ISSN Print : 2621-3745
ISSN Online : 2621-3753
(Page.27-44)

Journal of Science and Applied Engineering (JSAE)
Vol. 7, No. 2, October 2024
DOI : 10.31328/jsae.v7i2.6487

DETERMINING DEALER LOCATION BY USING FUZZY - ANALYTICAL HIERARCHY PROCESS (F-AHP) METHOD IN ELECTRIC VEHICLE MANUFACTURER

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Submitted : 11 September 2024; *Revision :* 27 September 2024; *Accepted :* 22 October 2024

ABSTRACT

Selecting the most strategic dealer sites for electric vehicles (EVs), particularly electric motorbikes, is crucial for market penetration and profitability. The decision-making process is complicated by uncertainties related to market proximity, accessibility, operational costs, and infrastructure. The Fuzzy Analytical Hierarchy Process (FAHP) technique solves these problems by merging fuzzy logic with traditional AHP to handle uncertainty and subjectivity. This research provides five criteria for dealer site selection: Building Facilities, demographics, cost, market circumstances, and accessibility, each with their own sub-criteria. Cost (0.224) is the most important factor, followed by demographics (0.212), market circumstances (0.205), Building Facilities (0.193), and accessibility (0.166). Rent cost is the most important sub-criterion, having a global weight of 0.186. The report identifies four possible locations for PT. XYZ's electric motorcycle dealers. Alexandrite 3 (Boulevard) has the highest score of 0.279, excelling in terms of rent and environmental management expenses. Shophouse 1B (BA3 no. 16) comes in second with a score of 0.261, recognized for its size and parking facilities. Ruko Maggiore 1 holds the third position with a score of 0.238, demonstrating strong performance in land expansion and architectural design. Jalur Sutera comes fourth with a score of 0.200, adding considerably to shophouse size and parking lot.

Keywords Optimal Dealer Sites; Electric Vehicles (EVs); Multi-Criteria Decision-Making; Location Selection Method; Fuzzy Logic; Fuzzy Triangular Numbers; AHP; Fuzzy AHP;
Paper type Research paper

INTRODUCTION

Selecting optimal dealer sites for electric vehicles (EVs), including electric motorcycles, is crucial for maximizing market penetration and profitability. However, determining the best appropriate criteria and sub-criteria for such selections is a hard task. Traditional techniques frequently lack the flexibility to account for the inherent uncertainties and imprecisions that arise throughout site selection decision-making procedures [1].

The choice of a dealer location for electric motorcycles is crucial for new companies, as it significantly impacts their success in the competitive electric vehicle industry. Factors like market proximity, accessibility, operational costs, and infrastructure support the decision-making process. A structured approach allows companies to assess various options, making optimal choices to support their business growth and sustainability [2].

PT XYZ is a fairly new EV manufacturer in Indonesia, for now they want to expand dealer branches in many regions of Indonesia to increase sales and try to introduce their products to the public. However, the lack of measurable aspects based on the company's standards makes it difficult to establish a structured approach for location selection because the selection is still unstructured for each weighting of which location to choose.

Based on the results of consultations with the experties, the main concern when selecting a dealer location is cost. The lack of weight given to each criterion and sub-criteria in location supplier evaluation can result in subjective assessments, leading decision makers to focus on one criterion.

The result from discussing with several heads of departments in the Purchasing Division who are experts in this study, each of them has a preference in selecting suppliers. As a result, the final result of the selection of the PT XYZ dealer location for the SCBD area was less than in accordance with the company's expectations and did not meet the expectations and comfort of customers who came to

ISSN Print : 2621-3745
ISSN Online : 2621-3753
DOI : 10.31328/jsae.v7i2.6487
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the dealer location, due to the difficulty of access, small parking areas, and lack of land making it difficult to make changes and add facilities that make customers comfortable.

In previous studies on site selection criteria, several studies have used the Multi-Criteria Decision-Making (MCDM) method to overcome the complexities involved in site selection. This method allows for the evaluation of multiple, often conflicting criteria that influence the suitability of a potential location. The most common criteria identified in these studies include: 1) Accessibility: The ease with which customers and suppliers can reach a location, often evaluated through proximity to transportation networks, such as highways, public transportation, and airports [3]. 2) Market Potential: The potential customer base in the surrounding area, including population density, income level, and demographic characteristics [4]. 3) Cost Factors: These include land costs, construction, taxes, and operating costs, which directly affect the financial viability of a location [5].

For example, [3] used the Analytical Hierarchy Process (AHP) to prioritize these criteria in selecting a retail store location in an urban environment. Their study highlighted the importance of accessibility and market potential as key drivers of location success. Similarly, [5] applied the Preference Ordering Technique based on Similarity to Ideal Solution (TOPSIS) to assess industrial site locations, focusing on cost and infrastructure quality as the main factors.

Despite the progress made by these studies, they often rely on deterministic models that assume precise and unambiguous data. However, in real-world scenarios, decision makers often face uncertainty and ambiguity in the available information. Factors such as fluctuating market conditions, evolving consumer preferences, and incomplete data can introduce ambiguity into the decision-making process, which may not be adequately addressed by traditional MCDM methods.

For the current study, the authors incorporate Fuzzy Logic into site selection, to overcome these limitations, this study proposes the integration of Fuzzy Analytical Hierarchy Process (FAHP) into the site selection process. Fuzzy logic allows for the handling of imprecise data and subjective judgments, making it well-suited for complex decision-making environments where uncertainty is prevalent. By applying FAHP, this study aims to provide a more nuanced evaluation of location criteria, especially in the growing electric vehicle (EV) sector.

In addition, researchers also focus more on the selection of electric vehicle (EV) dealer locations, electric vehicles (EV) are a rapidly growing market, driven by increasing environmental concerns and supportive government policies. However, the success of electric vehicle dealers depends on additional criteria that are less important in the traditional automotive market. These criteria include: 1) Charging Infrastructure: The availability of charging stations around the location, which is very important for the convenience of electric vehicle customers. Such as 1) Environmental Impact: Alignment of the location with sustainability goals, considering factors such as carbon footprint and local environmental regulations. 2) Infrastructure: The availability and quality of physical infrastructure, such as roads, electricity, water supply, and communication networks [6]. 3) Cost Factors: This includes the cost of land, construction, taxes, and operational expenses, which directly impact the financial feasibility of a location [5].

By incorporating these specific criteria into the FAHP model, this study not only addresses traditional location selection factors but also adapts to the unique challenges posed by the EV market. The results of this study aim to offer a more flexible and comprehensive framework for businesses looking to establish a competitive presence in the EV sector.

In the context of site selection, Multi-Criteria Decision Making (MDCM) is an important approach to address complexity and uncertainty in decision-making. The Analytical Hierarchy Process (AHP) method is one of the popular MDCM techniques, serving to compare and assess alternatives based on multiple criteria, but has limitations in handling uncertainty and interactions between criteria simultaneously [7]. On the other hand, Analytic Network Process (ANP) offers a solution by considering interdependencies between criteria, ANP also relies on the subjective judgment of the decision makers to determine the weights which lead to biased results if the judgment is not objective [8]. Fuzzy AHP methods, integrate fuzzy logic to handle uncertainty and ambiguity in judgment, providing advantages in situations involving uncertain and subjective data [9]. With the ability to handle uncertain information and provide more realistic results in multi-criteria decisions, this method offers a more flexible solution than AHP and ANP in site selection [10].

For instance, [2] applied FAHP in selecting electric vehicle charging station locations in Turkey, enabling better assessment of criteria like cost and accessibility. Additionally, [5] used FAHP for industrial site location selection, demonstrating that FAHP yields more accurate results compared to traditional methods due to its ability to handle uncertain data. Other studies, such as those by [11] and

[12], highlight FAHP applications in the manufacturing sector and supply chain management, showcasing its effectiveness in addressing market uncertainties and consumer preferences. In Indonesia, [13] also employed FAHP to select battery swap station locations for electric vehicles, aiding in the evaluation of criteria such as road conditions and operational costs.

Based on that, the researcher use Fuzzy Analytical Hierarchy Process (FAHP) is a methodology that uses fuzzy logic and the traditional AHP approach to assign relative weights to criteria, taking into account uncertainty and subjectivity in judgment. It helps handle ambiguity in judgment, particularly when data is subjective or unclear [14]. Fuzzy AHP provides a flexible rating scale, allowing for smoother and more accurate comparisons. It also allows for more flexible decision-making due to its ability to handle various levels of uncertainty in evaluation. This makes it more adaptive to changing conditions.

The selection of location criteria in this study differs from existing journals, as the main focus lies on the integration of variables specific to the electric vehicle market in Indonesia. The criteria used not only consider traditional factors such as accessibility and land cost but also incorporate innovative aspects such as the potential adoption of charging infrastructure support and the demographic trends of electric vehicle users. This ensures a more relevant and contextual site selection to support optimal electric vehicle market penetration.

The two main aspects of this research are 1) To determination of the selection of criteria and sub-criteria to be used for the selection dealer sites. 2) To determine the most strategic location using a combination of Fuzzy Analytical Hierarchy Process (Fuzzy AHP). PT. XYZ has no weight given to each criterion and sub-criteria when evaluating a site supplier. This creates a subjective assessment, which causes decision makers to only focus on one criterion and ignore the others. This happened at one of the previously selected dealer locations located in the SCBD location, based on the results of discussions with experts at PT XYZ. The following is some bad complaints given to the dealer location located in SCBD:

- There is no large parking area
- Difficult road access
- Incomplete facilities because the room size is not big enough

Due to the above shortcomings, customers feel dissatisfied and become reluctant to buy products again, which has the potential to harm the company in the long run. The AHP (Analytical Hierarchy Process) model is a functional hierarchy with the main input being human perception. AHP has many advantages in explaining the decision-making process. One of them is that it can describe graphically so that it is easily understood by all parties involved in decision making [15].

Procedures or steps in the AHP method include [15]. Define the problem and determine the desired solution, then compile a hierarchy of the problem at hand.

1. Determine the priority of elements:
    a. Making pair comparisons, namely comparing elements in pairs according to the criteria given.
    b. The pairwise comparison matrix is filled using numbers to represent the relative importance of an element to other elements.
2. Synthesis
   Consideration of pairwise comparisons is synthesized to obtain overall priorities. The steps are:
    a. Summing up the values of each column of the matrix
    b. Divide each value of a column by the total of the corresponding column to obtain a normalized matrix.
    c. Summing the values of each row and dividing them by the number of elements to obtain the average value.
3. Measuring Consistency
   To find out how good the consistency is because decision making is not based on considerations with low consistency. The steps are:
    a. Multiply each time in the first column by the relative priority of the first element, the value in the second column by the relative priority of the second element, and so on.
    b. Sum each row
    c. The result of the row sum is divided by the corresponding relative priority element.
    d. Sum the quotient above with the number of elements present, the result is called π.

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ISSN Online : 2621-3753
DOI : 10.31328/jsae.v7i2.6487
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4. Calculate the Consistency Index (CI) with the formula:

$$CI = (\pi \text{ max-n/n}) \quad (1)$$

Where n = number of elements

5. Calculate the Consistency Index (CI) with the formula:

$$CR = CI/IR \quad (2)$$

Where CR = Consistency Ratio; CI = Consistency Index; IR = Random Consistency Index

6. Checking the consistency of the hierarchy. If the value is more than 10%, then the judgment data assessment must be corrected, but if the consistency ratio (CI/IR) is less than or equal to 0.1, then the calculation results can be declared correct.

Linguistic judgements may depict different levels of importance for different persons. Fuzzy logic is often used Zadeh to capture this variation in the level of importance. The degree of membership is given by a membership function, which is usually depicted on two axis diagram. The horizontal axis represents the domain elements of the fuzzy sets and the vertical axis represents the degree of membership, where zero means non-membership and one implies full membership. The membership function can be formulated in different ways, for example, using linear, S-curves, triangular or trapezoidal representations. Figure 1 represents the membership functions of the linguistic importance scale, taken from Ordoobadi.

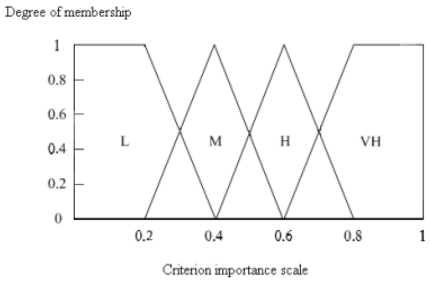

Figure 1. Membership functions of the linguistic importance weight Ordoobadi

The Fuzzy AHP solution steps are as follows [16]:

a. Create a hierarchical structure of the problem to be solved and determine the pairwise matrix comparison between criteria with the TFN (Triangular Fuzzy Number) scale.
b. Determine the fuzzy synthesis value (Si) priority with the formula:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \quad (3)$$

c. Determining the vector value (V) and the ordinate value Defuzzification (d'). For k = 1,2,...n; k ≠ i, the weight vector value is obtained:

$$W' = (d'(A_1), (d'(A_2), \dots, d'(A_n))^T \quad (4)$$

d. Normalization of fuzzy vector weight values (W) The normalized vector weight value is like the following formula:

$$W_f = (d'(A_1), (d'(A_2), \dots, d'(A_n))^T \quad (5)$$

Where W is a non-fuzzy number. The normalization formulation is:

$$\widetilde{d_{ij}} = \frac{\sum_{k}^{k}=1\, \widetilde{d_{ij}^{k}}}{k} \quad (6)$$

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TABLE I. NUMERICAL SCALE AND LINGUISTIC SCALE FOR LEVEL OF IMPORTANCE

Saaty Scale	Definition	Fuzzy Triangular Scale
1	Equally Important	(1,1,3)
3	Weakly Important	(1,3,5)
5	Fairly Important'	(3,5,7)
7	Strongly Important	(5,7,9)
9	Absolutely Important	(7,9,9)

METHOD

The research methodology carried out to analyze the above problems is carried out in several stages, as follows:

1. Searching for literature that discusses fuzzy ahp and ahp methods of selecting best dealer location
2. Comparing and setting criteria for methods used to select dealer locations
3. Conclude the right method used in dealer locations

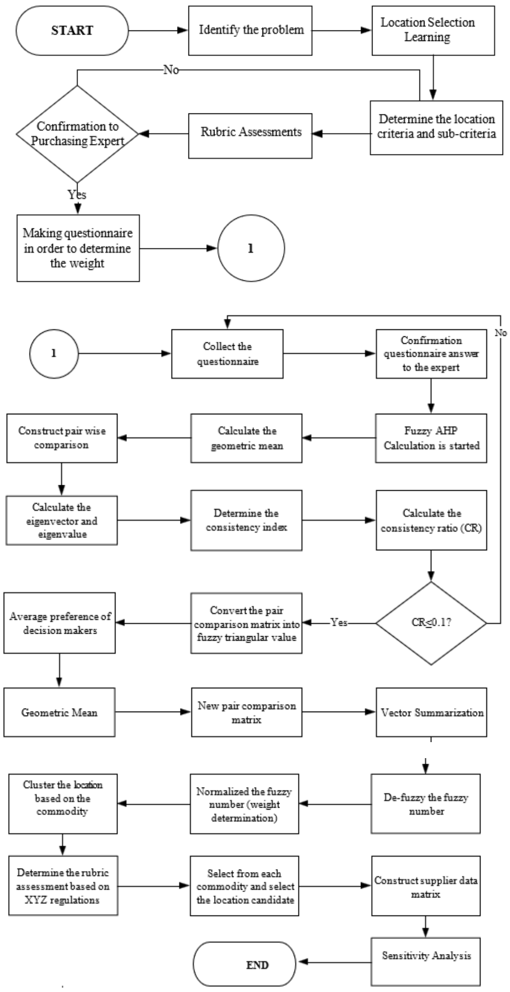

Figure 2. Research Framework

ISSN Print : 2621-3745
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Identification of Criteria, Sub-Criteria

In this study, 5 criteria were used to determine the assessment indicators, namely Factors like market proximity, accessibility, operational costs, and infrastructure support the decision-making process. A structured approach allows companies to assess various options, making optimal choices to support their business growth and sustainability [2]. The sub-criteria and indicators were generated by combining studies from several journals and regulations.

Determination of Criteria and Sub-Criteria Weights Based on Expert Judgment

To determine the weight of each criterion and sub-criteria, a questionnaire will be distributed to several related experts. Data collection starts with the assessment of questionnaires to 3 experts from the purchasing and dealership divisions. The expert questionnaire aims to collect expert judgment about the weight of each criterion and sub-criteria. They will fill out the questionnaire by giving the importance scale number from one criterion to another and from one sub-criterion to another in a pairwise comparison table.

Data will be collected and calculated by using the F-AHP method to determine the level of importance of each criterion and sub-criteria. When uncertainty is present in a problem, the use of fuzzy can be an option in terms of language judgment criteria. Fuzzy numbers are a single subset of real numbers that reflect human decisions according to certain requirements in their judgment [17].

The fuzzy AHP method is a development of the standard AHP method, using the uncertainty inherent in the AHP approach by using a comparison ratio defined with a triangular membership function [18] so that F-AHP produces more accurate decision-making results [19].

The steps of fuzzy AHP are as follows 1) pairwise comparison; 2) comparison of consistency ratios; 3) transformation of triangular intro fuzzy numbers; 4) calculation of geometric mean; 5) calculation of relative fuzzy weights; and 6) defuzzyfied and normalized to determine weights.

Assessment Rubic

After the criteria, sub-criteria, and indicators are generated and weighted, the next step is to create an assessment rubric for each criterion. This rubric is used to assign an integer score to each indicator to be assessed. Thus, the assessment results can be more easily assessed by comparing the actual score with the target score.

Location Selection Indicator Specification

Interviews and discussions were carried out by asking several questions to the Purchasing Manager, then to the indirect purchasing supervisor and the Dealer Development Network. From literature studies conducted by several researchers, there are several criteria and sub-criteria for the supplier selection process such as building, demographics, cost, market conditions, and accessibility.

Based on the interviews and discussions that have been conducted, 5 criteria influence the decision to select suppliers at XYZ company.

The criteria and sub-criteria for suppliers at PT XYZ will be thoroughly integrated with the criteria identified in the literature review, ensuring a comprehensive and holistic approach. These integrated criteria will form the foundation for this research, guiding the selection and evaluation of suppliers. This collaborative approach ensures that the criteria and sub-criteria are both relevant and tailored to the specific needs of PT XYZ.

The objective is to determine the most appropriate and effective criteria for selecting and assessing suppliers, ultimately enhancing the decision-making process. The finalized criteria and sub-criteria that will be utilized in this study are presented in Table 2 below:

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DOI : 10.31328/jsae.v7i2.6487

TABLE II. THE REFERENCE OF SELECTED CRITERIA, SUB-CRITERIA

No.	Criteria	Sub-Criteria	Description	Source
1	Building Facilities	Availability of interior and facade renovation	The idea is to choose a dealer location that not only fulfills current needs but also allows for future scalability and development, maximizing long-term profitability.	*Company Expert (2024)*
		Shop Size	Shop size refers to the physical dimensions and layout of a retail space, including the total area for product display, storage, customer service, and other operational needs.	*Company Expert (2024)*
		Parking Lot	The availability and adequacy of parking lot facilities as a critical aspect in the selection of dealer locations	*Company Expert (2024)*
		Architecture	Factors such as building design, spatial layout, aesthetic appeal, and their impact on customer experience and operational efficiency.	*(Mohamed et al., 2023)*
2	Demographics	Current Population	Density and demographics, businesses can predict market demand, tailor marketing strategies, and ensure the sustainability of the dealership.	*(Mohamed et al., 2023)*
		Age Profile	Predominant age groups within the target market to determine the most suitable location for a business	*(Mohamed et al., 2023)*
		Prospective Density	High prospective density indicates a higher likelihood of attracting customers	*(Guler & Yomralioglu, 2020)*
3	Cost	Rent Cost	Rent cost is the financial expenditure for leasing a business location, including monthly or annual fees for securing premises, which can significantly impact dealership profitability and financial feasibility.	*Company Expert (2024)*
		Environ - mental Manage - ment Fee	An Environmental Management Fee (EMF) is a fee levied on enterprises to cover the costs of reducing and managing their environmental effect.	*Company Expert (2024)*
4	Market Conditions	Market Growth Rate	Identify locations with high growth potential, thereby maximizing opportunities for business expansion and profitability	*(Mohamed et al., 2023)*
		Income Rates	In determining the economic capability of potential customers and their likelihood of purchasing products or services	*(Guler & Yomralioglu, 2020)*
		Rivalry	Assess the level of competition and its implications for the selection of an optimal location.	*Ari Basuki (2011)*
		Shop Areas	Capitalize on existing commercial infrastructure and consumer traffic	*(Guler & Yomralioglu, 2020)*
5	Accesability	Road Conditions	Road conditions, including surface quality, traffic congestion, accessibility, and connectivity, significantly influence operational efficiency and customer convenience for dealerships, determining the viability of a new electric motorbike location.	*(Maghfiroh & Kavirathna, 2023)*
		Distance with DC	Distance with a Distribution Center (DC) is the distance between a dealership and the nearest center, affecting logistical efficiency, transportation costs, and delivery times.	*Company Expert (2024)*

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Figure 3 depicts the hierarchical design for the supplier selection process at PT.XYZ.

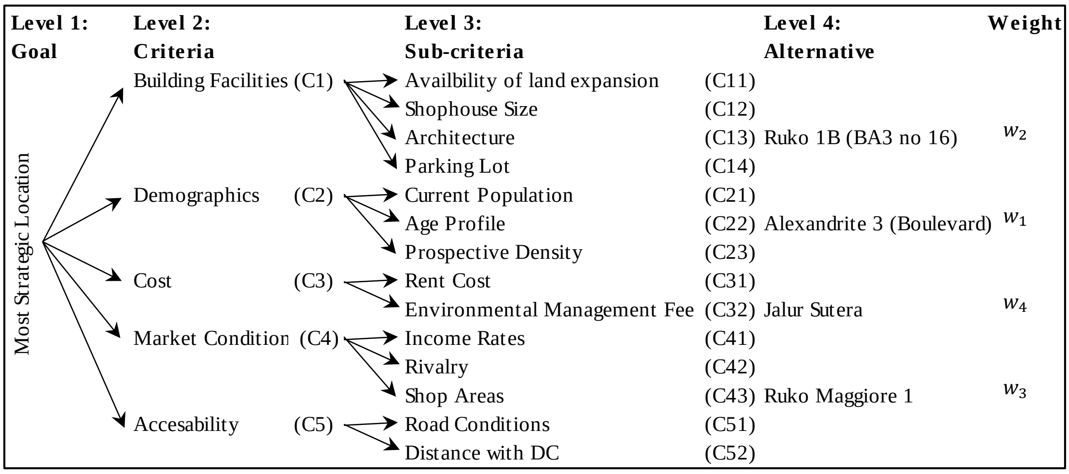

Figure 3. Hierarchy Design of Supplier Selection

DISCUSSION

In this case, the calculation for employee selection using the AHP and Fuzzy AHP models, selection is carried out for 4 employees where the selection is based on several aspects, namely: (1) Building Facilities, (2) Demographics, (3) Cost, (4) Market Conditions, (5) Accessability. With sub-criteria, namely: (1)Availbility of land expansion, (2)Shop Size, (3)Parking Lot, (4)Architecture, (5)Current Population, (6)Age Profile, (7)Prospective Density, (8)Rent Cost, (9)Environmental Management Fee (IPL), (10)Income Rates, (11)Rivalry, (12)Shop Areas, (13)Road Conditions, (14)Distance with DC.

AHP (Analytical Hierarchy Process) Method

The following steps must be taken in the completion of the AHP method, the information will be shown on Table III.

TABLE III. COMPARISON RATING SCALE

Level Scale Interest	Definition	Information
1	Equally important	Both elements have an equally important influence
3	A little more important	Experience and judgment slightly favor one element over its counterpart
5	More important	Experience and judgment strongly favor one element over its counterpart
7	Very important	One element is very favorable and practically its dominance is very real compared to its partner
9	Absolutely more important	One element is proven to be absolutely preferable to its counterpart, at the highest level of confidence
The opposite	Aij = 1/ Aij	If activity i gets a number when compared to activity j, then j has the opposite value when compared to i

In Table IV, the comparison value is determined based on the policy by the decision maker by assessing the level of importance between one element and another.

TABLE IV. RANDOM CONSISTENCY INDEX VALUE

N	Indeks Random Consistency
1	0,00
2	0,00
3	0,58

ISSN Print : 2621-3745 Journal of Science and Applied Engineering (JSAE)
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TABLE V. RANDOM CONSISTENCY INDEX VALUE

N	Indeks Random Consistency
5	1,12
6	1,24
7	1,32
8	1,41
9	1,45
10	1,49
11	1,51

Table 5 is a table for determining the random Index value which is seen from how many criteria are used.

Data Processing & Analysis

Before the assessment is carried out, it is necessary to determine the weight of each criterion and sub-criteria. The weight is needed to determine the level of importance of each indicator and sub-indicator. Thus, in the end, it can be found out which indicators have a major impact on the sustainability of the selection of dealer locations. Determination of weight is done by distributing surveys to several purchasing experts. There are three respondents from the purchasing and dealership divisions of this company. Combining the assessment of questionnaire results from three experts in this company by calculating the geomean for each criterion. The example calculation for criteria to criteria in Table VI.

TABLE VI. THE GEOMEAN CALCULATION

Criteria						
No	Criteria	Expert			Geomean	Criteria
		1	**2**	**3**		
1	C1	0.33	0.33	1.00	0.48	C2
2	C1	0.33	1.00	1.00	0.69	C3
3	C1	0.33	1.00	1.00	0.69	C4
4	C1	3.00	3.00	3.00	3.00	C5
5	C2	0.20	0.33	1.00	0.41	C3
6	C2	1.00	1.00	1.00	1.00	C4
7	C2	3.00	1.00	3.00	2.08	C5
8	C3	1.00	0.33	1.00	0.69	C4
9	C3	1.00	3.00	1.00	1.44	C5
10	C4	1.00	1.00	1.00	1.00	C5

Before determining the weights using Fuzzy-AHP, it is essential to verify the consistency of the preference comparison matrix. A consistency ratio below 0.10, or 10%, is considered acceptable. If the ratio surpasses this limit, it indicates that the preference comparison matrix is inconsistent or incorrect, rendering it unfit for further calculations. Should the consistency ratio surpass 10%, the following three actions must be taken:

a. Identify the judgment in the matrix that exhibits the highest level of contradiction.
b. Identify the range of inconsistencies to improve.
c. Request that the expert review the decision and revise it based on a more probable value within the range.

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TABLE VII. CONSISTENCY RATIO CALCULATION FOR EACH CRITERION

Criteria Comparison Matrix							
	C1	**C2**	**C3**	**C4**	**C5**	**Priority**	**Eigen Value**
C1	1	0.48	0.69	0.69	3.00	0.19	1.18
C2	2	1	0.41	1.00	2.08	0.22	1.19
C3	1.44	2.47	1	1	1.44	0.25	0.97
C4	1.44	1	1	1	1.00	0.20	0.90
C5	0.33	0.48	0.69	1.00	1	0.13	1.14
Total	6.30	5.43	3.79	4.39	8.52	1	5
CI	0.09						
RI	1.12						
CR	0.08	CONSISTENT					

Table VIII is the summary result of the weight of each criterion using AHP.

TABLE VIII. SUMMARY OF CRITERIA WEIGHT

	Criteria	Weight	%
C1	Building Structure	0.188	18.81%
C2	Demographics	0.219	21.87%
C3	Cost	0.255	25.49%
C4	Market Conditions	0.204	20.44%
C5	Accesability	0.134	13.39%

Table IX is the summary result of the weight of each sub criterion using AHP.

TABLE IX. SUMMARY OF SUB CRITERIA WEIGHT

	Sub-Criteria	**Weight**	**%**
C11	Availbility of land expansion	0.127	12.66%
C12	Shophouse Size	0.381	38.14%
C13	Architecture	0.225	22.48%
C14	Parking Lot	0.267	26.72%
C21	Current Population	0.332	33.17%
C22	Age Profile	0.294	29.38%
C23	Prospective Density	0.375	37.45%
C31	Rent Cost	0.781	78.06%
C32	Environmental Management Fee	0.219	21.94%
C41	Income Rates	0.648	64.75%
C42	Rivalry	0.130	12.96%
C43	Shop Areas	0.223	22.29%
C51	Road Conditions	0.325	32.47%
C52	Distance with DC	0.675	67.53%

From Table 9 above, it shows that the consistency ratio between each sub- criterion is less than 0.1 which means that the data is consistent enough and did not need to be retaken. Table X below is the result of ranking alternative dealer locations using the AHP method, Shop 1B (BA3 no 16) has position 1 with a weight of 0.283.

TABLE X. RANKING FOR ALTERNATIVE LOCATIONS

Alternatives	AHP	
	Weight	Priority
Ruko 1B (BA3 no 16)	0.283	1
Alexandrite 3 (Boulevard)	0.279	2
Jalur Sutera	0.215	4
Ruko Maggiore 1	0.223	3

F-AHP (Fuzzy Analytical Hierarchy Process) Method

The field of fuzzy set theory was first introduced by Lotfi A. Zadeh in 1965. Zadeh This theory represents a mathematical framework that is employed to illustrate uncertainty, vagueness, imprecision, and a lack of information. In the context of fuzzy set theory, the membership function represents a pivotal component, exerting a profound influence on the theory's overall structure. In the fuzzy method, triangular fuzzy number (TFN) is employed. TFNs are employed to describe linguistic variables with certainty. TFN is symbolised by $l \leq m \leq u$, all of these judgments are made by all individuals involved in group decision-making, and they are then converted into fuzzy number representations using fuzzy AHP.

TABLE XI. NUMERICAL SCALE AND LINGUISTIC SCALE FOR LEVEL OF IMPORTANCE

Saaty Scale	Definition	Fuzzy Triangular Scale
1	Equally Important	(1,1,3)
3	Weakly Important	(1,3,5)
5	Fairly Important'	(3,5,7)
7	Strongly Important	(5,7,9)
9	Absolutely Important	(7,9,9)

After the consistency ratio has been calculated, the next step is determining the weight of each criterion and sub-criterion by using Fuzzy AHP method. The first step in calculating weight determination is transforming the preference comparison matrix to a Triangular Fuzzy Number (TFN). The C2 and C2 score is 1/3 in the pair comparison rating matrix. If the expert says that C2 is more important than C1, then the fuzzy triangle scale between C1 and C2 is (1/1,1/3,1/5).

TABLE XII. TRIANGULAR FUZZY NUMBER OF CRITERION

Criteria	C1	C2	C3	C4	C5
			Respondent 1		
C1	(1,1,3)	(1/1,1/3,1/5)	(1/1,1/3,1/5)	(1/1,1/3,1/5)	(1,3,5)
C2	(1,3,5)	(1,1,3)	(1,1,3)	(1,1,3)	(1,3,5)
C3	(1,3,5)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)
C4	(1,3,5)	(1,1,3)	(1,1,3)	(1,1,3)	(1,3,5)
C5	(1/1,1/3,1/5)	(1/1,1/3,1/5)	(1,1,3)	(1/1,1/3,1/5)	(1,1,3)
			Respondent 2		
C1	(1,1,3)	(1/1,1/3,1/5)	(1,1,3)	(1,1,3)	(1,3,5)
C2	(1,1,3)	(1,1,3)	(1/1,1/3,1/5)	(1,1,3)	(1,1,3)
C3	(1,1,3)	(1,3,5)	(1,1,3)	(1/1,1/3,1/5)	(1,3,5)
C4	(1,1,3)	(1,1,3)	(1,3,5)	(1,1,3)	(1,1,3)
C5	(1/1,1/3,1/5)	(1,1,3)	(1/1,1/3,1/5)	(1,1,3)	(1,1,3)
			Respondent 3		
C1	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,3,5)
C2	(1,1,3)	(1,1,3)	(1,3,5)	(1,1,3)	(1,1,3)
C3	(1,1,3)	(1/1,1/3,1/5)	(1,1,3)	(1,1,3)	(1,1,3)
C4	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)
C5	(1/1,1/3,1/5)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)

According to the calculations above, the average value of experts' preference for C1 over C2 is (0.24, 0.48, 1). Based on the calculated averaged preferences, the new pairwise contribution is displayed in Table XIII.

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TABLE XIII. NEW PAIRWISE COMPARISON

Criteria	C1			C2			C3			C4			C5		
	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u
C1	1	1	1	0.24	0.48	1	0.29	0.78	1	0.29	0.78	1	1	3	5
C2	1	2.33	4.33	1	1	1	0.23	0.51	0.56	0.33	1	1	0.78	2	3.67
C3	1	1.67	3.67	1.67	3.00	5	1	1	1	0.29	1	1	0.56	1.67	2.33
C4	1	1.67	3.67	1	1	3	1	2	4	1	1	1	0.33	1	1
C5	0.20	0.33	1	0.47	0.56	1.67	0.73	0.78	2.33	1	1	3	1	1	1

After calculating the pairwise comparison, the next step is to determine the fuzzy synthesis limit by calculating each column's lower, middle, and upper, called the fuzzy triangular number. The data are shown in Table XIV.

TABLE XIV. FUZZY TRIANGULAR NUMBER

	Fuzzy Triangular Number		
	l	**m**	**u**
C1	2.81	6.04	9.00
C2	3.34	7.18	10.56
C3	4.51	8.11	13.00
C4	4.33	6	12
C5	3.40	3.67	9.00
Total	**18.4**	**31.33**	**53.89**

Once the fuzzy triangular number has been computed, the fuzzy synthetic can be determined using the following method. The data are shown in Table XV.

TABLE XV. FUZZY SYNTHETIC VALUE

	Fuzzy Synthetic Value		
	l	**m**	**u**
C1	0.05	0.19	0.49
C2	0.06	0.23	0.57
C3	0.08	0.26	0.71
C4	0.08	0.20	0.67
C5	0.06	0.12	0.49
Total	0.34	1.00	2.93

After calculating and getting the results of the fuzzy system, the next step is to calculate the priority vector value, as shown in Table XVI.

TABLE XVI. PRIORITY VALUE VECTOR

Priority Value Vector					
SK	**C1**	**C2**	**C3**	**C4**	**C5**
C1	1	0.92	0.86	0.98	1
C2	1	1	0.94	1	1
C3	1	1	1	1	1
C4	1	0.96	0.91	1	1
C5	0.85	0.79	0.74	0.83	1

After getting the vector priority value, the next step is to determine the defuzzification ordinate value by finding the minimum value. Table 17 presents the defuzzification.

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TABLE XVII. DEFUZZIFICATION

Priority Value Vector						
SK	**C1**	**C2**	**C3**	**C4**	**C5**	**Defuzzification**
C1	1	0.92	0.86	0.98	1	0.86
C2	1	1	1	1	1	1
C3	1	1	1	1	1	1.00
C4	1	0.96	0.91	1	1	0.91
C5	1	0.79	0.74	0.83	1	0.74
Total						**4.45**

The next step is to normalize the weight value vector, as shown in Table XVIII.

TABLE XVIII. WEIGHT VALUE VECTOR

Weight Value Vector		
	W	**Rank**
C1	0.193	4
C2	0.212	2
C3	0.224	1
C4	0.205	3
C5	0.166	5
Total	**1.00**	

Table XIX is the summary result of the weight of each criterion using F-AHP.

TABLE XIX. SUMMARY OF CRITERIA WEIGHT

Criteria	Mi	Ni	%
C1	0.86	0.193	19.30%
C2	0.94	0.212	21.16%
C3	1.00	0.224	22.45%
C4	0.91	0.205	20.47%
C5	0.74	0.166	16.63%
Total	4.45	1	100%

Table XX is the summary result of the weight of each sub-criterion using F-AHP.

TABLE XX. SUMMARY OF SUB-CRITERIA WEIGHT

Sub-Criteria	Relative Fuzzy Weight			Mi	Ni	Global Weight	%
C11	0.11	0.20	0.47	0.42	0.20	0.038	3.82%
C12	0.22	0.54	0.90	1.00	0.47	0.090	9.04%
C13	0.12	0.25	0.35	0.31	0.15	0.028	2.80%
C14	0.13	0.27	0.41	0.40	0.19	0.036	3.64%
C21	0.15	0.31	1.03	0.90	0.32	0.067	6.67%
C22	0.10	0.29	0.64	0.96	0.34	0.071	7.10%
C23	0.12	0.41	1.03	1.00	0.35	0.074	7.39%
C31	0.32	0.78	1.73	1.00	0.83	0.186	18.63%
C32	0.14	0.22	0.46	0.21	0.17	0.038	3.82%
C41	0.23	0.62	1.51	1.00	0.59	0.122	12.17%
C42	0.06	0.12	0.30	0.12	0.07	0.014	1.44%
C43	0.10	0.25	0.71	0.56	0.34	0.069	6.86%
C51	0.20	0.32	0.82	0.61	0.38	0.063	6.33%
C52	0.24	0.68	1.44	1.00	0.62	0.103	10.30%

ISSN Print : 2621-3745
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DOI : 10.31328/jsae.v7i2.6487
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Assessment Rubric

Assessment guidelines are needed to evaluate quality when conducting an assessment. Therefore, an assessment rubric needs to be determined before the assessment is conducted. Rubric scoring will be generated for each indicator. 14 indicators will be paired with scoring rubrics. Each scoring rubric has a score to convert the scoring results into integer form, as seen in Table XXII.

TABLE XXII. SAMPLE RUBRIC FOR THE AVAILABILITY INDICATOR OF INTERIOR AND FAÇADE RENOVATION

Rubric Assessment				
Ruko 1B (BA3 no 16)	**Alexandrite 3 (Boulevard)**	**Jalur Sutera**	**Ruko Maggiore 1**	
C11 : Availability of interior and facade renovation				
Class	**Class**	**Class**	**Class**	**Score**
Not permitted	Not permitted	Not permitted	Not permitted	1
Permitted, but adding fee	Permitted, but adding fee	Permitted, but adding fee	Permitted, but adding fee	3
Permitted	Permitted	Permitted	Permitted	5

Assessment Results

Indicators have also been paired with each standard. The next step is to directly assess four study areas: Shophouse 1B (BA3 no 16), Alexandrite 3 (Boulevard), Silk Road, and Maggiore Shophouse 1. The result of the assessment carried out using the location supplier data matrix assessment rubric for the 14 sub-criteria can be seen in Table XXIII.

TABLE XXIII. RESULT FOR LOCATION SUPPLIER DATA MATRIX

Alternative	C1				C2			C3		C4			C5	
	C11	**C12**	**C13**	**C14**	**C21**	**C22**	**C23**	**C31**	**C32**	**C41**	**C42**	**C43**	**C51**	**C53**
Ruko 1B (BA3 no 16)	3	5	5	5	3	5	3	3	1	5	1	5	5	1
Alexandrite 3 (Boulevard)	3	3	3	5	1	5	5	5	5	1	3	5	5	5
Jalur Sutera	1	5	5	5	5	5	1	1	1	3	5	1	3	3
Ruko Maggiore 1	1	1	5	5	3	5	3	3	5	5	3	3	3	3

After calculating the weight score for each alternative, the next step is to rank each alternative dealer selection location to be chosen. This ranking process comprehensively evaluates all previously assessed factors, such as accessibility, rental cost, market potential, and supporting infrastructure, as seen in Table XXIV.

TABLE XXIV. RANKING FOR THE ALTERNATIVE DEALER LOCATION

Alternative	Weight Score	Rank
Ruko 1B (BA3 no 16)	0.574	2
Alexandrite 3 (Boulevard)	0.624	1
Jalur Sutera	0.312	4
Ruko Maggiore 1	0.444	3

The table presents the ranking of four alternative locations for dealer selection based on their weight scores. The site "Alexandrite 3 (Boulevard)" had the greatest weight score of 0.652, ranking first, suggesting that it is the most desired option among the alternatives. "Ruko 1B (BA3 no 16)" is ranked second, with a weighted score of 0.522.

Comparative Analysis of AHP and Fuzzy AHP Methods

The sensitivity of criteria and sub-criteria weighting will be seen as the overall trend. This sensitivity examines the difference in weight between each method's highest and lowest weights in a particular criterion or sub-criteria. The sensitivity of criteria and sub-criteria can be seen in Table XXV.

TABLE XXV. SUMMARY OF ALTERNATIVES RESULT USING AHP AND F-AHP METHOD

Alternatives	AHP		F-AHP		The difference	
	Weight	Priority	Weight	Priority	Point	(%)
Ruko 1B (BA3 no 16)	0.283	1	0.574	2	0.291	29%
Alexandrite 3 (Boulevard)	0.279	2	0.624	1	0.344	34%
Jalur Sutera	0.215	4	0.312	4	0.097	10%
Ruko Maggiore 1	0.223	3	0.444	3	0.222	22%
Total					0.238	24%

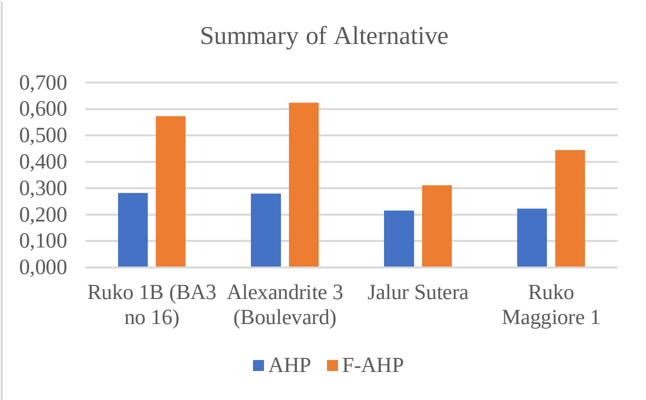

Figure 4. Summary of Alternatives Result using AHP and F-AHP Method

Table 25 shows a total difference of 0.238 or 24%. It can be concluded that Fuzzy AHP generally gives greater weight to all alternatives than AHP. It could be due to Fuzzy AHP's ability to handle uncertainty and provide more flexible judgment.

Fuzzy AHP is more sensitive to uncertainty and ambiguity in judgment, which is reflected in the significant weight difference between AHP and Fuzzy AHP methods. Alternatives such as Alexandrite 3 that may have high uncertainty variables are benefited by the Fuzzy AHP method. As an example, that alternative will rank second with a weight of 0.279 using the AHP method, while it will rank first with the highest weight, which is 0.624, using the Fuzzy-AHP method

Fuzzy AHP shows that this alternative is superior when uncertainty in criteria is evaluated. This may be due to factors with high uncertainty, such as accessibility, being assessed more conservatively in AHP.

These results show that although AHP and Fuzzy AHP are used for the same purpose, which is to assess and prioritize alternatives based on certain criteria, the results can differ significantly due to differences in the handling of uncertainty. Fuzzy AHP tends to give higher weights and prioritize alternatives in a more adaptive way to uncertainty, while AHP is more deterministic and less flexible in assessment.

Sensitivity Analysis

Sensitivity analysis is employed to examine how variations in criterion weights affect supplier rankings and assess the stability of these rankings. This analysis examines how priority weight variations affect the overall outcomes. Three different scenarios will be explored to evaluate the impact of altering weight requirements, as seen in Table XXVI.

Journal of Science and Applied Engineering (JSAE)
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TABLE XXVI. THREE SCENARIOS FOR SENSITIVITY ANALYSIS EXPERIMENTS

Sub-Criteria	Weight	Sce. 1	Sce.2
Availbility of land expansion	0.038	0.100	0.100
Shophouse Size	0.090	0.100	0.100
Architecture	0.028	0.100	0.100
Parking Lot	0.036	0.100	0.100
Current Population	0.067	0.100	0.100
Age Profile	0.071	0.100	0.100
Prospective Density	0.074	0.100	0.100
Rent Cost	0.186	0.200	0.100
Environmental Management Fee	0.038	0.100	0.100
Income Rates	0.122	0.100	0.100
Rivalry	0.014	0.100	0.250
Shop Areas	0.069	0.100	0.100
Road Conditions	0.063	0.100	0.100
Distance with DC	0.103	0.100	0.100

According to Table XXVII, when the weight of the criteria increases to 0.2, the rent cost sub-criteria becomes the most influential sub-criteria. Although the supremacy of the criterion changes, the picked supplier's outcome remains constant. As a result, even if the cost criteria change, the supplier ranking remains stable.

Alternative	Rank	Sce. 1	Sce.2
Ruko 1B (BA3 no 16)	2	2	3
Alexandrite 3 (Boulevard)	1	1	1
Jalur Sutera	4	4	4
Ruko Maggiore 1	3	3	2

In the second scenario, when the competition weight is increased to 0.25, it becomes the most influential criterion. The results of the selected suppliers do not change except for ranking 2 and 3 swapping positions. As a result of the sensitivity analysis above, the analysis is very strong except for the shophouse section of Ruko 1B (BA3 no 16) and shophouse Ruko Maggiore 1. Therefore, the selected location is sensitive, especially for shophouse Alexandrite 3 (Boulevard), when there is a change in the weight, which is very strong and has no change in the sub-criteria rent cost and rivalry.

CONCLUSION

Based on the discussion, the following conclusions can be drawn:
Although AHP is commonly used in handling qualitative and quantitative criteria, fuzzy AHP is considered better at describing vague decisions than AHP. This study identifies five criteria for supplier selection: Building Facilities, demographics, cost, market conditions, and accessibility. These criteria include available land, shophouse size, architecture, and parking lot. Demographics include population, age profile, and prospective density. Cost parameters include rent and environmental management fees. Market conditions assess income rates, rivalry, and shop areas. Accessibility criteria include road conditions and distance to DC. The decision-making process in a business is influenced by five key criteria: cost, demographics, market conditions, Building Facilities, and accessibility. Cost is the most significant factor, with a normalized importance of 0.224. Demographics and market conditions are crucial for targeting potential customers. Building facilities are important for their physical features and commercial suitability. Accessibility is seen as the least critical of the five criteria, with a normalized value of 0.166. The most significant sub-criterion in dealer location selection is rent cost, with a global weight of 0.186. Income level is also crucial, with a weight of 0.122. Despite having the least weight, architecture, and competition are still considered in dealer site selection.

Alexandrite 3 (Boulevard) ranked first with a score of 0.279, notably in the Rent Cost and Environmental Management Fee criteria. Shophouse 1B (BA3 no 16) ranked second with a score of 0.261, excelling in shophouse size and parking fees. In the sensitivity analysis, the results obtained from changing the weights of the two scenarios show the location for Alexandrite 3 (Boulevard) shophouses when there is a strong weight change and no change in the sub-criteria of rental costs and competition.

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