 0.0718.

Overall, the results indicate that students prioritize a conducive, comfortable, and well-equipped environment, while adequate space, accessibility, and flexibility also contribute to the selection of suitable study spaces. Practically, these results provide clear guidance for university management when planning campus facility.

Conclusion and Recommendations

In this study, Fuzzy Analytical Hierarchy Process (FAHP) was used to select the most suitable study space by evaluating four criteria and four alternatives based on the judgments of five decision-makers. FAHP was chosen because it can handle both qualitative and quantitative data, as well as uncertainty and subjectivity in decision-making. The results showed that environmental conditions (C_1) was the most important criterion, while flexibility and availability (C_4) was the least important. Among the alternatives, the Library (A_1) was ranked as the most preferred study space, while the Dormitory Room (A_4) was the least preferred. Overall, the study successfully achieved its objectives by identifying the importance of the criteria and ranking the study space alternatives. The findings summarize that FAHP is an effective method for supporting decisions related to optimizing study environments.

There are a few recommendations that would benefit the research in the future, especially addressing the limitations identified in this research, such as the small sample size, which may not fully represent the wider student population. Increasing the number of participants from diverse backgrounds could provide more reliable and comprehensive results.

In addition, future research could apply FAHP to other fields, particularly in economics and environmental management. Besides that, FAHP can be combined with other uncertainty theories such as neutrosophic set.

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Conflict of Interest Statement

The authors agree that this research was conducted in the absence of any selfbenefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

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