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Selection of Courier Service Providers Among Student UiTMCK using Fuzzy Analytical Hierarchy Process (FAHP)

Nur Jesnita Junera binti Luxman Alhakim [1], Wan Nurul Husna binti Wan Nordin [2*], Masnira binti Ramli [3] , W. Nurfahizul Ifwah binti W. Alias [4] and Aimi Zulliayana binti Rosli [5]

[1,2,3,4,5] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Kelantan, Bukit Ilmu, Machang, Kelantan, Malaysia
Authors' email: 2023305227@student.uitm.edu.my, husna78@uitm.edu.my*, masnira@uitm.edu.my, nurfahizul226@uitm.edu.my and zullia068@uitm.edu.my

[*]Corresponding author

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Abstract: Courier services are now a vital component of contemporary life, enabling timely delivery of goods and documents while supporting the fast growth of e-commerce. Students frequently utilize these services for both personal and academic objectives and their decision is heavily influenced by elements like cost, delivery time, and consistency. In order to assess and rank four courier service provider such as GDEX, J&T Express, Pos Laju, and Ninja Van among students at Universiti Teknologi MARA Kelantan Branch (UiTMCK), this study suggests using the Fuzzy Analytical Hierarchy Process (FAHP). Ratings for criteria and alternatives were provided by five experienced decision makers using a linguistic scale. Decision makers evaluate the criteria using triangular fuzzy numbers within the context of FAHP which enables them to handle uncertain decision situations. Subsequently the calculated fuzzy weights adjust the influence of each criterion. These criteria serve as evaluation bases for alternatives after going through normalization procedures. The evaluation was conducted based on four main criteria which are cost efficiency, tracking and traceability, delivery timeliness and order accuracy. The results indicates that J&T Express ranked as the most preferred courier service, followed by Ninja van, GDEX and Pos Laju. Cost efficiency was identified as the most significant criterion, suggesting that pricing remains the primary consideration among student users. FAHP helps to deal with uncertainty in decision making, making it suitable for evaluating complex criteria.

Keywords: Courier services, Multi-Criteria Decision Making (MCDM), Fuzzy Analytical Hierarchy Process (FAHP), criteria, alternatives

1 Introduction

The courier service industry has become an integral part of the modern economy, providing quick and reliable delivery of parcels, documents, and information across various regions. In the context of Malaysia, the courier service market has expanded rapidly due to the surge in e-commerce activities and technological advancement. In today's modern world, many services depend on courier services, which typically offers faster delivery times compared to other transport options. The courier delivery industry is a rapidly expanding segment within the service sector. According to [1], the growth of the online store or e-Commerce, is one of the main reasons why this business is growing and creating new opportunities. Similarly, [2] highlighted that improved communication technologies have enabled individuals and organizations to engage in virtual transactions, increasing the dependency on courier services.

Nationwide Express, City Link Express, and GD Express have been providing essential delivery services across the nation. Despite advances in technology that have changed certain courier works, people still depend on getting physical goods delivered quickly. However, it encourages businesses in the industry to go digital, making their operations more effective, efficient and adaptable. In addition, [3] mentioned that several courier companies have made shipping more convenient for Malaysians by offering user-friendly application like J&T Tracking, EasyParcel.com, and many others where customers have the convenience of getting shipping cost estimates, arranging pick-ups, and monitoring deliveries throughout the country, all through text messages.

The courier companies provide the same features in terms of delivering goods that have been ordered by customers on many platforms. However, the delivery charges, the speed of delivery and other benefits they provide are not the same [4]. Therefore, this study can be seen as a detailed process of making choices to find the most reliable services that focus on long-term sustainability. In this process, people often use multi-criteria decision making (MCDM), a method that has been used for a long time to assess various options, such as strategies, policies and decisions, to solve problems efficiently [5].

Fuzzy sets are sets containing elements that have degrees of membership. The first concept of fuzzy set was introduced by Zadeh. It has been discovered that applied fuzzy logic is rather useful in handling the vagueness and uncertainty that might be present in certain decisions [6]. Unlike traditional decision-making methods, fuzzy logic allows the representation of vague and ambiguous preferences through linguistic terms. Numerous papers have been published and written about the application of fuzzy logic in an effort to aid in decision making process. In addition, fuzzy logic lets us include our own opinions and what we know in the decision-making process. This flexibility makes fuzzy MCDM methods a good choice for complex decision-making environments where it is not possible to derive accurate numerical values [7]. Decision makers can carefully compare and rank different alternatives, taking into account several conflicting criteria and uncertainties at the same time [8].

Generally, MCDM is used to indicate a situation in which the researcher or decision maker has to identify the best alternatives given the different criteria [9]. In the same sense, [10] noted that MCDM approaches can indeed help decision makers since they tend to facilitate unbiased decisions and are easy to implement for decision makers in selecting the most suitable alternatives. Based on the limitations mentioned above, this study presents the fuzzy analytical hierarchy process (FAHP) using the triangular fuzzy set in the MCDM technique, as it can improve the decision-making process when there are uncertainties and vagueness between experts [11]. FAHP can be used for pairwise comparison with other options in terms of service aspects to recommend the best quality of a courier service and also to help develop a sustainable competitive advantage [12].

Consequently, this study is carried out to select the most preferable courier service providers among students in UiTM Kelantan Branch. To better understand how decision makers think, we often use fuzzy numbers, such as triangular fuzzy numbers (TFN) or trapezoidal fuzzy numbers (TrFN). These numbers are popular because they are easy to work with and make it simpler to grasp and explain complex ideas [13]. TFN and TrFN are two types of fuzzy sets known for their smoothness, commonly used to represent fuzzy data in a wide range of applications [14]. However, TFN was specifically applied in this study to describe how significant each factor is within the hierarchy.

Therefore, in this study, fuzzy AHP has been chosen in order to obtain the optimum result in choosing the most preferable alternatives for courier service providers. Using fuzzy AHP, this study aims to make decisions easier by considering uncertainties and vagueness with fuzzy logic.

2 Literature review

Numerous research has looked into what influences customers' preferences when choosing courier services. [15] found that cost efficiency is one of the most important factors, particularly for consumers on a tight budget like students. Affordability by itself, however, does not ensure client retention. Maintaining customer loyalty depends equally on perceived service quality, delivery speed, and accuracy. Real-time shipment tracking and traceability has become a fundamental requirement. Customers are more likely to trust businesses that invest in advanced tracking systems. In the same way, timeliness is frequently linked to dependability and professionalism [16]. Deliveries that are uneven or delayed can seriously harm a courier business's reputation. Customer satisfaction is also significantly influenced by order accuracy, which is defined as the proper delivery of items without loss or damage [17]. The criteria utilized in earlier research are displayed in Table 1.

Table 1: The criteria used in previous studies

Criteria	Sources
Cost Efficiency	[15],[16],[18]
Tracking and Traceability	[15],[18],[19]
Delivery Timeliness	[16],[17],[18]
Order Accuracy	[16],[17],[18]

The process of selecting the best courier service can be considered as a multiple-criteria Decision-Making (MCDM) problem, which requires the simultaneous evaluation of several competing factors. Logistics and service selection have made substantial use of MCDM techniques like AHP, FAHP, TOPSIS, and VIKOR [6]. AHP, which was created by [20], is still the most often used of these due to its systematic methodology and ease of comparison of options using hierarchical criteria.

Nevertheless, the traditional AHP has limitations. It assumes decision makers can express their preferences precisely, which may not hold true in real world contexts involving uncertainty or linguistic ambiguity. To address this limitation, researchers have proposed the Fuzzy Analytical Hierarchy Process (FAHP), which integrates fuzzy set theory introduced by [21] into the AHP framework. FAHP allows decision makers to express their judgments using linguistic variables (e.g., “equally important,” “moderately important,” “very important”) represented by triangular fuzzy numbers (TFN).

However, there are drawbacks to the traditional AHP. It makes the assumption that decision makers can convey their preferences clearly, which could not be the case in situations where there is uncertainty or linguistic ambiguity in the real world. The Fuzzy Analytical Hierarchy Process (FAHP), which incorporates fuzzy set theory established by [21] into the AHP framework, has been proposed by scholars as a solution to this weakness. Using linguistic variables (such as "equally important," "moderately important," and "very important") represented by triangular fuzzy numbers (TFN), FAHP enables decision makers to express their opinions.

FAHP offers an effective way to evaluate service quality in the context of courier services where there is uncertainty, particularly when human perception is involved. This study uses FAHP to evaluate and rank courier service providers based on four main criteria which are order accuracy, tracking and traceability, cost efficiency, and delivery timeliness.

3 Methodology

The objective of this study is to rank the courier service providers that UiTMCK students prefer using FAHP. There are eight steps [6] involved as shown in Figure 1.

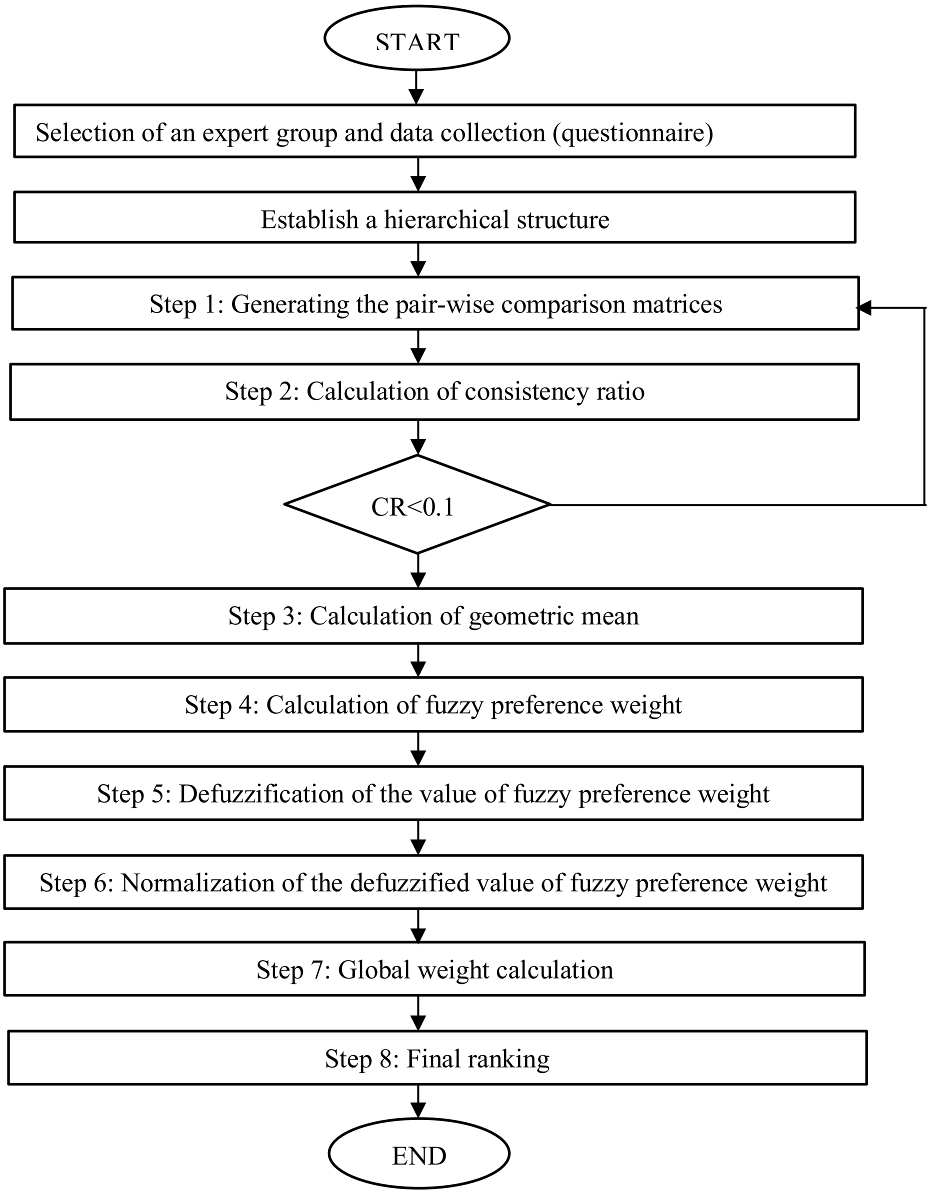

Figure 1: The flow chart structure to rank the most preferable courier service providers

Figure 2 below shows the hierarchical structure of this study for selection of the most preferable courier service providers for four high demanding courier service providers based on four criteria.

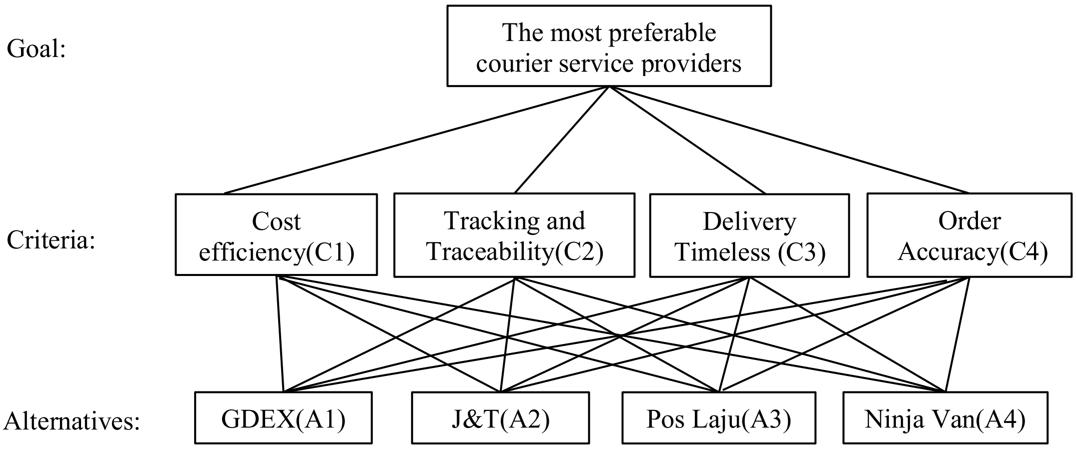

Figure 2: The hierarchical structure diagram in selection of courier service providers

Step 1: Generating the pairwise comparison matrices

The importance 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. In FAHP, triangular fuzzy number (TFN) was used for the comparison of criteria, adapted from [6].

Table 2: Linguistic terms in FAHP model

Fuzzy Number	Linguistic Variables	Fuzzy Triangular Scale	Reciprocal TFN
1	Equal importance	(1,1,1)	(1,1,1)
2	Weak importance	(1,2,3)	$\left(\frac{1}{3},\frac{1}{2},1\right)$
3	Not bad	(2,3,4)	$\left(\frac{1}{4},\frac{1}{3},\frac{1}{2}\right)$
4	Preferable	(3,4,5)	$\left(\frac{1}{5},\frac{1}{4},\frac{1}{3}\right)$
5	Important	(4,5,6)	$\left(\frac{1}{6},\frac{1}{5},\frac{1}{4}\right)$
6	Fairly importance	(5,6,7)	$\left(\frac{1}{7},\frac{1}{6},\frac{1}{5}\right)$
7	Very importance	(6,7,8)	$\left(\frac{1}{8},\frac{1}{7},\frac{1}{6}\right)$
8	Absolute	(7,8,9)	$\left(\frac{1}{9},\frac{1}{8},\frac{1}{7}\right)$
9	Prefect	(8,9,10)	$\left(\frac{1}{10},\frac{1}{9},\frac{1}{8}\right)$

The comparison of criterion measured according to the numerical scale 1-9 in the form of linguistic variables as shown in Table 2. The fuzzy pairwise comparison matrix, $\tilde{M}$ which represents the relative importance of each member in a pair, is provided by

$$\tilde{M} = \begin{bmatrix} 1 & \tilde{l_{12}} & \dots & \tilde{l_{1n}} \\ \tilde{l_{21}} & 1 & \dots & \tilde{l_{2n}} \\ \dots & \dots & \dots & \dots \\ \tilde{l_{n1}} & \tilde{l_{n2}} & \dots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{l_{12}} & \dots & \tilde{l_{1n}} \\ 1/\tilde{l_{21}} & 1 & \dots & \tilde{l_{2n}} \\ \dots & \dots & \dots & \dots \\ 1/\tilde{l_{n1}} & 1/\tilde{l_{n2}} & \dots & 1 \end{bmatrix} \quad (1)$$

Step 2: Calculation of consistency ratio

The consistency ratio (*CR*) helps in measuring the consistency of a matrix. The difference between the maximum eigenvalue (λ_{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 3 illustrates the value of the Random Consistency Index (*RI*) adopted from [24].

Table 3: Saaty's Random Consistency Index, *RI*

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Let $\tilde{M}$ denotes pairwise comparison matrix and priority weight matrix. Consistency index (*CI*) and consistency ratio (*CR*) computed according to Equations (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: Calculation of geometric mean

The fuzzy geometrical mean technique was used to define the fuzzy geometrical mean, $\tilde{r_i}$ of each criterion, which shown by Equation (4).

$$\tilde{r_i} = \left(\prod_{j=1}^{n} \tilde{l_{ij}} \right)^{\frac{1}{n}} \text{ such that } i = 1, 2, \dots, n \quad (4)$$

Where $\tilde{r_i}$ is the fuzzy geometrical mean and $\tilde{l_{ij}}$ is the fuzzy comparison value from a group of decision-makers with respect to the i^{th} dimension over the j^{th} criterion.

Step 4: Calculation of fuzzy preference weight

By including the subs steps which finding the vector summation of each $\tilde{r_i}$ 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, $\tilde{w_i}$ of each criterion, which is calculated by Equation (6).

$$\text{Vector summation} = \sum \tilde{r}_i \text{ such that } i = 1,2,...,n \tag{5}$$

$$\tilde{w}_i = \tilde{r}_i (\times) \left(\tilde{r}_1 (+) \tilde{r}_2 (+) ... (+) \tilde{r}_n \right)^{-1} \tag{6}$$

Step 5: Defuzzification of the value of fuzzy preference weight

Defuzzification of the fuzzy weights is also known as average weight criteria. The fuzzy weights $\tilde{w}_i$ need to be defuzzified because it still in fuzzy triangular numbers form. The calculation of the defuzzification, $\tilde{G}_i$ can be done using Equation (7).

$$\tilde{G}_i = \frac{\tilde{w}_1 (+) \tilde{w}_2 (+) \tilde{w}_3}{3} \tag{7}$$

Step 6: Normalization of the defuzzified value of fuzzy preference weight

The normalization of the defuzzified weight of criterion is required as $\tilde{G}_i$ is a non-fuzzy number. Calculation of the normalized preference weight, $\tilde{H}_i$ of each criterion which is presented in Equation (8).

$$\tilde{H}_i = \frac{\tilde{G}_i}{\sum_{i=1}^{n} \tilde{G}_i} \tag{8}$$

Step 7: Global weight calculation

Determining the global weight involves taking into consideration the weight vectors of each criterion and alternatives. The weight assigned to the main criteria, $\tilde{H}_C$ is multiplied by the weights of alternatives, $\tilde{H}_A$ to calculate the global weight. This global weight is then used to develop a selection scoring model which shown in Equation 9.

$$\text{Global weight} = \tilde{H}_{Cn} \times \tilde{H}_{An} \tag{9}$$

where C stands for criteria, A for alternatives and n = 1,2,3, . . .

Step 8: Final ranking

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

4 Implementation

In this study, five students from UiTM Kelantan Branch who became the decision makers namely DM1, DM2, DM3, DM4 and DM5 have been selected to answer the questionnaires. Figure 3 shows the sample of the questionnaires. These decision makers were chosen because they have experience using all the selected courier services as both senders and receivers. The alternatives refer to the courier service providers that students are familiar with and are located in the Machang area, while the criteria represent the factors that influence students' decisions in choosing the best courier service providers. The labels for each of the alternatives and criteria in this study are shown in Table 4.

Table 4: Labels of alternatives and criteria

Alternatives	**Labels**	**Criteria**	**Labels**
GDEX	A1	Cost Efficiency	C1
J&T Express	A2	Tracking and Traceability	C2
Pos Laju	A3	Delivery Timeliness	C3
Ninja Van	A4	Order Accuracy	C4

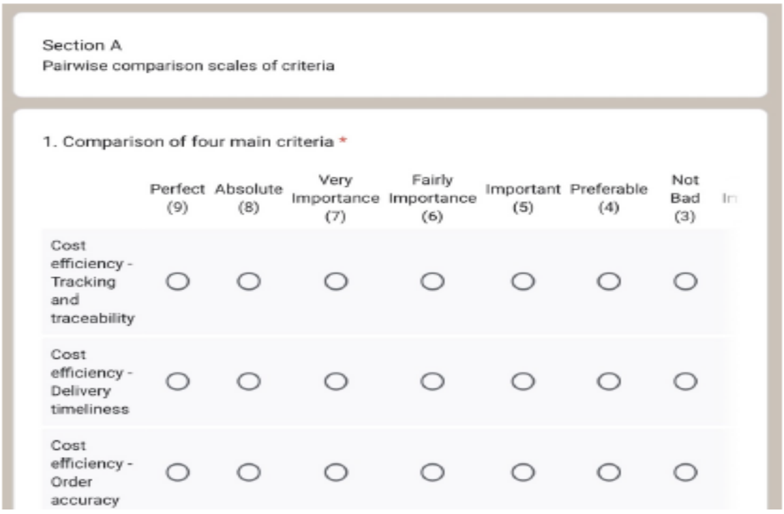

Figure 3: Sample of questionnaires

Step 1: Generating the pairwise comparison matrices

A comparison matrix based on the survey responses was created. The linguistic variables used for the pairwise comparisons were replaced with membership values according to Saaty's 1-9 scale. For example, based on Table 4, if "Criteria 3 (C3) is more important than Criteria 4 (C4)," the fuzzy triangular scale (2,3,4) is used, representing a low to moderate preference. Conversely, when comparing C4 to C3, the reciprocal scale (0.2500, 0.3333, 0.5000) is applied to maintain consistency in the matrix. This process was systematically followed for all criteria and alternatives. The resulting pairwise comparison matrices for criteria are presented in Tables 5.

Table 5: Pairwise comparison matrices for criteria

Criteria				
DM1	C1	C2	C3	C4
C1	(1,1,1)	(3,4,5)	(1,1,1)	(1,2,3)
C2	(0.2000,0.2500,0.3333)	(1,1,1)	(0.2000,0.2500,0.3333)	(1,1,1)
C3	(1,1,1)	(3,4,5)	(1,1,1)	(2,3,4)
C4	(0.3333,0.5000,1.0000)	(1,1,1)	(0.2500,0.3333,0.5000)	(1,1,1)
DM2	C1	C2	C3	C4
C1	(1,1,1)	(2,3,4)	(0.3333,0.5000,1.0000)	(1,2,3)
C2	(0.2500,0.3333,0.5000)	(1,1,1)	(0.1667,0.2000,0.2500)	(0.3333,0.5000,1.0000)
C3	(1,2,3)	(4,5,6)	(1,1,1)	(2,3,4)
C4	(0.3333,0.5000,1.0000)	(1,2,3)	(0.2500,0.3333,0.5000)	(1,1,1)
DM3	C1	C2	C3	C4
C1	(1,1,1)	(5,6,7)	(1,2,3)	(3,4,5)
C2	(0.1429,0.1667,0.2000)	(1,1,1)	(0.2000,0.2500,0.3333)	(0.3333,0.5000,1.0000)
C3	(0.3333,0.5000,1.0000)	(3,4,5)	(1,1,1)	(1,2,3)

C4	(0.2000,0.2500,0.3333)	(1,2,3)	(0.3333,0.5000,1.0000)	(1,1,1)
DM4	C1	C2	C3	C4
C1	(1,1,1)	(6,7,8)	(2,3,4)	(7,8,9)
C2	(0.1250,0.1429,0.1667)	(1,1,1)	(0.2000,0.2500,0.3333)	(1,1,1)
C3	(0.2500,0.3333,0.5000)	(3,4,5)	(1,1,1)	(4,5,6)
C4	(0.1111,0.1250,0.1429)	(1,1,1)	(0.1667,0.2000,0.2500)	(1,1,1)
DM5	C1	C2	C3	C4
C1	(1,1,1)	(4,5,6)	(2,3,4)	(1,1,1)
C2	(0.1667,0.2000,0.2500)	(1,1,1)	(0.3333,0.5000,1.0000)	(0.2000,0.2500,0.3333)
C3	(0.2500,0.3333,0.5000)	(1,2,3)	(1,1,1)	(0.3333,0.5000,1.0000)
C4	(1,1,1)	(3,4,5)	(1,2,3)	(1,1,1)

After gathering the opinions of five decision makers, an average was calculated based on their preferences. Updated pairwise comparison matrices were then created for all the criteria and alternatives. The aggregated fuzzy evaluation matrix, which represents the combined opinions of the decision makers, is presented in Table 6. For example, to fill the cell of C2 to C1 for criteria, we calculated the average of the pairwise comparisons by

$$\left(\begin{array}{l}\frac{0.2000+0.2500+0.1429+0.1250+0.1667}{5},\frac{0.2500+0.3333+0.1667+0.1429+0.2000}{5},\\ \frac{0.3333+0.5000+0.2000+0.1667+0.2500}{5}\end{array}\right)$$
$$=(0.1769,0.2186,0.2900)$$

Followed the same process to determine the aggregated fuzzy numbers for all the criteria and alternatives in this study.

Table 6: Aggregated fuzzy number for criteria

	C1	C2	C3	C4
C1	(1,1,1)	(4,5,6)	(1.2667,1.9000,2.6000)	(2.6000,3.4000,4.2000)
C2	(0.1769,0.2186,0.2900)	(1,1,1)	(0.2200,0.2900,0.4500)	(0.5733,0.6500,0.8667)
C3	(0.5667,0.8333,1.2000)	(2.8000,3.8000,4.8000)	(1,1,1)	(1.8667,2.7000,3.6000)
C4	(0.3956,0.4750,0.6952)	(1.4000,2.0000,2.6000)	(0.4000,0.6733,1.0500)	(1,1,1)

Step 2: Calculation of consistency ratio

The calculation of the Consistency Index (*CI*) and Consistency Ratio (*CR*) for Decision Maker 1 with respect to the criteria for *N* equal to 4 is shown below. The calculation is using Equation (2) and Equation (3). Tables 7 present the calculations of *CI* and *CR* for the criteria.

$$CI_{DM1}=\frac{4.1561-4}{4-1}=0.0520$$

$$CR_{DM1}=\frac{0.0520}{0.89}=0.0585$$

Table 7: Consistency Index and Consistency Ratio for Criteria

	$\lambda_{\max}$	*CI*	*RI*
DM1	4.1561	0.0520	0.0585
DM2	4.2093	0.0698	0.0784
DM3	4.1938	0.0646	0.0726
DM4	4.1141	0.0380	0.0427
DM5	4.1655	0.0552	0.0620

Step 3: Calculation of geometric mean

Using Equation (4), the geometric mean of the fuzzy comparison values for each criterion and alternative was determined. Below is the calculation of the geometric mean for Criterion 1 with respect to the other criteria:

$$l = \tilde{r}_{C1} = (1 \times 4 \times 1.2667 \times 2.600)^{\frac{1}{4}} = 1.9051$$

$$m = \tilde{r}_{C1} = (1 \times 5 \times 1.9000 \times 3.400)^{\frac{1}{4}} = 2.3840$$

$$u = \tilde{r}_{C1} = (1 \times 6 \times 2.6000 \times 4.200)^{\frac{1}{4}} = 2.8451$$

Tables 8 present the geometric means of fuzzy comparison values for criteria, reflecting the fuzzy triangle numbers represented as (l,m,u). This table also include the values in increasing order, the total values, and their inverse values.

Table 8: Geometric Mean of Fuzzy Comparison Values for Criteria

Criteria	*l*	*m*	*u*
C1	1.9051	2.3840	2.8451
C2	0.3865	0.4505	0.5799
C3	1.3119	1.7100	2.1339
C4	0.6860	0.8943	1.1784
Total	4.2895	5.4388	6.7373
Inverse	0.2331	0.1839	0.1484
Increasing order	0.1484	0.1839	0.2331

Step 4: Calculation of Fuzzy Preferences Weight

Fuzzy preference weights of each criterion and alternatives are defined and calculated by Equation (6), the calculation of fuzzy preferences weight for C1 was shown below;

$$l = \tilde{w}_{C1} = (1.9051 \times 0.1484) = 0.2828$$

$$m = \tilde{w}_{C1} = (2.3840 \times 0.1839) = 0.4383$$

$$u = \tilde{w}_{C1} = (2.8451 \times 0.2331) = 0.6633$$

Table 9 show an additional information on calculation fuzzy preference weights of each criterion.

Table 9: Fuzzy Preferences Weight for Criteria

Criteria	*l*	*m*	*u*
C1	0.2828	0.4383	0.6633
C2	0.0574	0.0828	0.1352
C3	0.1947	0.3144	0.4975
C4	0.1018	0.1644	0.2747

Step 5: Defuzzification of the value of fuzzy preference weight

The average weight of the criteria was calculated, which involves defuzzifying the fuzzy preference weights using the average weight criteria as shown in Equation (7).

$$\tilde{G}_{C1} = \frac{(0.2828 + 0.4383 + 0.6633)}{3} = 0.4615$$

$$\tilde{G}_{C2} = \frac{(0.0574 + 0.0828 + 0.1352)}{3} = 0.0918$$

$$\tilde{G}_{C3} = \frac{(0.1947 + 0.3144 + 0.4975)}{3} = 0.3355$$

$$\tilde{G}_{C4} = \frac{(0.1018 + 0.1644 + 0.2747)}{3} = 0.1803$$

$$\sum \tilde{G}_i = 1.0691$$

Step 6: Normalization of the defuzzified value of fuzzy preference weight

Next, the defuzzified weights (relative non-fuzzy weights) must be normalized before being computed using Equation (8). The normalized weights for each criterion and alternative, along with their defuzzified weights, are presented in Tables 10 and Table 11.

Therefore, the calculation of the normalized weight for C1 with respect to the criteria is as follows, followed by the calculations for the other criteria and alternatives.

$$\tilde{H}_{C1} = \frac{0.4615}{1.0691} = 0.4316$$

$$\tilde{H}_{C2} = \frac{0.0918}{1.0691} = 0.0859$$

$$\tilde{H}_{C3} = \frac{0.3355}{1.0691} = 0.3138$$

$$\tilde{H}_{C4} = \frac{0.1803}{1.0691} = 0.1687$$

Table 10: Defuzzification and Normalization of Criteria

Criteria	Defuzzification	Normalization
C1	0.4615	0.4316
C2	0.0918	0.0859
C3	0.3355	0.3138
C4	0.1803	0.1687
Total	1.0691	1

Table 11: Defuzzification and Normalization of Alternative with respect to all criteria

Cost Efficiency(C1)		
C1	Defuzzification	Normalization
A1	0.2101	0.1919
A2	0.4863	0.4441
A3	0.1214	0.1108
A4	0.4622	0.2533
Total	1.2800	1
Tracking and Traceability(C2)		
C2	Defuzzification	Normalization
A1	0.2228	0.2109
A2	0.3919	0.3709
A3	0.1710	0.1618
A4	0.2710	0.2564
Total	1.0567	1
Delivery Timeliness (C3)		

C3	Defuzzification	Normalization
A1	0.1911	0.1730
A2	0.4854	0.4394
A3	0.1373	0.1243
A4	0.2909	0.2633
Total	1.1047	1
Order Accuracy(C4)		
C2	Defuzzification	Normalization
A1	0.2600	0.2391
A2	0.3766	0.3464
A3	0.1830	0.1684
A4	0.2676	0.2461
Total	1.0872	1

Step 7: Global weight calculation

The weight assigned to the main criteria times by the weights of alternatives to calculate the global weight as expressed in Equation (9). The calculation of C1 with respect to A1 is as follows, followed by the calculations for the other criteria and alternatives.

$$\tilde{H}_{C1} \times \tilde{H}_{A1} = 0.4316 \times 0.1919 = 0.0828$$

Step 8: Final ranking

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. The ranking of all the alternatives was shown in Table 12 below.

Table 12: Ranking of the alternatives

Criteria/Alternatives	A1	A2	A3	A4
C1	0.0828	0.1917	0.0478	0.1093
C2	0.0181	0.0319	0.0139	0.0220
C3	0.0543	0.1379	0.0390	0.0826
C4	0.0403	0.0584	0.0284	0.0415
Total	0.1956	0.4199	0.1291	0.2555
Ranking	3	1	4	2

5 Results and discussion

A summary of the weight assign for the criteria and alternatives was shown in Table 13, which derived from the information in Table 10 and 11.

Table 13: A summary of the weight assign for the criteria and alternatives

Criteria/Alternatives	weight	GDEX	J&T	PosLaju	NinjaVan
Cost Efficiency	0.4316	0.1919	0.4441	0.1108	0.2533
Tracking and Traceability	0.0859	0.2109	0.3709	0.1618	0.2564
Delivery Timeliness	0.3138	0.1730	0.4394	0.1243	0.2633
Order Accuracy	0.1687	0.2391	0.3464	0.1684	0.2461

The evaluation of criteria for selecting courier service providers revealed four key factors which are cost efficiency (C1), tracking and traceability (C2), delivery timeliness (C3), and order accuracy (C4). Based on Table 12, cost efficiency (C1) was found to be the most important factor, with the highest weight of 0.4316, indicating its primary role in decision-making as both businesses and consumers prioritize affordable pricing. Delivery timeliness (C3) ranked second with a weight of 0.3138, emphasizing the importance of reliable and on-time deliveries, particularly in e-commerce. Order accuracy (C4) came third with a weight of 0.1687, highlighting the need for correct deliveries to avoid customer dissatisfaction. Finally, tracking and traceability (C2) had the lowest weight of 0.0859, though it remains essential for providing transparency and reassurance to customers. Overall, the findings emphasize the significance of cost and timely deliveries, while accuracy and traceability serve as complementary factors in the selection of a courier service provider.

Table 14: Final Ranking of Alternatives

Criteria/Alternatives	GDEX	J&T	PosLaju	NinjaVan
Cost Efficiency	0.0828	0.1917	0.0478	0.1093
Tracking and Traceability	0.0181	0.0319	0.0139	0.0220
Delivery Timeliness	0.0543	0.1379	0.0390	0.0826
Order Accuracy	0.0403	0.0584	0.0284	0.0415
Total	0.1956	0.4199	0.1291	0.2555
Ranking	3	1	4	2

The ranking of the alternatives was determined by adding up the global weight values for each alternative and criterion. The courier service provider with the score closest to 1 is considered the best, as it indicates the most optimal performance as the result was shown in Table 14.

As a result, J&T Express (A2) was ranked as the top courier service provider by students from UiTM Kelantan Branch, securing the highest score of 0.4199. Following J&T Express, the other providers, NinjaVan (A4), GDEX (A1), and PosLaju (A3) were ranked second, third, and fourth, with scores of 0.2555, 0.1956, and 0.1291, respectively. These rankings demonstrate a clear preference among the students, highlighting J&T Express as the leading choice, while the others followed at a considerable distance.

6 Conclusion

This study used a mathematical approach called the fuzzy analytical hierarchy process (FAHP) to address the problem of selecting courier service providers. This method can aid to assess both qualitative and quantitative data while also accounting for uncertainty and subjectivity. Five decision makers participated in developing the pairwise comparison matrix that comprised four criteria and four alternatives. Based on this matrix, the FAHP method was used to find out the weight of each criterion and to rank of the different alternatives.

The FAHP method successfully ranked the alternatives. It was able to provide a clear overview of students' choice based on the ranking obtained. The most preferred and least preferred alternatives according to the implementation of the FAHP method are J&T Express and Pos Laju, respectively.

Future studies could expand the scope of the sample to include a more diverse group of users in different regions or industries. This would help validate the findings of this study and allow a more generalizable conclusion on the key factors that influence the selection of courier service. By addressing these areas, future research could provide valuable insights that further enhance the decision-making models for evaluating courier services. A larger sample size or integration with other MCDM techniques like TOPSIS or VIKOR could also enhance the robustness of the findings.

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Conflict of Interest Statement

The authors declare no conflict of interest in relation to the research, authorship, or publication of this article.

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