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FAHP-Based Assessment of Courier Service Preferences Among Malaysian Users

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ABSTRACT

This study addresses the problem of understanding users' preferences for courier services in Malaysia. As online shopping and package delivery become increasingly prevalent, it is essential to identify the key factors that influence users' decisions when choosing a courier service. The Fuzzy Analytical Hierarchy Process (FAHP) method is employed to tackle this problem. The study aims to determine the relative importance of criteria such as responsiveness, reliability, empathy, assurance, and tangibility, along with their corresponding sub-criteria. A group of experts defined these criteria and sub-criteria, and a questionnaire was distributed to gather data on customer preferences. Using the FAHP technique, the study constructed a hierarchy tree, created a fuzzy pairwise comparison matrix, and calculated criterion and sub-criteria weights. The findings highlight the importance of responsiveness, particularly easy contact with courier companies, as the primary criterion. Enhancing services based on these insights can help users select suitable courier services while improving competitiveness in the industry.

1. INTRODUCTION

Courier services are crucial in today's globalized and fast-paced economy, acting as the backbone for efficient business operations and seamless customer communication. These services ensure the timely and reliable delivery of goods, which is essential for maintaining customer satisfaction and operational efficiency. Prominent international courier companies such as DHL, JNT, GDEX, POS LAJU, and NINJA VAN have significantly contributed to the courier industry by providing extensive local and international express services. Their ability to deliver products swiftly and reliably has made them indispensable to both individuals and businesses worldwide (Gruenwald, 2020).

Despite their importance, courier services face numerous challenges, particularly in aligning with customer preferences. The COVID-19 pandemic has further complicated this landscape, with lockdowns

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in Malaysia leading to a surge in online shopping and an unprecedented demand for delivery services. In 2021, Malaysian courier service providers delivered approximately 737.36 million domestic items, driven by an e-commerce market valued at 28.5 billion Malaysian ringgit (Statista Research Department, 2022). However, this rapid growth has also highlighted issues such as service quality, reliability, and the handling of increased volumes of packages. Reports of mishandling and delays have surfaced, emphasizing the need for improved service management to maintain customer satisfaction and competitive edge. Understanding and addressing these challenges related to customer preferences is the main intention of this research.

To address the complex decision-making involved in selecting courier services, several Multi-Criteria Decision-Making (MCDM) techniques have been developed. These techniques aid in evaluating and prioritizing multiple criteria to make informed decisions. Common MCDM methods include the Analytical Hierarchy Process (AHP), which uses a structured hierarchy to model a decision problem and performs pairwise comparisons to determine the relative importance of criteria (Siekelova et al., 2021). Another method is the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), which identifies solutions from a finite set of alternatives based on their distance to an ideal solution (Dutta et al., 2019). Additionally, the Elimination and Choice Expressing Reality (ELECTRE) method is based on outranking and is used to handle complex decision-making scenarios with conflicting criteria (Zahid et al., 2022).

The Fuzzy Analytical Hierarchy Process (FAHP) extends the traditional AHP by incorporating fuzzy logic to handle the uncertainty and vagueness in human judgment. FAHP is particularly advantageous in situations where decision-makers face ambiguity in their evaluations. The method's ability to process imprecise data makes it highly suitable for assessing complex, subjective preferences in courier service selection. Previous applications of FAHP have demonstrated its effectiveness in various fields, including supply chain management, where it has been used to prioritize factors affecting supply chain performance (Mistarihi et al., 2023), healthcare, where it has helped in evaluating healthcare service quality by integrating fuzzy logic to manage subjective assessments (Azam et al., 2017), and transportation, where it has been applied to assess transportation modes considering multiple criteria and their fuzzy interactions (Zaid et al., 2024). Given its ability to handle complex, subjective, and imprecise data, FAHP is chosen for this research to assess customer preferences for courier services in Malaysia effectively.

The structure of this paper is as follows: Section 2: Preliminaries provides an overview of the key concepts and background information relevant to the study, including an introduction to the FAHP method and a review of the literature on courier service preferences. Section 3: Methodology describes the research design, including the selection and definition of criteria and sub-criteria, data collection methods, and the implementation of the FAHP technique. Section 4: Results and Discussion presents the findings from the FAHP analysis, detailing the calculated weights of criteria and sub-criteria, and discusses the implications of these findings in the context of existing literature and industry practices. Finally, Section 5: Conclusion summarizes the key findings of the study, discusses its contributions to the field, outlines its limitations, and provides suggestions for future research directions.

Through this FAHP-based assessment, the study aims to contribute to the academic understanding of customer preferences in the courier service industry and offer practical recommendations for service improvement.

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2. PRELIMINARIES

2.1 Background of Courier Services in Malaysia

The courier service industry in Malaysia has seen significant growth over the past few decades, becoming a vital part of the country's economy. This growth is largely due to the rapid rise of e-commerce, which has increased the demand for reliable and efficient delivery services. Key players in the Malaysian market include international companies such as DHL and FedEx, as well as local providers like POS LAJU, JNT, GDEX, and NINJA VAN. These companies offer a variety of services, including local and international deliveries and comprehensive logistics solutions for both individual customers and businesses.

However, despite their importance, courier services face several challenges. Issues of service quality and reliability are ongoing, particularly during peak shopping seasons and promotional periods when the volume of packages increases. The COVID-19 pandemic further intensified these challenges, as lockdowns led to a surge in online shopping and increased pressure on courier services. This surge exposed weaknesses in the system, with delays, mishandling of packages, and customer dissatisfaction becoming more common. Addressing these issues is crucial for maintaining customer trust and competitive advantage.

Several studies have examined these challenges. For example, Yee & Daud (2011) investigated the impact of service quality dimensions on customer satisfaction in package delivery. They found that tangibility, reliability, and assurance significantly affected customer satisfaction, while empathy and responsiveness did not. Similarly, Tabassum & Badiuddin (2014) used a modified SERVQUAL approach to measure the gap between customer expectations and perceptions of service quality, identifying dependability and responsiveness as areas needing improvement.

SERVQUAL, though widely used, has been criticized for its generality and lack of differentiation between service quality and customer satisfaction. This has led researchers to explore other methods for evaluating courier services. Liu & Liu (2014) used SERVQUAL and Logistic Service Quality (LSQ) models to study express logistics in Changdao County, China. They found significant gaps between customer expectations and perceived service quality, particularly in the protection dimension.

Another study done by Valaei et al. (2016) developed a specialized scale called CouQual, which includes dimensions such as promptness, convenience, accuracy, safety, and tangibles. They found that promptness, safety, and convenience were the most critical factors influencing customer perception of service quality.

In summary, traditional methods like SERVQUAL have provided insights into service quality but come with limitations. As a result, alternative models have been developed and tested to better capture the specific characteristics and challenges of the courier service industry.

2.2 Understanding Customer Preferences

Understanding customer preferences is crucial for courier service providers to improve their services and enhance customer satisfaction. Key factors influencing these preferences include responsiveness, reliability, empathy, assurance, and tangibility. These factors significantly shape customer decisions and perceptions, impacting their overall experience and loyalty to the service provider.

2.2.1 Responsiveness

Responsiveness refers to how quickly and effectively a company responds to customer inquiries and issues. It includes administrative efficiency, attention to customer needs, flexible operating hours, and personal attention from staff (El Saghier & Nathan, 2013). A study found that responsiveness positively

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correlates with customer happiness (Al-Weshah et al., 2013). Ensuring staff can communicate directly with customers and assist promptly improves responsiveness. Delays and distance can affect response times, especially in supply chains (Naik et al., 2010).

2.2.2 Reliability

Reliability involves consistently providing services correctly, on time, and maintaining accurate records (El Saghier & Nathan, 2013). This includes fulfilling customer demands accurately, managing records correctly, and ensuring timely deliveries. A study indicated that reliability significantly impacts customer satisfaction (Janahi & Al Mubarak, 2017). Customers expect high reliability from service providers, and when met, it increases their satisfaction and trust (Shahin & Chan, 2006; S. Alnsour et al., 2014).

2.2.3 Empathy

Empathy is about providing personalized attention and understanding customer needs (El Saghier & Nathan, 2013). It includes convenient office hours and hiring agents who care about customers' demands. Studies have shown that empathy positively affects customer satisfaction (Sureshchandar et al., 2002; S. Alnsour et al., 2014). Customers appreciate when service providers consider their needs, leading to higher satisfaction.

2.2.4 Assurance

Assurance involves the confidence customers have in the service, influenced by employees' expertise, friendliness, and professionalism (El Saghier & Nathan, 2013). It includes aspects like capability, kindness, validity, and security. Studies show that assurance positively impacts customer satisfaction and trust (Shahin & Chan, 2006; Naik et al., 2010). Ensuring that customers feel confident in the services provided is crucial for maintaining trust and satisfaction.

2.2.5 Tangibility

Tangibility refers to the physical aspects of the service, such as the condition of delivered packages and the appearance of facilities and equipment (El Saghier & Nathan, 2013). While tangibility has a less significant link to customer satisfaction, it still plays a role in the overall perception of service quality (Parasuraman et al., 1998). Contradictory findings suggest that in some sectors, like telecommunications in China, tangibility significantly impacts service quality and customer happiness (Noble et al., 2002).

2.3 Fuzzy Analytical Hierarchy Process (FAHP)

The Fuzzy Analytic Hierarchy Process (FAHP) is a robust methodology that integrates the traditional Analytic Hierarchy Process (AHP) with fuzzy set theory, employing triangular fuzzy numbers to enhance decision-making and problem-solving (Chang, 1996). While AHP is widely recognized and utilized, it faces criticism for not adequately addressing the inherent volatility and imprecision when translating decision-makers' subjective perceptions into exact values (Deng, 1999). FAHP was developed to mitigate these limitations by incorporating fuzziness into the decision-making process (Mikhailov & Tsvetinov, 2004). Through the use of fuzzy numbers, FAHP allows decision-makers to express preferences and approximations that more accurately reflect the inherent uncertainty in their judgments (Erensal et al., 2006; Wang et al., 2008; Feng, 1995).

Fuzzy set theory, developed by Zadeh (1965), underpins FAHP by providing a mathematical framework to simulate the fuzziness of human cognitive processes. Unlike traditional set theory, fuzzy set theory does not have sharp boundaries between classes (Van Laarhoven & Pedrycz, 1983). The membership function of a fuzzy set spans the range of real numbers, typically normalized to the interval [0, 1], allowing

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for a spectrum of membership levels. FAHP utilizes this flexibility by allowing decision-makers to choose from a range of values that reflect their confidence levels and to describe their outlook in broad terms, such as optimistic, pessimistic, or moderate (Jeganathan, 2003; Lee et al., 2008).

The versatility and effectiveness of FAHP have been demonstrated across various fields. For instance, Bhatt et al. (2021) applied FAHP to select an appropriate ERP system for SMEs, identifying deployment cost as the most critical factor. Büyüközkan et al. (2011) used FAHP to evaluate healthcare service quality in Turkey, highlighting the importance of compassion, competence, and reliability in delivering satisfactory services. Al-Shammari & Mili (2021) implemented FAHP for customer selection in commercial banks, showcasing the method's efficacy through a detailed numerical example.

Recent research further underscores the broad applicability of FAHP. Idris (2020) used FAHP to determine and rank the factors contributing to divorce in Perlis, Malaysia. FAHP was also employed to identify effective measures to prevent the spread of COVID-19 (Idris et al., 2023), select the best student award (Abd Aziz et al., 2023), determine the criteria for choosing tour packages in Langkawi Island (Zahrin et al., 2022), analyze the factors influencing career choices of graduate students at UiTM Perlis (Abd Aziz et al., 2024), and rank factors in selecting online shopping platforms in Malaysia (Abd Aziz et al., 2024).

From the extensive review of literature, it is evident that FAHP is a practical and straightforward approach to tackling complex selection problems, particularly in scenarios where uncertainty and imprecision are significant. The following section will outline the characteristics and applications of FAHP, providing a deeper understanding of its utility and effectiveness.

3. METHODOLOGY

This section outlines the methodology employed to assess courier service preferences among Malaysian users using the FAHP. The FAHP approach is utilized through a structured set of procedural steps to ensure a comprehensive and systematic analysis.

Step 1: Establish the hierarchical structure.

The methodology begins with the construction of a comprehensive three-tiered hierarchical framework to assess courier service preferences among Malaysian users, as depicted in Fig. 1. This hierarchical structure is designed to systematically break down and evaluate the complex factors influencing user preferences. At the top level, the primary objective is to rank the factors that influence users in selecting the most preferable courier services in Malaysia.

The second level, known as the criteria layer, categorizes the factors influencing user preferences into five main groups: Responsiveness, Reliability, Empathy, Assurance, and Tangibility. Responsiveness (C1) refers to the ability of the courier service to respond promptly and effectively to customer needs, while Reliability (C2) denotes the consistency and dependability of the courier service in fulfilling its promises. Empathy (C3) involves the courier service's ability to understand and address customer needs and concerns. Assurance (C4) encompasses the confidence and trust that customers have in the courier service, including the knowledge and courtesy of employees. Tangibility (C5) pertains to the physical aspects of the courier service, such as the condition of delivered packages and the appearance of personnel.

The third level, the sub-criteria layer, further breaks down these main criteria into more specific factors, resulting in a detailed and nuanced assessment framework. Under Responsiveness, the factors include easy contact with the courier company (SC1), efficient communication with the courier company (SC2), and efficient handling of returns (SC3). Reliability is broken down into successful delivery attempt

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(SC4), lack of damage to packages (SC5), and timeliness of delivery (SC6). Empathy includes readiness to react quickly to problem interference (SC7), availability of services (SC8), and understanding the demand of customers (SC9). Assurance is divided into knowledge and competency of employees (SC10), polite and courteous employees (SC11), and trust in the courier company (SC12). Finally, Tangibility includes the aesthetic and neat appearance of the courier (SC13), characteristic trademark and uniform color (SC14), and the goodness of the package condition (SC15).

Structuring the decision-making problem into these hierarchical levels allows for a methodical evaluation of each factor's relative importance. This framework provides a clear and organized approach to understanding and prioritizing the various elements that influence courier service preferences among Malaysian users.

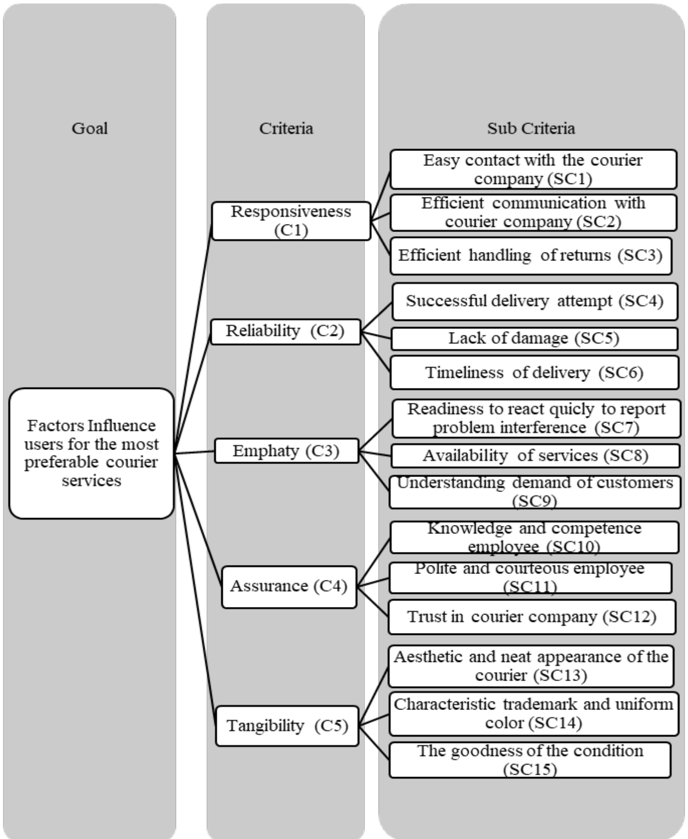

Fig. 1. A hierarchical model for preferable courier service

Step 2: Create a Fuzzy Pairwise Comparison Matrix

In this step, the decision-maker utilizes linguistic concepts, as provided in Table 1, to perform pairwise comparisons of criteria or sub-criteria. These linguistic concepts are associated with triangular fuzzy numbers (TFNs) to incorporate the inherent fuzziness and uncertainty in human judgment. The process for creating a fuzzy pairwise comparison matrix using TFNs is detailed below.

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The decision-maker starts by comparing each pair of criteria (or sub-criteria) using the linguistic terms that best describe their relative importance. These linguistic terms are then converted into TFNs, which are represented by three values: the minimum possible value a, the most possible value b, and the maximum possible value c. The membership function of a TFN, which defines how each value within the range contributes to the degree of membership, is mathematically expressed as follows:

$$\mu_{TFN}(x) = \begin{cases} \dfrac{x-a}{b-a} & ; \quad a \le x \le b \\ \dfrac{c-x}{c-b} & ; \quad b \le x \le c \\ 0 & ; \quad otherwise \end{cases} \tag{1}$$

These TFNs are typically expressed using a 1-9 scale, where each scale value corresponds to a linguistic term. This approach acknowledges that experts often find it challenging to quantify their judgments precisely using numerical values, hence the use of linguistic variables (Zadeh, 1965).

For instance, if the decision-maker states that "Criterion 1 (C1) is Slightly Important compared to Criterion 2 (C2)," they would use the fuzzy triangular scale (2, 3, 4). Conversely, when comparing C2 to C1, the inverse fuzzy triangular scale (1/4, 1/3, 1/2) would be employed, reflecting the reciprocal relationship between the two criteria (Ayhan, 2013). This process is repeated for all pairs of criteria and sub-criteria, resulting in a complete fuzzy pairwise comparison matrix.

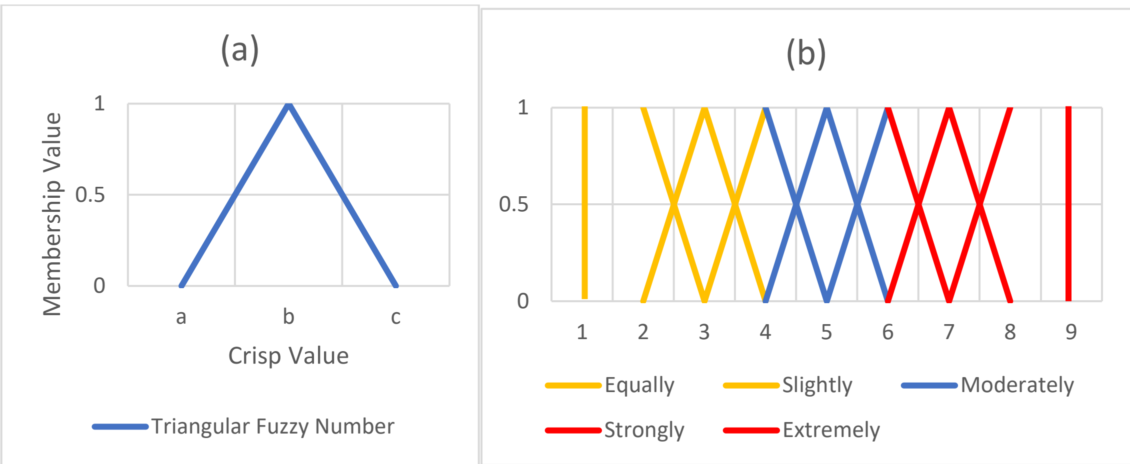

Fig. 2. (a) Membership function of triangular fuzzy numbers, (b) Linguistic variables

Fig. 2 illustrates the degree of possibility for TFNs, while Table 1 provides the non-fuzzy numbers representing the 1-9 scale, linguistic variables, and the TFNs with their reciprocal values used in the comparisons. By systematically applying this method, the decision-maker can construct a matrix that accurately captures the relative importance of each criterion and sub-criterion, taking into account the fuzziness and uncertainty inherent in human judgments.

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Table 1. Linguistic variables with its associated non-fuzzy number and TFN for pairwise comparison

Linguistic Variables	AHP Scale (Non-Fuzzy Numbers)	Fuzzy AHP Scale (TFNs)	Fuzzy AHP Scale (Reciprocal TFNs)
Equally Important	1	(1,1,1)	(1,1,1)
Slightly Important	3	(2,3,4)	(1/4,1/3,1/2)
Moderately Important	5	(4,5,6)	(1/6,1/5,1/6)
Strongly Important	7	(6,7,8)	(1/8,1/7,1/6)
Extremely Important	9	(9,9,9)	(1/9,1/9,1/9)
Intermediate Value	2	(1,2,3)	(1/4,1/2,1)
	4	(3,4,5)	(1/5,1/4,1/3)
	6	(5,6,7)	(1/7,1/6,1/5)
	8	(7,8,9)	(1/9,1/8,1,7)

The approach used to obtain input from expert decision-makers involves conducting interviews or using questionnaires. At this stage, the scale used is the non-fuzzy number scale, specifically the 1-9 scale. The collected input is then converted into a pairwise comparison matrix (PCM) to be checked for consistency, which will be demonstrated in the next step. Once the consistency value has been verified, the original PCM will be transformed into a PCM with TFN values, as shown in equation (3). From this updated PCM, the subsequent steps in the FAHP process will be carried out.

The following equation (2) is the general form of the PCM using the 1-9 scale values.

$$A^k = \begin{bmatrix} 1 & d_{12}^k & \cdots & d_{1n}^k \\ d_{21}^k & 1 & \cdots & d_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1}^k & d_{n2}^k & \cdots & 1 \end{bmatrix} \tag{2}$$

where k denotes the k-th expert, and $d_{11}^k, d_{12}^k, \dots, d_{nn}^k$ represent the input values for each factor given by the experts on a scale of 1 to 9. It is important to note that $d_{ji}^k = 1/d_{ij}^k$ and $d_{ii}^k = 1$ for every $i, j = 1,2, \dots, n$. In other words, if the essential preference d_{ij}^k is located in the upper triangle of the matrix, then the reciprocal value $d_{ji}^k = 1/d_{ij}^k$ must be positioned in the lower triangle, and vice versa. This ensures that the matrix accurately reflects the relative importance of each factor as assessed by the experts.

Next, the general form of the pairwise comparison matrix (PCM) with triangular fuzzy number (TFN) values is presented.

$$\tilde{A}^k = \begin{bmatrix} (1,1,1) & \tilde{d}_{12}^k & \cdots & \tilde{d}_{1n}^k \\ \tilde{d}_{21}^k & (1,1,1) & \cdots & \tilde{d}_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{d}_{n1}^k & \tilde{d}_{n2}^k & \cdots & (1,1,1) \end{bmatrix} \tag{3}$$

Here, $\tilde{d}_{11}^k, \tilde{d}_{12}^k, \dots, \tilde{d}_{nn}^k$ represent the input values that have been transformed from non-fuzzy numbers to TFNs, as illustrated in Table 1. This transformation allows for a more nuanced and accurate representation of the expert assessments, capturing the inherent uncertainty and fuzziness in their judgments.

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Step 3: Verifying the Consistency Test of the Judgement Matrix.

Verifying the consistency of the judgment matrix is an indispensable task due to the complexity of the objective and the subjectivity inherent in decision-makers' understanding. To ensure the reliability of the judgments, the consistency ratio index (CR) is calculated using the following formula:

$$CR = \frac{CI}{RI} \tag{4}$$

where

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{5}$$

and λ_{max} represents the largest eigenvalue of the comparison matrix, and *n* denotes the order or size of the matrix. *RI* stands for the average random consistency index of the judgment matrix, as shown in Table 2.

Table 2. Random consistency index

Matrix Order, *n*	1	2	3	4	5	6	7	8	9	10
Ratio Index, *RI*	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

If the *CR* is less than 10% or 0.1, the matrix consistency is considered reliable and acceptable. If it exceeds 10%, the assessor must re-evaluate and adjust the pairwise comparison matrix. The matrix used in calculating this consistency index is in the form of a matrix with non-fuzzy number elements, as shown in Equation (2).

Step 4: Calculate the Fuzzy Geometric Mean.

Once the consistency of the judgment matrices has been confirmed, these matrices are transformed into pairwise comparison matrices (PCM) with triangular fuzzy numbers (TFN), as shown in Equation (3). If multiple experts are involved, the next step is to calculate the average value for each PCM obtained. The formula used to obtain the updated matrix is as follows:

$$\tilde{A} = [\tilde{d}_{ij}] = \frac{\sum_{k=1}^{K} \tilde{d}_{ij}^{k}}{K} \tag{6}$$

where K is the number of experts. Here $\tilde{d}_{ij}^{k} = (l_{ij}^{k}, m_{ij}^{k}, u_{ij}^{k})$, where *l,m,u* represent the values in the TFNs separately.

According to Buckley & Eslami (2002), the fuzzy geometric mean, $\tilde{r}_i$ for the fuzzy comparison values of each criterion *i*, is calculated using Equation (7).

$$\tilde{r}_i = (\tilde{d}_{i1} \times \tilde{d}_{i2} \times \cdots \times \tilde{d}_{iN})^{\frac{1}{N}} \tag{7}$$

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where N is the number of factors. Following this, determine the vector summation of the geometric mean, $\sum_{i=1}^{N} \tilde{r}_i$ and its reciprocal, $(\sum_{i=1}^{N} \tilde{r}_i)^{-1}$ by applying Equations (8) and (9), respectively.

$$\sum_{i=1}^{N} \tilde{r}_i = \left(\sum l_{\tilde{r}_i}, \sum m_{\tilde{r}_i}, \sum u_{\tilde{r}_i}\right) \tag{8}$$

$$\left(\sum_{i=1}^{N} \tilde{r}_i\right)^{-1} = \left(\frac{1}{\sum u_{\tilde{r}_i}}, \frac{1}{\sum m_{\tilde{r}_i}}, \frac{1}{\sum l_{\tilde{r}_i}}\right) \tag{9}$$

Step 5: Calculate the Fuzzy Weight.

To obtain the fuzzy weight of each criterion $\widetilde{w}_i$, multiply each $\tilde{r}_i$ by the reciprocal of the vector summation of the geometric mean, as specified in Equation (10).

$$\widetilde{w}_i = \tilde{r}_i \times \left(\sum_{i=1}^{N} \tilde{r}_i\right)^{-1} \tag{10}$$

Step 6: Defuzzify and Normalize the Weight of Criteria

It must be noted that $\widetilde{w}_i$ are still expressed as triangular numbers, $\left(\tilde{l}_i, \widetilde{m}_i, \tilde{u}_i\right)$. To convert these into crisp values, the Center of Area method proposed by Chou & Chang (2008) can be employed in the defuzzification process, as shown in Equation (11):

$$M_i = \frac{\tilde{l}_i + \widetilde{m}_i + \tilde{u}_i}{3} \tag{11}$$

Next, to obtain the final weight values, Equation (12) is used to normalize M_i and find the normalized weight, Z_i.

$$Z_i = \frac{M_i}{\sum_{i=1}^{N} M_i} \tag{12}$$

By following these steps, the fuzzy weights are converted into crisp, normalized values suitable for further analysis. These six processes determine the normalized weights of the criteria and sub-criteria. The global weight for each sub-criterion is then calculated by multiplying each sub-criteria's weight by the corresponding criterion's weight. These results highlight to the decision-maker which sub-criteria have the greatest global weight, providing clear insights into the most influential factors.

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4. RESULT AND DISCUSSION

This section presents the results and discussion based on the FAHP process to identify the factors influencing users in choosing courier services. The study gathers insights from two experts with extensive experience in the courier service industry. Separate discussions and interviews were conducted with each expert to obtain input, which was then used to create the Pairwise Comparison Matrix (PCM) for criteria and sub-criteria from Fig. 1- an essential first step in the FAHP process. These matrices are shown in Tables 3 and 4, along with the consistency ratio (CR) values for each.

4.1 Consistency Test

Table 3. Pairwise comparison matrix for criteria, including the consistency ratio for experts 1 and 2

EXPERT 1						
Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**CR**
C1	1	5	6	8	9	
C2	1/5	1	1/2	3	7	
C3	1/6	2	1	2	6	0.0849
C4	1/8	1/3	1/2	1	4	
C5	1/9	1/7	1/6	1/4	1	
EXPERT 2						
Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**CR**
C1	1	8	3	4	1	
C2	1/8	1	1/5	1/2	1/4	
C3	1/3	5	1	2	1	0.0448
C4	1/4	2	1/2	1	1/6	
C5	1	4	1	6	1	

Table 4. Pairwise comparison matrix for sub-criteria including the consistency ratio for experts 1 and 2

EXPERT 1				
Sub-Criteria	**SC1**	**SC2**	**SC3**	**CR**
SC1	1	5	9	
SC2	1/5	1	4	0.062
SC3	1/9	1/4	1	
Sub-Criteria	**SC4**	**SC5**	**SC6**	**CR**
SC4	1	5	1/3	
SC5	1/5	1	1/9	0.025
SC6	3	9	1	
Sub-Criteria	**SC7**	**SC8**	**SC9**	**CR**
SC7	1	1/2	1/9	
SC8	2	1	1/5	0.001
SC9	9	5	1	
Sub-Criteria	**SC10**	**SC11**	**SC12**	**CR**
SC10	1	1/5	1/8	
SC11	5	1	1/3	0.038
SC12	8	3	1	

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EXPERT 2				
Sub-Criteria	**SC1**	**SC2**	**SC3**	**CR**
SC1	1	3	9	
SC2	1/3	1	2	0.016
SC3	1/9	1/2	1	
Sub-Criteria	**SC4**	**SC5**	**SC6**	**CR**
SC4	1	1/6	1/4	
SC5	6	1	1	0.016
SC6	4	1	1	
Sub-Criteria	**SC7**	**SC8**	**SC9**	**CR**
SC7	1	1/9	1/5	
SC8	9	1	4	0.062
SC9	5	1/4	1	
Sub-Criteria	**SC10**	**SC11**	**SC12**	**CR**
SC10	1	1/8	1/6	
SC11	8	1	3	0.064
SC12	6	1/3	1	

4.2 Fuzzy Geometric Mean

Based on the consistency ratio values obtained for each criterion and sub-criterion as shown in Tables 3 and 4, all values are within the acceptable range of less than 10% or 0.1. This indicates that the evaluations made by all experts are reliable and acceptable. The next step is to calculate the Fuzzy Geometric Mean. However, before proceeding, all PCM values in Tables 3 and 4 need to be converted to TFNs as indicated in Table 1. After converting to TFNs, the average value is calculated for each PCM of criteria and sub-criteria, as more than one expert is involved, as shown in Equation (6). These values are presented in Tables 5 and 6.

Table 5. Average of pairwise comparison matrix for criteria

Criteria	C1	C2	C3	C4	C5
C1	(1,1,1)	(5.5,6.5,7.5)	(3.5,4.5,5.5)	(5,6,7)	(5,5,5)
C2	(0.139,0.163,0.196)	(1,1,1)	(0.25,0.35,0.625)	(1.167,1.75,2.5)	(3.1,3.625,4.167)
C3	(0.196,0.25,0.35)	(2.5,3.5,4.5)	(1,1,1)	(1,2,3)	(3,3.5,4)
C4	(0.156,0.188,0.238)	(0.625,1.167,1.75)	(0.333,0.5,1)	(1,1,1)	(0.171,0.208,0.267)
C5	(0.556,0.556,0.556)	(1.563,2.071,2.583)	(0.571,0.583,0.6)	(2.6,3.125,3.667)	(1,1,1)

Table 6. Average of pairwise comparison matrix for sub-criteria.

Sub-Criteria	SC1	SC2	SC3
SC1	(1,1,1)	(3,4,5)	(9,9,9)
SC2	(0.208,0.267,0.375)	(1,1,1)	(2,3,4)
SC3	(0.111,0.111,0.111)	(0.267,0.375,0.667)	(1,1,1)
Sub-Criteria	**SC4**	**SC5**	**SC6**
SC4	(1,1,1)	(2.071,2.583,3.1)	(0.225,0.292,0.417)
SC5	(2.583,3.1,3.625)	(1,1,1)	(0.556,0.556,0.556)
SC6	(2.5,3.5,4.5)	(5,5,5)	(1,1,1)
Sub-Criteria	**SC7**	**SC8**	**SC9**

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SC7	(1,1,1)	(0.222,0.306,0.556)	(0.139,0.156,0.181)
SC8	(5,5.5,6)	(1,1,1)	(1.583,2.1,2.625)
SC9	(7.5,7,6.5)	(2.1,2.625,3.167)	(1,1,1)
Sub-Criteria	**SC10**	**SC11**	**SC12**
SC10	(1,1,1)	(0.139,0.163,0.196)	(0.127,0.146,0.171)
SC11	(5.5,6.5,7.5)	(1,1,1)	(1.125,1.667,2.25)
SC12	(6,7,8)	(1.125,1.667,2.25)	(1,1,1)

Once the average PCM values for each criterion and sub-criterion have been obtained, the process continues with the calculation of the Fuzzy Geometric Mean as shown in Equations (7), (8), and (9). The results of these calculations are presented in Tables 7 and 8.

Table 7. Fuzzy Geometric Mean for all criteria.

Criteria, $\tilde{r}_i$	***l***	***m***	***u***
C1, $\tilde{r}_1$	3.439	3.878	4.284
C2, $\tilde{r}_2$	0.660	0.816	1.050
C3, $\tilde{r}_3$	1.081	1.437	1.800
C4, $\tilde{r}_4$	0.354	0.469	0.644
C5, $\tilde{r}_5$	1.052	1.160	1.259
$\sum_{i=1}^{5} \tilde{r}_i$	**6.586**	**7.760**	**9.038**
$\left(\sum_{i=1}^{5} \tilde{r}_i\right)^{-1}$	**0.111**	**0.129**	**0.152**

Table 8. Fuzzy Geometric Mean for all sub-criteria.

Sub-Criteria, $\tilde{r}_i$	***l***	***m***	***u***
SC1, $\tilde{r}_1$	3.000	3.302	3.557
SC2, $\tilde{r}_2$	0.747	0.928	1.145
SC3, $\tilde{r}_3$	0.309	0.347	0.420
$\sum_{i=1}^{3} \tilde{r}_i$	**4.056**	**4.577**	**5.122**
$\left(\sum_{i=1}^{3} \tilde{r}_i\right)^{-1}$	**0.195**	**0.218**	**0.247**
Sub-Criteria, $\tilde{r}_i$	***l***	***m***	***u***
SC4, $\tilde{r}_1$	0.775	0.910	1.089
SC5, $\tilde{r}_2$	1.128	1.199	1.263
SC6, $\tilde{r}_3$	2.321	2.596	2.823

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$\sum_{i=1}^{3} \tilde{r}_i$	**4.224**	**4.705**	**5.175**
$\left(\sum_{i=1}^{3} \tilde{r}_i\right)^{-1}$	**0.193**	**0.213**	**0.237**
Sub-Criteria, $\tilde{r}_i$	***l***	***m***	***u***
SC7, $\tilde{r}_1$	0.314	0.362	0.465
SC8, $\tilde{r}_2$	1.993	2.260	2.507
SC9, $\tilde{r}_3$	2.507	2.639	2.741
$\sum_{i=1}^{3} \tilde{r}_i$	**4.813**	**5.261**	**5.712**
$\left(\sum_{i=1}^{3} \tilde{r}_i\right)^{-1}$	**0.175**	**0.190**	**0.208**
Sub-Criteria, $\tilde{r}_i$	***l***	***m***	***u***
SC10, $\tilde{r}_1$	0.260	0.287	0.323
SC11, $\tilde{r}_2$	1.836	2.213	2.565
SC12, $\tilde{r}_3$	1.890	2.268	2.621
$\sum_{i=1}^{3} \tilde{r}_i$	**3.986**	**4.768**	**5.509**
$\left(\sum_{i=1}^{3} \tilde{r}_i\right)^{-1}$	**0.182**	**0.210**	**0.251**
Sub-Criteria, $\tilde{r}_i$	***l***	***m***	***u***
SC13, $\tilde{r}_1$	0.439	0.471	0.538
SC14, $\tilde{r}_2$	0.512	0.615	0.716
SC15, $\tilde{r}_3$	3.377	3.653	3.915
$\sum_{i=1}^{3} \tilde{r}_i$	**4.327**	**4.738**	**5.168**
$\left(\sum_{i=1}^{3} \tilde{r}_i\right)^{-1}$	**0.193**	**0.211**	**0.231**

The process continues by obtaining the Fuzzy Weight for each criterion using Equation (10). Following this, the fuzzy weight values are defuzzified, and then normalized using Equations (11) and (12) respectively. These results are presented in Table 9. Based on the final values, a ranking is established, allowing for the subsequent decision analysis related to the criteria.

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Table 9. Fuzzy Weight, defuzzified and normalized value for all criteria.

Criteria	$\widetilde{w}_i$	M_i	Z_i	Rank
C1	(0.381,0.500,0.651)	0.510	0.494	1
C2	(0.073,0.105,0.159)	0.113	0.109	4
C3	(0.120,0.185,0.273)	0.193	0.186	2
C4	(0.039,0.060,0.098)	0.066	0.064	5
C5	(0.116,0.149,0.191)	0.152	0.147	3
	TOTAL	**1.034**	**1.000**	

The same procedure will be applied to the sub-criteria using Equations (10), (11), and (12) to obtain the Fuzzy Weight, defuzzified, and normalized values for the sub-criteria. To determine the overall ranking of the sub-criteria, the normalized value of each criterion is multiplied by the normalized value of each sub-criterion, resulting in the global weight. This global weight is then analyzed to establish the comprehensive ranking of the sub-criteria. All these results are presented in Table 10.

Table 10. Fuzzy Weight, defuzzified and normalized value for all sub-criteria.

Criteria	$Z_i(C)$	Sub-Criteria	$\widetilde{w}_i$	M_i	$Z_i(SC)$	$Z_i(C) \times Z_i(SC)$	Global Weight	Rank
C1	0.494	SC1	(0.586,0.721,0.877)	0.728	0.715	0.3532	0.353	1
		SC2	(0.146,0.203,0.282)	0.210	0.207	0.1023	0.102	3
		SC3	0.060,0.076,0.104)	0.080	0.078	0.0385	0.039	7
C2	0.109	SC4	(0.150,0.193,0.258)	0.200	0.198	0.0216	0.022	11
		SC5	(0.218,0.255,0.299)	0.257	0.254	0.0277	0.028	10
		SC6	(0.448,0.552,0.668)	0.556	0.549	0.0598	0.060	6
C3	0.186	SC7	(0.055,0.069,0.097)	0.073	0.073	0.0136	0.014	14
		SC8	(0.349,0.430,0.521)	0.433	0.429	0.0798	0.080	5
		SC9	(0.439,0.502,0.569)	0.503	0.498	0.0926	0.093	4
C4	0.064	SC10	(0.047,0.060,0.081)	0.063	0.061	0.0039	0.004	15
		SC11	(0.333,0.464,0.643)	0.480	0.464	0.0297	0.030	9
		SC12	(0.343,0.476,0.657)	0.492	0.475	0.0304	0.030	8
C5	0.147	SC13	(0.085,0.099,0.124)	0.103	0.102	0.0150	0.015	13
		SC14	(0.099,0.130,0.165)	0.131	0.103	0.0191	0.019	12
		SC15	(0.653,0.771,0.905)	0.776	0.768	0.1129	0.113	2
			TOTAL			**1.0001**	**1.000**	

The analysis of Table 9 reveals that Responsiveness (C1) is the most critical factor for users when choosing a courier service in Malaysia, with the highest normalized value z_i of 0.494. This is followed by Empathy (C3) and Tangibility (C5), with normalized values of 0.186 and 0.147, respectively. Reliability (C2) and Assurance (C4) are considered less critical, with values of 0.109 and 0.064. These findings suggest that courier services should prioritize improving responsiveness and empathy to meet user expectations, while also maintaining a focus on reliability and assurance. The consistency in weight distribution using the FAHP method highlights the reliability of these results.

The analysis of Table 10 identifies the most and least influential sub-criteria impacting user preferences for courier services in Malaysia. The sub-criteria with the highest global weight is SC1 (Easy contact with the courier company), which has a normalized value of 0.353, indicating its paramount

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importance. This is followed by SC15 (The goodness of the condition), with a global weight of 0.113, highlighting the significance of the condition in which items are delivered.

Other noteworthy sub-criteria include SC9 (Understanding the demand of customers) and SC2 (Efficient communication with the courier company), which rank third and fourth, respectively. This suggests that clear communication and understanding customer needs are also critical factors for users.

In contrast, the sub-criteria with the least influence include SC10 (Knowledge and competency of employees), SC7 (Readiness to react quickly to problem interference), and SC13 (Aesthetic and neat appearance of the courier), with the lowest global weights. While these factors are still important, they are less critical compared to responsiveness and the physical condition of deliveries.

These insights can guide courier service providers in prioritizing improvements in areas that matter most to users, such as ensuring ease of contact, maintaining the condition of deliveries, and understanding customer needs. However, it is also important to recognize that aspects like employee knowledge and aesthetic appearance, though less critical, should not be neglected entirely.

5. CONCLUSION

The study highlights that responsiveness, empathy, and tangibility are the most critical factors influencing user preferences for courier services in Malaysia, with responsiveness being the highest priority. Conversely, reliability and assurance are less critical but still important. The most influential sub-criteria include ease of contact with the courier company and the condition of delivered items. These findings suggest that courier services should prioritize improving responsiveness and empathy, while maintaining reliability and assurance, to meet user expectations.

Compared to previous studies using the SERVQUAL model, which provided valuable but somewhat limited insights, this study offers a more nuanced understanding of user preferences by employing the Fuzzy AHP method. This approach allows for a more accurate evaluation of the complex and subjective nature of service quality in the courier industry. The results indicate that the Fuzzy AHP method is better suited for capturing the specific characteristics of courier services, leading to more actionable recommendations.

For future studies, it is recommended to include a larger and more diverse sample size, explore the impact of technological advancements, and conduct comparative and longitudinal analyses. Additionally, integrating customer satisfaction metrics, qualitative insights, and examining the effects of e-commerce growth and environmental factors can provide a deeper understanding of user preferences. Incorporating Fuzzy TOPSIS as a complementary method could further refine decision-making processes by ranking courier services based on multiple criteria. Investigating policy implications and conducting global comparisons can also offer valuable insights and help tailor services to evolving demands.

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7. CONFLICT OF INTEREST STATEMENT

The authors confirm that this research was conducted without any personal, commercial, or financial conflicts of interest and declare no conflicting interests with the funders.

8. AUTHORS' CONTRIBUTIONS

Mohd Fazril Izhar Mohd Idris: Conceptualisation, supervision, methodology, formal analysis, investigation, writing- review and editing, and validation; **Khairu Azlan Abd Aziz**: Conceptualisation, methodology, and formal analysis; **Nurfilzah Muhammad Munib**: Conceptualisation, methodology, formal analysis, and writing-original draft.

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