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Evaluation and Selection of Online Food Delivery (OFD) Companies in Perlis Using Fuzzy Analytical Hierarchy Process (AHP)

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HIGHLIGHTS

- Fuzzy Analytical Hierarchy Process (FAHP) is used to determine the relative importance of the criteria used in ranking OFD.
- Economy is the main criteria with discounts and offers as the sub-criteria that effect the customers the most.
- All online food delivery companies rated almost the same in Economy, but very significant difference in Service Quality and Technology.
- Foodpanda is the most preferred online food delivery company.

ABSTRACT

The COVID-19 pandemic has accelerated the global expansion of online food delivery (OFD) services. Food delivery services are comparable to courier services in that the ordered food is delivered to customers by workers or rider delivery companies. As the number of OFD companies continues to rise, the selection of OFD companies, such as GrabFood, Foodpanda, Halo Delivery, and others, is extremely competitive. Customers must choose carefully which OFD companies offer the best services. The objectives of this research are to investigate the evaluation criteria for OFD companies, then evaluate the OFD companies based on the evaluation criteria and rank the best OFD companies that provide the best services to customers in Perlis based on certain criteria. As a result, this study proposes a solution to this problem by developing a technique from multi criteria decision making (MCDM) known as the Fuzzy Analytical Hierarchy Process (FAHP) to determine the relative importance of criteria used in ranking OFD services. This study's findings indicate that Foodpanda is the most preferred food delivery service, followed by Grabfood and Halo Delivery. The most crucial main criteria is the economy, with discounts and offers as the priority sub-criteria. The second most important criterion is service quality, and the last is technology.

Keywords: *online food delivery, fuzzy analytical hierarchy process, multi criteria decision making, criteria, rank.*

INTRODUCTION

Due to advancements in internet technology, a general trend toward e-commerce, rising urbanization, and shifting social patterns, the online food delivery (OFD) business has been growing since the mid-2000s. Food delivery is now a common feature of city life. Customers can order from a wide range of restaurants and doorstep delivery options with a single tap of their mobile phone on online food delivery platforms, which offer a plethora of options and convenience, as well as cashback benefits, incentives, fantastic deals, and discounts. Prior to the alarming COVID-19 making global headlines, online food delivery benefited from evolving technology and a variety of delivery apps. Without a doubt, the unusual pandemic has pushed consumer acceptance of these delivery services, with a significant increase in new clients joining platforms, particularly in developing countries. While millions of businesses, primarily in the aviation, tourism, and hospitality industries, were severely impacted by the COVID-19 issue and experienced significant revenue losses, the OFD industry grew dramatically as a result of the pandemic, with global OFD turnover increasing by nearly 140 percent (Arkansas Democrat Gazette, 2020).

Food delivery services are similar to courier services in that the ordered meal is delivered to the client by either restaurant workers or food ordering delivery agents from the restaurant. Of course, the manner in which a customer places their order has an impact on the procedure. Ordering meals from a food cooperative or restaurant can be done over the phone, using mobile applications or websites, or through the establishment's online portals and aggregator apps. Customers are typically charged a fixed shipping cost, which is occasionally waived depending on the merchandise purchased. Contactless delivery has become increasingly common since the outbreak began. Food delivery services have also benefited from technological advancements, which have made them more accessible to customers. Due to a surge in demand, OFD has been in the spotlight as a viable alternative in Malaysia for several years. The COVID-19 pandemic, along with numerous other factors driving the market's expansion, proved to be a critical accelerant that has seen OFD adoption rise in the country over the last year.

As demand grows, many online food delivery companies offer their services to deliver orders. Each company offers the same advantages in terms of delivering the food that customers order through online applications. However, the delivery charges, cashback, offers and discounts, and other benefits they provide to customers are not the same. Nevertheless, customers must make an informed decision about which online food delivery services will best satisfy their needs. As a result, this evaluation can be viewed as a complex decision-making process aimed at identifying the best services provided by the OFD business in terms of long-term sustainability. This study aims to evaluate major OFD operators in Perlis based on three main criteria which are economy, service quality, and technology There are at least five OFD companies operating in Perlis; Foodpanda, GrapFood, Halo Delivery, Tapaw and Feedme Express. GrabFood, Foodpanda, and Halo Delivery are the three most prominent players in Perlis' OFD business. This study proposes the analytic hierarchy process (AHP) using triangular fuzzy sets in the MCDM technique as it can address better judgement in the uncertainties and ambiguities of the expert.

The AHP is a useful decision-making tool proposed by Saaty in 1980. In the case with different selection criteria and alternatives, it would be useful first to determine which selection criteria are more important than another, and then to evaluate which alternative is more likely (Saaty, 2006). Buckley (1985) introduced Fuzzy Analytic Hierarchy Process (FAHP) with the merging of fuzzy theory into the AHP. By applying the principles of fuzzy set theory and hierarchical structure analysis, these methods are systematic strategies for alternative and justification problems. The concept is to use triangular fuzzy numbers (TFNs) to describe the weights of the judgment nine-level scales to reflect the relative importance of the parameters of the hierarchy (Zhu, Jing & Chang, 1999). Decision-makers normally find that judgments on intervals are more

confident than judgments on a fixed value. This is because of the fuzzy nature of the comparison process they are usually incapable to make explicit their preferences.

The application of FAHP are used in various fields including food industries. Nguyen et al. (2021) use FAHP and the Weighted Aggregated Sum Product Assessment (WASPAS) to evaluate major OFD companies in Vietnam based on a comprehensive set of criteria. The criteria include social and environmental (healthy and safety, information security, and environmental impact), economic (delivery cost, operational capability, and risk management), service quality (order fulfillment, delivery speed, and payment convenience) and technology (web design, real-time tracking systems, and marketing techniques).The study prioritized convenience of payment as extremely essential to fulfill the customers' need, followed by delivery speed, online service level, order fulfillment, and delivery cost. Foody is currently the leading OFD player in Vietnam, followed by GrabFood and Now according to the final WASPAS rating.

Ajjipura Shankar et al. (2022) used a FAHP and Fuzzy TOPSIS to rank OFD enterprises in India based on characteristic chosen. The characteristic are financial norms (supply rate, operating skill and hazard managing), facility value (order satisfaction, supply speed, handiness expense, virtual and offline facility level, and patron response), expertise (network strategy, instantaneous tracking, and marketing technique), and societal and eco-friendly (health, communication and ecological influence). The study showed network strategy is the most essential influencing the OFD selection followed by instantaneous tracking system and order satisfaction.

Study by Peetawan (2019) investigates the decision factors affecting the selection of OFD providers using AHP. The result found that the key influential factors are availability of the service providers, accuracy of order, service innovation and service people's attitude.

Gunden et al. (2020) investigated consumers' persuasion in OFD system by using the information available in an online meal delivery system. The study discovered that shoppers' desire to save money comes first in both types of browsing behavior (utilitarian and hedonic). Persuasion was predicted by hedonic browsing and also by social influences, while utilitarian browsing had no effect on consumer persuasiveness.

Gonzalez et al. (2022) conducted a comprehensive review ICT study in food services and restaurants. The finding concluded that now a day the restaurant industry is increasingly based on the creation of experiences. ICTs can enhance the simple meal, create and repeat experiences to attract and retain sophisticated and ICT-dependent clients. ICTs are essential for top management in food services and restaurants, and not just as a technical tool.

Study by Saad (2020) on the factors affecting online food delivery service in Bangladesh showed delivery time, service quality, price and condition of the food are factors directly affecting the success of online food delivery. Where else the factors such as variety, numbers of menu, delivery tracking and attitude of the delivery person are considered as indirect factors.

METHODOLOGY

This study aims to evaluate major OFD operators in Perlis using FAHP. The research methodology can be divided into 2 phases (Figure 1). Phase 1 is selecting the criteria, applying FAHP and identifying the preference weight of each criteria. Phase 2 is ranking the alternatives using the weight of alternative with respect to each criteria.

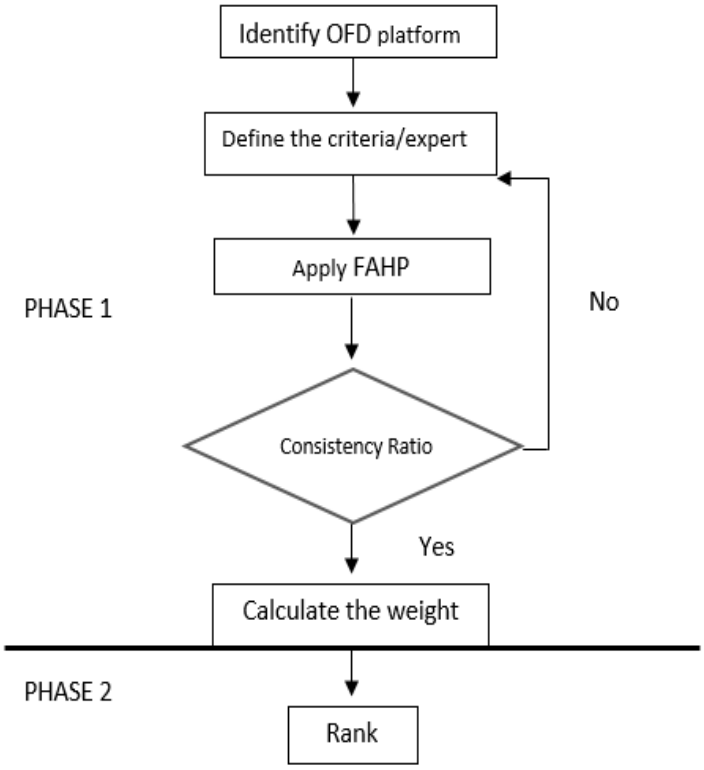

Figure 1: Research methodology of selection OFD Companies

Method of Data Collection

The data used in this study is primary data from a questionnaire filled out by some of the respondents. After preliminary assessment, three respondents were chosen to do survey questionnaires to rank the three OFD companies in Perlis (Foodpanda, Grabfood, and Halo Delivery). They were the respondents who ordered their food online at least once a week and also experience all three OFD apps. The questionnaire is designed with main criteria, sub-criteria, and alternatives as individual pairs. The respondents were asked to rate pairs on a scale of 1 to 9. 1 being "equally important" to 9 being "perfect". The criteria and sub-criteria used in this study are adapted from Nguyen et al. (2021) with some amendments to suit Malaysians' life style. The main criteria and description of sub-criteria are as shown in Table 1 below.

Table 1: The description and abbreviation of the sub-criteria

Main Criteria	Sub-Criteria	Description
Economy	Delivery cost	Cost charge by the company which include transportation, labour and administration costs
	Discounts and offers	Initiative given to the customers
Service Quality	Order fulfillment	Time saving of ordering, pick-up, and cleanliness of the food
	Delivery speed	Timeliness of order arrival

	Service level	Timeliness of SMS, response of customer service and delivery staff
Technology	Time tracking system	Time taken for online tracking and tracing
	Location tracking system	Smart technology to track the location of the order.

Data Analysis

All of the data collected via questionnaire was analyzed using Microsoft Excel. In order to observe the problem clearly, the 4-level hierarchical diagram was formed. The first level of the hierarchy is the goal of the study, the second level of the hierarchy is the main criteria, and the third level of the hierarchy is the sub-criteria used to select the OFD companies. The criteria of economy and technology have 2 sub-criteria, while criteria of Service Quality has 3 sub-criteria. The fourth level of the hierarchy is the alternatives of the OFD companies that need to be evaluated by the experts. The hierarchical diagram is shown in the Figure 2.

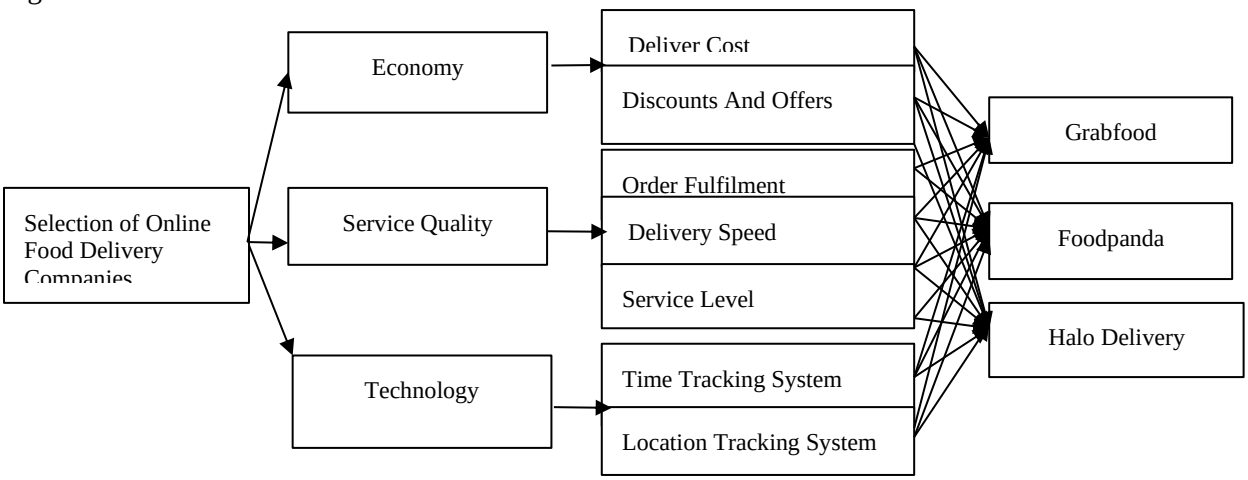

Figure 2: Hierarchical diagram in evaluation and selection OFD Companies

The relative importance of the two criteria is determined using a numerical scale of 1-9 by assigned linguistic variables which are represented by triangular fuzzy number (TFN). Table 2 shows the fuzzy triangle scale assigned by TFN used in FAHP defined by Sun (2010). A triangular fuzzy number is represented by (lower value *l*, middle value *m*, upper value *u*).

Table 2: Linguistic Term in FAHP model

Scale	Definition	Fuzzy Triangle Scale
1	Equally important	(1, 1, 1)
2	Weakly important	(1, 2, 3)
3	Not bad	(2, 3, 4)
4	Preferable	(3, 4, 5)
5	Important	(4, 5, 6)
6	Fairly important	(5, 6, 7)
7	Very important	(6, 7, 8)
8	Absolute important	(7, 8, 9)
9	Perfect	(8, 9, 10)

Assume that a decision group is comprised of K experts. Following a pairwise comparison of main criteria, sub-criteria, and alternatives, a triangular fuzzy comparison matrix is generated as follows:

$$A = \begin{bmatrix} (a_{11}^k, b_{11}^k, c_{11}^k) & (a_{12}^k, b_{12}^k, c_{12}^k) \ldots \left(a_{1n}^k, b_{1n}^k, c_{1n}^k\right) \\ a_{21}^k, b_{21}^k, c_{21}^k & (a_{22}^k, b_{22}^k, c_{22}^k) \ldots \left(a_{2n}^k, b_{2n}^k, c_{2n}^k\right) \\ a_{31}^k, b_{31}^k, c_{31}^k & (a_{32}^k, b_{32}^k, c_{32}^k) \ldots \left(a_{3n}^k, b_{3n}^k, c_{3n}^k\right) \end{bmatrix} = \left[d^k{}_{ij}\right]$$

where $\tilde{d}_{ij}^{\,k}$ indicates the k[th] decision maker's preference of i[th] criterion over a j[th] criterion in fuzzy triangular numbers.

Fuzzy Analytical Hierarchy Process (FAHP)

The procedure of FAHP is shown as below (Sun, 2010):
Step 1: Construct the pairwise comparison matrix based on the average preferences of the decision-makers.

$$\tilde{M}^k = \begin{bmatrix} \left(a_{11}^k, b_{11}^k, c_{11}^k\right) & \left(a_{12}^k, b_{12}^k, c_{12}^k\right) & \cdots & \left(a_{1n}^k, b_{1n}^k, c_{1n}^k\right) \\ \left(a_{21}^k, b_{21}^k, c_{21}^k\right) & \left(a_{22}^k, b_{22}^k, c_{22}^k\right) & \cdots & \left(a_{2n}^k, b_{2n}^k, c_{2n}^k\right) \\ \\ \left(a_{n1}^k, b_{n1}^k, c_{n1}^k\right) & \left(a_{n2}^k, b_{n2}^k, c_{n2}^k\right) & \cdots & \left(a_{nn}^k, b_{nn}^k, c_{nn}^k\right) \end{bmatrix}$$

If there are multiple decision makers, K represents the number of decision makers, and the procedure involves calculating the average of each decision maker's preferences. The equations below show the formula for it.

$$\text{average } \left(a_{ij}, b_{ij}, c_{ij}\right) = \frac{\sum_{k=1}^{K} \left(a_{nn}^k, b_{nn}^k, c_{nn}^k\right)}{K} \quad \text{where } i, j, K = 1,2,\ldots,n. \tag{1}$$

Step 2: Calculate the Geometric Mean of Fuzzy Comparison Value

Use the fuzzy geometrical mean technique to define the fuzzy geometrical mean of each criterion $\tilde{r}_i$, which is calculated by Eq.(2).

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{d}_{ij}\right)^{1/n}, \; i = 1,2,\ldots,n$$

where n is the number of criteria. (2)

Step 3: Calculate the Fuzzy Weight for criterion i , [$\tilde{w}_i$], multiply each $\tilde{r}_i$ with this reverse vector.

$$W_i = \tilde{r}_i \times s^{-1} = (a_i, b_i, c_i) \quad \text{where } s^{-1} = \left(\frac{1}{\sum c_n}, \frac{1}{\sum b_n}, \frac{1}{\sum a_n}\right) \tag{3}$$

Step 4: De-fuzzified $\tilde{w}_i$ by using the Centre of Area method proposed by Chou & Chang (2008), by applying the Eq. (4).

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \tag{4}$$

Step 5: Normalize the de-fuzzified weight of criterion M_i using Eq.(5).

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \tag{5}$$

Consistency Test

It is critical in expert evaluations to ensure that pairwise comparisons are accurate. This FAHP method includes a consistency test and measures to help to avoid problem. In order to assess how consistent are the experts in giving their opinion, a consistency index (CI) for each matrix is calculated. The consistency ratio (CR) was then obtained by dividing CI by random index (RI). According to Saaty (1980) and Saaty (1994) if CR is less than 0.1, the judgments are consistent, and the resulting weights can be used. As indicated in Table 3 the judgements of the three experts were consistent since all matrices had the CR value less than 0.1.

Table 3: Consistency Ratio (CR) of three experts

Experts	Consistency Ratio (CR)
E^1	0.03799
E^2	0.01219
E^3	0.08616

Rank

The ranking is determined from the score obtain by multiplying the weight of the criteria by the weight of each alternative with respect to the criteria.

FINDINGS AND DISCUSSIONS

Three respondents were surveyed and asked to complete a questionnaire in order to prioritized criteria and sub-criteria for online food delivery. Prior to further analysis, all questionnaires were collected and converted to a triangular fuzzy number in Excel. The average of the three respondents' choices was computed. Following completion, a new set of pairwise comparison matrices for criteria is constructed (Table 4).

Table 4: Pairwise Comparison Matrices for Main Criteria

Main Criteria	Economy	Service Quality	Technology
Economy	(1.000,1.000,1.000)	(5.000,6.000,7.000)	(5.667,6.667,7.667)
Service Quality	(0.145,0.170,0.206)	(1.000,1.000,1.000)	(1.444,2.167,3.000)
Technology	(0.134,0.156,0.187)	(0.5,0.889,1.333)	(1.000,1.000,1.000)

The geometric means of fuzzy comparison values are calculated using Eq. (2) and the result is shown Table 5. Each column represents a fuzzy triangular number denoted as (*l, m, u*), where *l*=lower, *m*=medium, and *u*=upper. The total and inverse values are also shown in the table, and the last row displays the order in increasing values.

Table 5: Geometric Means of Fuzzy Comparison Values $\tilde{r}_i$

Criteria	*l*	*m*	*u*
Economy	3.04859	3.41995	3.77197
Service Quality	0.59365	0.71660	0.85117
Technology	0.40642	0.51754	0.62885
Total	4.04866	4.65410	5.25199
Inverse (power of -1)	0.24700	0.21486	0.19040
Increasing Order	0.19040	0.21486	0.24700

The fuzzy weight of criterion *i* ($\tilde{w}_i$), is calculated using Eq. (3). It is then de-fuzzified and normalized using Eq. (4) and Eq. (5) respectively. The result is shown in Table 6.

Table 6: Relative fuzzy weights of each criterion Non fuzzy and normalized relative weights of criteria

Criteria	W_i			M_i	N_i
	l	*m*	*u*	Non-fuzzy	Normalized
Economy	0.58046	0.73483	0.93166	074898	0.73236
Service Quality	0.11303	0.15397	0.21024	0.15908	0.15555
Technology	0.07738	0.11120	0.15532	0.11464	0.11209
Total	0.77087	1.00000	1.29722	1.02270	1.00000

Table 6 shows that the highest weight is economy with relative normalize weight of 0.73236 which means that is extremely essential criterion in selecting OFD companies. Service quality is the second priority with the weight of 0.15555 followed by technology. However, in the study conducted by Ganapathi &Abu-Shanab (2020) on customer satisfaction with online food ordering in Qatar showed that service quality had direct effect on satisfaction and loyalty. The respondents in Perlis agreed the technology is their least priority in choosing OFD service. This show that customers seem to care less on the delivery speed, order fulfillment and tracking as long as the discounts and offers are attractive.

Table 7: Normalized relative weights of sub-criteria

Economy	**Service Quality**	**Technology**
Delivery Cost 0.37895	Order Fulfillment 0.51589	Time Tracking System 0.45350
Discounts and Offers 0.62105	Delivery Speed 0.16843	Location System 0.54650
	Service Level 0.31568	

Table 7 shows the normalize relative weight of sub-criteria. For criteria of economy sub-criteria discounts and offers plays an important role in deciding the OFD company with the score of 0.62105 compare to delivery cost with the score of 0.37895. The outcome is similar to the study by Das (2018) in Pune, India which also found that the choice of OFD company mostly influenced by better reward and cashback. On service quality, the respondents agree that order fulfillment is top priority (0.51589) followed by service

level (0.31568) and delivery speed (0.16843). In the technology aspect both location and time tracking system are almost equally important to the customer with the weight of 0.54650 and 0.45350 respectively with location tracking is slightly higher. This show that the respondents agree that by good tracking of location system their food will be deliver at the right address.

Table 8 displays the weight of alternative with respect to each criteria. Lets N_{ij} denote the weight of alternative i with respect to criteria j where $i = 1,2,3$ and $j = 1,2,3$.

Table 8: Non fuzzy and normalized relative weights N_{ij} of alternative with respect to criteria

Alternatives i	**Criteria** j		
	Economy	Service Quality	Technology
Foodpanda	0.38030	0.71310	0.54693
GrabFood	0.29984	0.21435	0.38384
Halo Delivery	0.31986	0.07256	0.06923

The ranking of the alternatives is determined from the score obtain by multiplying the weight of the criteria by the weight of each alternative with respect to the criteria.

Foodpanda =0.73236 (0.38030)+ 0.15555 (0.71310)+ 0.11209 (0.54693)= 0.45075
GrabFood =0.73236 (0.29984)+ 0.15555(0.21435)+ 0.11209 (0.38384)= 0.29596
Halo Delivery =0.73236 (0.31986)+ 0.15555 (0.07256)+0.11209(0.06923)= 0.25330

Table 9: The rank

Alternative *i*	**Score**	**Rank**
Foodpanda	0.45075	1
GrabFood	0.29596	2
Halo Delivery	0.25330	3

Table 9 shows the result of the multiplication of the weight of each criteria by the weight of each alternative with respect to the criteria and also the ranking of each OFD. The result shows that Foodpanda rank number 1 with 0.45075, GrabFood rank number 2 with the score of 0.29596 and Halo Delivery ranked at number 3 with 0.2330. The result is consistent with the finding by Mat Nayan & Hassan (2020) on customer evaluation satisfaction for OFD system in Malaysia. Their finding showed that Foodpanda and Grab Food are the most widely accepted delivery system in Malaysia. Even though Halo Delivery ranked last but in economy criteria it performs better than GrabFood.

CONCLUSION AND RECOMMENDATIONS

The objective of this study is to evaluate and rank three well known OFD companies in Perlis namely Foodpanda, GrabFood and Halo Delivery based on certain criteria. The criteria used are economy, service quality and technology. The respondents are three customers in Perlis aged 22 to 35 who ordered their food online at least once a week and have used all the three companies. According to the findings, the most important factor considered by customers when selecting OFD companies is the economy with discounts and offers as the most influence sub-criteria compare to the delivery cost. Service quality which include order fulfillment, delivery speed and service level is the second factor considered by the respondent in

choosing the OFD company. Technology is the least important factor for the respondent in deciding the service provider with location tracking is the priority.

This research also determined the rank which OFD companies are most preferred by customers. Based on the evaluation criteria, Foodpanda is the most popular company for online food delivery in Perlis, followed by Grabfood and Halo Delivery. The outcome is not surprising because Foodpanda is the first food delivery platform in Malaysia since it first entered in 2012 compare to GrabFood and Halo Delivery both became the player in food industry in 2018.

This study is accomplished by FAHP model to determine which criteria are most important in choosing the preferred OFD companies. In short, the FAHP model assists people in determining which option is best under difficult circumstances. This study could also be conducted with additional criteria and sub-criteria for a more precise and detailed outcome. Since the respondents in this study are between 22-35 years old only, it is interesting to see the finding if different age group are used. For future study, MCDM approach such as Fuzzy PROMETHEE (Preference Ranking Organization Method for Enrichment of Evaluations), Fuzzy TOPSIS (Order of Choice Technique Close to Ideal Solution), DEMATEL (Decision Making Trial and Evaluation Laboratory) and MAUT (Multi-Attribute Utility Theory) could be applied.

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CONFLICT OF INTEREST DISCLOSURE

All authors declare that they have no conflicts of interest to disclose.

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