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Utilizing the Fuzzy Analytical Hierarchy Process (FAHP) Approach to Identify the Best Online Food Delivery Services

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Abstract: The rapid growth of online food delivery (OFD) services has led to an overwhelming number of options available to consumers. Choosing the best service provider among the multitude of available options has become a complex decision-making process. This study proposes Fuzzy Analytical Hierarchy Process (FAHP) approach to evaluate and rank three popular OFDs: Foodpanda, GrabFood, and OdaMakan, among students at Universiti Teknologi MARA (UiTM) Kelantan Branch, Kota Bharu Campus. Three experts were invited to assess and rate the performance values of criteria and alternatives using a linguistic scale. The evaluation is based on four criteria: service, cost, time, and quality. The fuzzy set theory is utilized to transform the linguistic evaluation statements of experts into criteria weights that are produced by the FAHP. The results demonstrate the effectiveness of the FAHP in selecting the best OFD and that GrabFood is at the first ranking followed by Foodpanda and OdaMakan. Cost is identified as the most important criterion followed by time, service, and quality. The findings of this study can assist OFD providers in understanding the factors that contribute to customer satisfaction and help them to improve their services accordingly.

Keywords: Decision-making, Fuzzy Analytical Hierarchy Process, Online food delivery services

1 Introduction

Online food delivery (OFD) is the practise of placing an online meal order with a restaurant or other eating facilities and having the food delivered to a predetermined location. Customers can browse menus, choose dishes, personalise orders, and place payments online by using a website or mobile app that connects them with several dining options. This service is analogous to shopping on the internet. Today's culture has many options for living, including food selection. The Analytic Hierarchy Process (AHP) is a decision-making framework applicable to a variety of domains, such as online food delivery.

The AHP approach, introduced by Thomas Saaty [1], is a modern tool for dealing with complex decision-making and may help the decision maker to set priorities to make the best decision. According to Idris [2], due to its potential and aptitude, FAHP is the best way to improve the consistency and accuracy of decision makers' judgement. AHP also allows the decision maker to analyse the consistency of their choices and do sensitivity analysis. Besides that, the fuzzy AHP method is applicable as a control for quality and useful for multi criteria decision making problems [3]. The AHP approach is a typical MCDM method for determining criterion weights. This method can help improve user experience and selection process for online meal delivery.

Van Laarhoven and Pedrycz Laarhoven, as cited in Nguyen [4], compared fuzzy ratios defined by fuzzy triangular numbers, which was the first work on FAHP. The approach uses a fuzzy logarithmic

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least squares method to extract fuzzy weights from fuzzy comparison matrices. As stated by Buckley, the geometric mean approach was used to estimate fuzzy weights of comparison ratios with trapezoidal fuzzy integers. An extent analysis approach was suggested for FAHP that derived crisp weights using fuzzy triangular numbers for pairwise comparison matrices [5]. Then, a fuzzy prioritization approach was proposed for nonlinear optimization to extract crisp weights from fuzzy comparison matrices [6]. The weights of the criteria proposed in this study were determined using the fuzzy AHP technique.

Due to their ease of modelling and understanding, triangular fuzzy numbers (TFNs) and trapezoidal fuzzy numbers (TrFNs) can be used to represent fuzzy numbers to reflect decision makers' judgements [7]. It has been common practise to model fuzzy data using TFNs and TrFNs, two restrict fuzzy sets with convexity and normalisation. However, as TFNs are suitable to express the level of fuzzy linguistic variables, our study concentrated on them. TFNs are utilised because they effectively ensure the integrity of decision-making information.

Since the growth of the internet and electronic commerce, information and communication technology have become integral aspects of people’s daily lives. OFD services have also become prompter and quicker to keep increasing among consumers. At the same time, the battle between the OFD providers has become more competitive [8]. As consumers, we will seek the most advantageous offers, including OFD services. Consequently, how do we, as consumers, identify the finest service on the market?

Therefore, this study aims to identify the best online food delivery services among students by measuring service factors as well as technical factors for selecting food delivery service providers in UiTM Kelantan Branch, Kota Bharu Campus by using FAHP. The alternatives that have been chosen are Foodpanda, GrabFood and OdaMakan while service, cost, time, and quality are the criteria for the alternative to present the result of the best online food delivery services.

2 Methodology

This paper used the method of FAHP, in order to achieve the main purpose of this paper which is to apply Fuzzy Triangular Number in MCDM as well as to rank the most reliable online food delivery services by using FAHP method. There are six steps involved in this study.

Step 1: Construct the pairwise comparison matrices, $\tilde{M}$ for all criteria.

This matrix was an n x 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 experts made pairwise comparisons of the importance or preference between each pair of criteria.

Table 1: Linguistic Terms in FAHP model.

Fuzzy Number	Linguistic Variables	Fuzzy Triangle Scale
1	Equal Importance	(1,1,1)
2	Weak Importance	(1,2,3)
3	Not Bad	(2,3,4)
34	Preferable	(3,4,5)
5	Important	(4,5,6)
6	Fairly Important	(5,6,7)
7	Very Important	(6,7,8)
8	Absolute	(7,8,9)
9	Perfect	(8,9,10)

The comparison of criterion was measured according to the numerical scale 1-9 in the form of linguistic variables adapted from Nguyen et al. [9] as shown in Table 1. This can be achieved through questionnaires. Suppose that a decision group consists of K experts. The geometrical mean was used to create an aggregated fuzzy pairwise comparison matrix as seen in Equation (1).

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

Step 2: Calculating consistency ratio for criteria pairwise comparison matrix.
Eigenvalue method was suggested to perform the consistency check. The consistency ratio (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, as shown in Table 2 [10].

Table 2: Random Consistency Index, RI

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Let $\tilde{M}$ denotes pairwise comparison matrix and priority weight matrix. $\lambda_{\max}$ was computed by taking average of eigenvalues. N is denoted by a number of criteria. Finally, consistency index (CI) and consistency ratio (CR) were computed according to Equation (2) and Equation (3). If the CR of criteria is less than 0.1, the comparisons' consistency is validated, and other steps can be performed. If not, comparisons must be revised.

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

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

Step 3: Calculating the geometric mean of fuzzy comparison values.
Used the fuzzy geometrical mean technique to define the fuzzy geometrical mean of each criterion, which was calculated by Equation (4).

$$\tilde{r}_i = (\prod_{j=1}^{n} l_{ij})^{1/n} \text{ such that } i = 1, 2, ..., n \quad (4)$$

where 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: Calculating the fuzzy preference weights.
By including the subs steps which is 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. Defined the fuzzy preference weights of each criterion, which was calculated by Equation (6).

$$\text{vector summation} = \sum r_i \quad (5)$$

$$w_i = r_i (\times) \left(\tilde{r}_1 (+) \tilde{r}_2 (+) ... (+) \tilde{r}_n \right)^{-1} \quad (6)$$

Step 5: Defuzzifying the fuzzy preference weights of criterion.
Defuzzification of the fuzzy weights is also known as average weight criteria. The fuzzy weights need to be defuzzified because w_i are still fuzzy triangular numbers. The calculation of the defuzzification can be done by using Equation (7) below.

$$G_i = \frac{w_1(+)w_2(+)...(+)w_n}{n} \tag{7}$$

Step 6: Normalizing the defuzzified weight of criterion.
The normalization of the defuzzified weight of criterion is required as G_i is a non-fuzzy number. Equation (8) below shows how to calculate the normalization of each criteria.

$$H_i = \frac{G_i}{\sum_{i=1}^{n} G_i} \tag{8}$$

Step 6 will result in the normalized weights for the criterion, H_i. The results were then ordered according to the normalized weights for each of the criteria.

3 Implementation

In this study, three students from UiTM Kelantan Branch, Kota Bharu Campus who became the decision makers namely DM_1, DM_2, and DM_3 have been selected to voice their opinion regarding the survey on the factors that influence people to purchase food online based on the chosen alternatives. This study's scope is limited to students at the Kota Bharu Campus who consistently use the services. Three online food delivery services were chosen namely A_1 = Foodpanda, A_2 = GrabFood and A_3 = OdaMakan. The criteria involved are C_1 = service, C_2 = cost, C_3 = time, and C_4 = quality.

Step 1: Construct the pairwise comparison matrices, $\tilde{M}$ for all criteria.
The data obtained from questionnaires were transformed into linguistic terms fuzzy numbers using Table 1. The importance comparison for each factor was performed via questionnaire. The pairwise comparison matrix is shown in Table 3 and Table 4.

Table 3: Pairwise Comparison Matrices for Criteria.

Criteria				
DM₁	**C₁**	**C₂**	**C₃**	**C₄**
C₁	(1, 1, 1)	(2, 3, 4)	(4, 5, 6)	(4, 5, 6)
C₂	(0.25, 0.33, 0.5)	(1, 1, 1)	(1, 1, 1)	(2, 3, 4)
C₃	(0.1667, 0.2, 0.25)	(1, 1, 1)	(1, 1, 1)	(4, 5, 6)
C₄	(0.1667, 0.2, 0.25)	(0.25, 0.33, 0.5)	(0.1667, 0.2, 0.25)	(1, 1, 1)
DM₂				
C₁	(1, 1, 1)	(0.1, 0.111, 0.1250)	(2, 3, 4)	(0.25, 0.33, 0.5)
C₂	(8, 9, 10)	(1, 1, 1)	(6, 7, 8)	(4, 5, 6)
C₃	(0.25, 0.33, 0.5)	(0.1250, 0.1429, 0.1667)	(1, 1, 1)	(0.1667, 0.2, 0.25)
C₄	(2, 3, 4)	(0.1667, 0.2, 0.25)	(4, 5, 6)	(1, 1, 1)
DM₃				
C₁	(1, 1, 1)	(2, 3, 4)	(0.1667, 0.2, 0.25)	(0.25, 0.33, 0.5)
C₂	(0.25, 0.33, 0.5)	(1, 1, 1)	(0.1250, 0.1429, 0.1667)	(0.1667, 0.2, 0.25)
C₃	(4, 5, 6)	(6, 7, 8)	(1, 1, 1)	(4, 5, 6)
C₄	(2, 3, 4)	(4, 5, 6)	(0.1667, 0.2, 0.25)	(1, 1, 1)

Table 3: Pairwise Comparison Matrices for Alternatives.

Service			
DM₁	**A₁**	**A₂**	**A₃**
A₁	(1, 1, 1)	(0.25, 0.33, 0.5)	(6, 7, 8)
A₂	(2, 3 4)	(1, 1, 1)	(8, 9, 10)
A₃	(0.1250, 0.1429, 0.1667)	(0.1, 0.111, 0.1250)	(1, 1, 1)

DM2			
A1	(1, 1, 1)	(0.1667, 0.2, 0.25)	(2, 3 4)
A2	(4, 5, 6)	(1, 1, 1)	(6, 7, 8)
A3	(0.25, 0.33, 0.5)	(0.1250, 0.1429, 0.1667)	(1, 1, 1)
DM3			
A1	(1, 1, 1)	(2, 3 4)	(8, 9, 10)
A2	(0.25, 0.33, 0.5)	(1, 1, 1)	(6, 7, 8)
A3	(0.1, 0.111, 0.1250)	(0.1250, 0.1429, 0.1667)	(1, 1, 1)
Cost			
DM1	**A1**	**A2**	**A3**
A1	(1, 1, 1)	(0.25, 0.33, 0.5)	(6, 7, 8)
A2	(2, 3 4)	(1, 1, 1)	(8, 9, 10)
A3	(0.1250, 0.1429, 0.1667)	(0.1, 0.111, 0.1250)	(1, 1, 1)
DM2			
A1	(1, 1, 1)	(1, 1, 1)	(6, 7, 8)
A2	(1, 1, 1)	(1, 1, 1)	(8, 9, 10)
A3	(0.1250, 0.1429, 0.1667)	(0.1, 0.111, 0.1250)	(1, 1, 1)
DM3			
A1	(1, 1, 1)	(2, 3 4)	(8, 9, 10)
A2	(0.25, 0.33, 0.5)	(1, 1, 1)	(6, 7, 8)
A3	(0.1, 0.111, 0.1250)	(0.1250, 0.1429, 0.1667)	(1, 1, 1)

Time			
DM1	**A1**	**A2**	**A3**
A1	(1, 1, 1)	(0.25, 0.33, 0.5)	(6, 7, 8)
A2	(2, 3 4)	(1, 1, 1)	(8, 9, 10)
A3	(0.1250, 0.1429, 0.1667)	(0.1, 0.111, 0.1250)	(1, 1, 1)
DM2			
A1	(1, 1, 1)	(0.333, 0.5, 1)	(7, 8, 9)
A2	(1, 2, 1)	(1, 1, 1)	(7, 8, 9)
A3	(0.111, 0.1250, 0.1429)	(0.111, 0.1250, 0.1429)	(1, 1, 1)
DM3			
A1	(1, 1, 1)	(2, 3 4)	(0.1667, 0.2, 0.25)
A2	(0.25, 0.33, 0.5)	(1, 1, 1)	(0.1429, 0.1667, 0.2)
A3	(4, 5, 6)	(5, 6, 7)	(1, 1, 1)
Quality			
DM1	**A1**	**A2**	**A3**
A1	(1, 1, 1)	(0.333, 0.5, 1)	(4, 5, 6)
A2	(1, 2, 3)	(1, 1, 1)	(4, 5, 6)
A3	(0.1667, 0.2, 0.25)	(0.1667, 0.2, 0.25)	(1, 1, 1)
DM2			
A1	(1, 1, 1)	(0.25, 0.33, 0.5)	(4, 5, 6)
A2	(2, 3, 4)	(1, 1, 1)	(5, 6, 7)
A3	(0.1667, 0.2, 0.25)	(0.1429, 0.1667, 0.2)	(1, 1, 1)
DM3			
A1	(1, 1, 1)	(3, 4, 5)	(6, 7, 8)
A2	(0.25, 0.33, 0.5)	(1, 1, 1)	(3, 4, 5)
A3	(0.1250, 0.1429, 0.1667)	(0.25, 0.33, 0.5)	(1, 1, 1)

The three experts then calculated an average based on each expert's preference. Following that, updated pairwise comparison matrices using Equation (1) for all the criteria and alternatives were constructed. Table 4 and Table 5 display the aggregated fuzzy evaluation matrix for criteria and alternatives in relation to the objective with a triangular fuzzy number.

Table 4: Aggregated Fuzzy Number for Criteria.

Criteria				
	C_1	**C_2**	**C_3**	**C_4**
C_1	(1, 1, 1)	(1.3667, 2.0370, 2.7083)	(2.0566, 2.7333, 3.4167)	(1.5000, 1.8889, 2.3333)
C_2	(2.8333, 3.2222, 3.6667)	(1, 1, 1)	(2.3750, 2.7143, 3.0556)	(2.0566, 2.7333, 3.4167)
C_3	(1.4722, 1.8444, 2.2500)	(2.3750, 2.7143, 3.0556)	(1, 1, 1)	(2.7222, 3.4000, 4.0833)
C_4	(1.3889, 2.0667, 2.7500)	(1.4722, 1.8444, 2.2500)	(1.4444, 1.8000, 2.1667)	(1, 1, 1)

Table 5: Aggregated Fuzzy Number for Alternatives.

Service			
C_1	**A_1**	**A_2**	**A_3**
A_1	(1, 1, 1)	(0.8056, 1.1778, 1.5833)	(5.3333, 6.3333, 7.3333)
A_2	(2.0833, 2.7778, 3.5)	(1, 1, 1)	(6.6667, 7.6667, 8.6667)
A_3	(0.1583, 0.1958, 0.2639)	(0.1167, 0.1323, 0.1528)	(1, 1, 1)
C_2			
A_1	(1, 1, 1)	(1.0833, 1.4444, 1.8333)	(6.6667, 7.6667, 8.6667)
A_2	(1.0833, 1.4444, 1.8333)	(1, 1, 1)	(7.3333, 8.3333, 9.3333)
A_3	(0.1167, 0.1323, 0.1528	(0.1083, 0.1217, 0.1389)	(1, 1, 1)
C_3			
A_1	(1, 1, 1)	(0.8611, 1.2778, 1.8333)	(4.3889, 5.0667, 5.7500)
A_2	(1.0667, 1.7778, 2.5000)	(1, 1, 1)	(5.0476, 5.7222, 6.4000)
A_3	(1.4120, 1.7560, 2.1032)	(1.7370, 2.0787, 2.4226)	(1, 1, 1)
C_4			
A_1	(1, 1, 1)	(1.1944, 1.6111, 2.1667)	(4.6667, 5.6667, 6.6667)
A_2	(1.0667, 1.7500, 2.4444)	(1, 1, 1)	(4, 5, 6)
A_3	(0.1528, 0.1810, 0.2222)	(0.1698, 0.2056, 0.2611)	(1, 1, 1)

Step 2: Calculating consistency ratio for criteria pairwise comparison matrix.

Table 6 shows the consistency ratio, CR of the pairwise comparison matrices. The value in Table 6 was used to check whether the comparison can be validated if CR is less than 0.1. If not, the comparison must be revised. The Eigenvalue method was used to perform consistency check by finding the value of $\lambda_{\max}$. Then, consistency index (CI) and consistency ratio (CR) can be done by using Equation (2) and Equation (3).

Table 6: Consistency Ratio, CR

Criteria			
	$\lambda_{\max}$	**CI**	**CR**
DM_1	4.2253	0.0751	0.0834
DM_2	4.2607	0.0869	0.0966
DM_3	4.2404	0.0801	0.0890
Service			
	$\lambda_{\max}$	**CI**	**CR**
DM_1	3.0803	0.0401	0.0772
DM_2	3.0649	0.0324	0.0624
DM_3	3.0803	0.0401	0.0772
Cost			
	$\lambda_{\max}$	**CI**	**CR**
DM_1	3.0803	0.0401	0.0772
DM_2	3.0070	0.0035	0.0068
DM_3	3.0803	0.0401	0.0772

Time			
	$\lambda_{\max}$	**CI**	**CR**
DM$_1$	3.0803	0.0401	0.0772
DM$_2$	3.0536	0.0268	0.0516
DM$_3$	3.0940	0.0470	0.0904
Quality			
	$\lambda_{\max}$	**CI**	**CR**
DM$_1$	3.0536	0.0268	0.0516
DM$_2$	3.0940	0.0470	0.0904
DM$_3$	3.0764	0..0382	0.0735

Step 3: Calculating the geometric mean of fuzzy comparison values.
The geometric mean of the fuzzy comparison values was found using the Fuzzy Analytic Hierarchy Process (FAHP) and Microsoft Excel for each criteria and alternatives. Using Equation (4), the geometric mean for criteria 1 was calculated as follows:

$$l : r_{C1} = (1 \times 1.3667 \times 2.0556 \times 1.5)^{\frac{1}{4}} = 1.4328$$

$$m : r_{C1} = (1 \times 2.0370 \times 2.7333 \times 1.8889)^{\frac{1}{4}} = 1.8008$$

$$u : r_{C1} = (1 \times 2.7083 \times 3.1467 \times 2.3333)^{\frac{1}{4}} = 2.1556$$

With similar steps, other calculation of the geometric means of fuzzy comparison values for each criteria and alternatives are shown in Table 7 and Table 8, respectively. It also includes the total values, the inverse values, and the values in increasing order.

Table 7: Geometric Mean of Fuzzy Comparison Values for Criteria.

Criteria			
Criteria	***l***	***m***	***u***
C$_1$	1.4328	1.8008	2.1556
C$_2$	1.9285	2.2112	2.4874
C$_3$	1.7565	2.0312	2.3018
C$_4$	1.3109	1.6185	1.9135
Total	6.4287	7.6617	8.8583
Inverse	0.1556	0.1305	0.1129
Increasing Order	0.1129	0.1305	0.1556

Table 8: Geometric Mean of Fuzzy Comparison Values for Alternatives.

Alternatives			
Service	***l***	***m***	***u***
A$_1$	1.6257	1.9539	2.2644
A$_2$	2.4037	2.7718	2.2644
A$_3$	0.2643	0.2959	0.3429
Total	4.2938	5.0216	5.7260
Inverse	0.2329	0.1991	0.1746
Increasing Order	0.1746	0.1991	0.2329
Cost			
A$_1$	1.9330	2.2290	2.5140
A$_2$	1.9954	2.2918	2.5769
A$_3$	0.2329	0.2525	0.2768
Total	4.1613	4.7732	5.3677
Inverse	0.2403	0.2095	0.1863
Increasing Order	0.1863	0.2095	0.2403

Time			
A_1	1.5577	1.8638	2.1927
A_2	1.7618	2.1668	2.5198
A_3	1.3486	1.5397	1.7208
Total	4.6680	5.5702	6.4333
Inverse	0.2142	0.1795	0.1554
Increasing Order	0.1554	0.1795	0.2142
Quality			
A_1	1.7731	2.0900	2.4354
A_2	1.6219	2.0606	2.4478
A_3	0.2961	0.3338	0.3871
Total	3.6910	4.4845	5.2703
Inverse	0.2709	0.2230	0.1897
Increasing Order	0.1897	0.2230	0.2709

Step 4: Calculating the fuzzy preference weights.
The fuzzy preference weights are calculated, and the results are displayed in Table 9 and Table 10 after fuzzy weights for each criterion were computed using Equation (6) as follows:

$$l : w_{C1} = (1.4328 \times 0.1129) = 0.1617$$
$$m : w_{C1} = (1.8008 \times 0.1305) = 0.2350$$
$$u : w_{C1} = (2.1556 \times 0.1556) = 0.3353$$

where, $\tilde{r}_i$ was multiplied by the inverse of the summation vector in the form of increasing order.

Table 9: Fuzzy Weight of the Criteria

Criteria			
Criteria	***l***	***m***	***u***
C_1	0.1617	0.2350	0.3353
C_2	0.2177	0.2886	0.3869
C_3	0.1983	0.2651	0.3581
C_4	0.1480	0.2112	0.2976

Table 10: Fuzzy Weight of the Alternatives

Alternatives			
Service	***l***	***m***	***u***
A_1	0.2839	0.3891	0.5274
A_2	0.4198	0.5520	0.7263
A_3	0.0462	0.0589	0.0799
Cost			
A_1	0.3601	0.4670	0.6041
A_2	0.3717	0.4801	0.6193
A_3	0.0434	0.0529	0.0665
Time			
A_1	0.2421	0.3346	0.4697
A_2	0.2739	0.3890	0.5398
A_3	0.2096	0.2764	0.3686
Quality			
A_1	0.3364	0.4661	0.6598
A_2	0.3077	0.4595	0.6632
A_3	0.0562	0.0744	0.1049

Step 5: Defuzzifying the fuzzy preference weights of criterion.
The average of the fuzzy values for each criterion, which was based on Equation (7), was used to determine the relative non-fuzzy weight or defuzzified weight of each criterion and alternatives, G_i. The calculation of defuzzification were as follows;

$$G_{C1} = \left(\frac{0.1617 + 0.2350 + 0.3353}{3}\right) = 0.2440$$

$$G_{C2} = \left(\frac{0.2177 + 02886 + 0.3869}{3}\right) = 0.2977$$

$$G_{C3} = \left(\frac{0.1983 + 0.2651 + 0.3581}{3}\right) = 0.2738$$

$$G_{C4} = \left(\frac{0.1480 + 0.2112 + 0.2976}{3}\right) = 0.2190$$

$$\sum G_i = 1.0346$$

Step 6: Normalizing the defuzzified weight of criterion.
Then, the defuzzified weights must be normalized using Equation (8) before being computed and presented in the table below along with the normalized weights for each criterion, H_i .Therefore, the normalization weight of C_1 can be calculated as follows:

$$H_{C1} = \frac{0.2440}{1.0346} = 0.2359$$

Table 11: Defuzzification and Normalization of Criteria.

Criteria		
Criteria	**Defuzzification**	**Normalization**
C_1	0.2440	0.2359
C_2	0.2977	0.2878
C_3	0.2738	0.2647
C_4	0.2190	0.2116
Total	1.0346	1.0000

Table 12: Defuzzification and Normalization of Alternatives.

Alternatives		
Service	**Defuzzification**	**Normalization**
A_1	0.2440	0.2359
A_2	0.2977	0.2878
A_3	0.2738	0.2647
Total	1.0346	1.0000
Cost		
A_1	0.4771	0.4669
A_2	0.4904	0.4799
A_3	0.0543	0.0531
Total	1.0217	1.0000
Time		
A_1	0.3488	0.3372
A_2	0.4009	0.3875
A_3	0.2849	0.2754
Total	1.0346	1.0000

Quality		
A_1	0.4874	0.4675
A_2	0.4768	0.4573
A_3	0.0785	0.0753
Total	1.0427	1.0000

4 Results and Discussion

According to Table 13, it shows the summary of weights of the criteria and alternatives from Table 11 and Table 12. Therefore, the ranking of the online food delivery services can be decided as shown in Table 14.

Table 13: The Summary of Weights

Criteria/ Alternatives	**Weight**	**A_1**	**A_2**	**A_3**
C_1	0.2359	0.3893	0.5507	0.0600
C_2	0.2878	0.4669	0.4799	0.0531
C_3	0.2647	0.3372	0.3875	0.2754
C_4	0.2116	0.4675	0.4573	0.0753

Table 14: Final Ranking of Alternatives

Criteria/Alternatives	**A_1**	**A_2**	**A_3**
C_1	0.0918	0.1299	0.0141
C_2	0.1344	0.1381	0.0153
C_3	0.0892	0.1026	0.0729
C_4	0.0989	0.0968	0.0159
SUM	0.4144	0.4674	0.1183
RANKING	**2**	**1**	**3**

Through the evaluation of the analysis, the highest score for Online Food Delivery services has finally come to a decision. The score of OFD services evaluation that is nearest to the value 1 can be considered the highest choice and with the best result. Thus, the final ranking shows the highest value of OFD services with a score of 0.4674. GrabFood (A_2) seems to be the most preferred among students at UiTM Kota Bharu Campus. Foodpanda (A_1) and OdaMakan (A_3) were in second and third place with a score of 0.4144 and 0.1183, respectively.

5 Conclusion and Recommendations

The main purpose of this study is to evaluate and rank the best online food delivery (OFD) services using the FAHP method. Three experts among students in UiTM Kelantan Branch, Kota Bharu Campus who are active consumers of the OFD services were selected to answer the fuzzy questionnaire to provide their own ratings. The fuzzy questionnaire consists of four main criteria which are Service (C_1), Cost (C_2), Time (C_3), and Quality (C_4). Besides, this study has been conducted on three alternatives: Foodpanda (A_1), GrabFood (A_2), and OdaMakan (A_3).

The results of the study indicate that GrabFood has the highest global weight with a value of 0.4674, followed by Foodpanda (0.4144), and OdaMakan (0.1183). These findings show that GrabFood emerges as the top OFD service among students at UiTM Kelantan Branch, Kota Bharu Campus. Besides, cost is identified as the most important criterion in the selection process.

The benefit of this research is the thorough development of the online food delivery market evaluation criteria using literature and expert answers. Second, decision-makers in the OFD business will gain knowledge from the management implications of the technique and its analysis, not only in

Kelantan but also in other markets. To evaluate the general validity of the findings, further studies may also apply the suggested method or similar approaches to specific situations in specific sectors, particularly those connected to e-commerce. Thus, future researchers can use fuzzy MCDM, such as fuzzy AHP, in the problem to help decision-makers set priorities and make the best decision. Besides, future studies may also use fuzzy TOPSIS and fuzzy PROMETHEE to implement various multi-criteria decision-making approaches for related applications. This study may also be conducted using additional criteria and subcriteria for a more precise and detailed outcome.

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