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Analysis of Vendor Selection Using Fuzzy Analytical Hierarchy Process (Fahp) (Case Study: Pt Pos Logistic Bandung)

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Abstract; *The purpose of this study is to choose the best goods distribution vendor of PT Pos Logistic Bandung. Vendors are one of the main factors that influence the speed of delivery. Good decision making based on the results of vendor selection can improve performance in sales and operation management. Data were collected by conducting interviews and questionnaires to three expert in the sales and operations department. Data were analyzed using the Fuzzy Analytical Hierarchy method (FAHP) by converting the weight of the questionnaire to a triangular fuzzy number, calculating the fuzzy synthetic extent, vector, defuzzification ordinate, and normalizing the vector fuzzy value. Weights using the FAHP method will be compared with the results of the Expert Choice weights. The results of the study can be used by PT Pos Logistic sales and operation management in making decisions based on the conditions of the available vendors, the selected vendor is PT X with a weight of 0.300 (FAHP) and 0.452 (Expert Choice), both methods produce different weight values but the same selected vendor. This research can be developed specifically with the Topsis method by considering customer satisfaction. Based on previous research, several studies are used to weigh in choosing vendors, but not many have combined FAHP with Expert Choice.*
Keyword: *Vendor Selection, FAHP, Expert Choice, Decision Making.*

I. INTRODUCTION

PT Pos Logisti Bandung is engaged in the field of services, the logistic company requires vendors to smooth out the process of goods distribution, so the company must be selective in choosing vendors as a business partner. Vendors who are partners of PT Pos Logistic Bandung consist of 4 companies and responsible for distributing goods to customers. These vendors were chosen because the criteria were in accordance with and agreed bythe PT Pos Logistic Bandung. Vendors are chosen if the proposed criteria can be met. Choosing a vendor through the selection and evaluation process is sometimes constrained due to differences in the criteria of each vendor, so it can be a problem in multi-criteria decision making (MCDM) (Liao et al., 2011). Therefore, companies must optimize vendor selection in terms of quality, safe delivery with a guarantee that the goods will be received by customers, and timeliness. With selecting the right vendor, the company can reduce shipping costs, increase competitiveness, and customer satisfaction (Önüt et al., 2009). Based on the multi-criteria proposed by each vendor, there is an alternative that is considered to be able to solve the vendor selection problem (Kilic, H.S., 2013). There are two types of problems in vendor selection (Xia, *et al.*, 2007). The first problem arises when a trader can meet customer needs and be accepted by some customers, but other customers are not satisfied with them because they do not meet the criteria (Demirtas,*et al*., 2009). As a pioneer in vendor selection issues (Dickson, GW, 1966) identification was carried out on 23 vendor selection criteria, the criteria must include aspects such as quality, performance history, delivery, price guarantee, technical capability, and financial problems (Jolai,*et al*., 2011). After conducting a comprehensive survey, there are 74 articles that have been classified, those articles reviewlinear weighting methods, mathematical programming models, and statistical approaches Weber, *et al.* (1991). Vendor selection is divided into four stages Weber,*et*

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al., (1991), De Boer,*et al*., (2001). The first stage is describing the problem, at this stage the company must look at the problem based on the conditions that occur at that time and the impact later on. The second stage is formulating the criteria, in selecting vendors the criteria must be considered in order to expedite the production process, then the third stage is qualifying the vendor selection criteria, and the fourth stage is conducting vendor selection (Boran, *et al*., 2009).

Classification of decision making in multi-attribute vendor selection is divided into six (Sanayei, *et al*., 2010) such as Analytic Hierarchy Process (Analytic Network Process, Technique for Order Preference by Similarity to Ideal Solution TOPSIS), mathematical programming (Linear Programming, Goal Programming or Mixed Integer Programming), probabilistic approaches, intelligent approaches (neural networks, expert systems), hybrid approaches, and others.

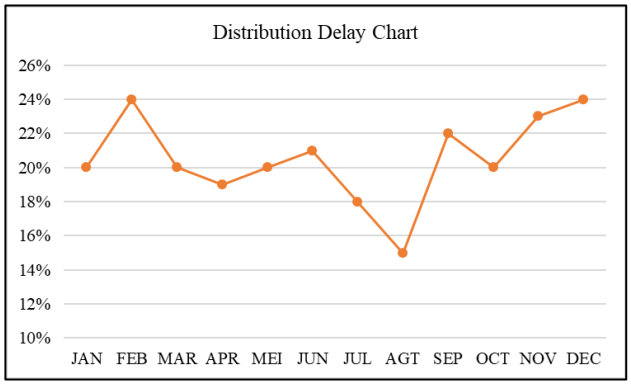

Figure 1: Distribution Delay Chart in 12 months

The selection of vendors in PT Pos LogisticBandunghas several problems due to the limitations of operational vehicles for the distribution of goods to customers. The limitations of this operational vehicle make PT Pos Logistic Bandungcollaborate with several vendors so that the process of distributing goods runs smoothly, in addition, the limitations of the vehicle causing queues for everyday delivery. This makes PT Pos Logistic Bandung requires a solution to determine which vendors will be used as business partners in accordance with the required criteria, these criteria include administration, financial, quality, vendor experience, flexibility, and service. The 2019 report as shown in Figure 1 is the accumulated delay of one year. The report shows that the highest delays occurred in January and December at 24%. This research was conducted to select the best goods distribution vendor in PT Pos Logistic based on the criteria proposed by respondents.

II. LITERATURE REVIEW

In 1980 Thomas Saaty introduced a new theory about The Analytic Hierarchy Process (AHP), this theory applies several approaches to the criteria for decision making and is used in almost all applications related to decision making (Vaidya & Kumar, 2006). AHP is used to help make decisions, AHP is divided into two namely subjective and objective. The use of AHP is expected to reduce complicated things because the problem is seen from two different sides, then the results will be compared as a solution to decision making(Saaty, 1980). Based on the problem at PT Pos Logistic Indonesia about vendor selection, hierarchical factors are broken down into criteria, sub-criteria, then comparing it with the results of decision criteria, weighting each criterion can be adjusted to the needs. The selection of alternatives to determine the selected results is done by considering the results at the final level of calculation of all alternatives (Singh, 2016). The AHP method used is able to adjust various counting techniques such as Quality Function Deployment, Linear Programming, Fuzzy Logic and so on (Vaidya & Kumar, 2006). Fuzzy Analytic Hierarchy Process (FAHP) is the most accurate research methodology because the results are proven in choosing the appropriate criteria in decision making using the fuzzy method (Wang & Chin, 2011). The FAHP method in this study can be applied in the future because it canweighthe alternative criteria faster, besides it is easier to use. The criteria used in decision making require a calculation process to get the weight and final results. The results obtained show a comparison of existing alternative criteria. According to Asuquou andAnudou (2016), when AHP

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is unable to handle personal judgment clearly to get the pairwise comparison, it will cause new problems. Therefore, the problem can be solved using FAHP. The model can be optimized by using Triangular Fuzzy Number (TFN) and linguistic variables that are more consistent and accurate in decision making. The FAHP model develops an architecture system in problem solving. Experts as they obtain information, conduct research using chang analysis based on TFN to improve their ability to make decisions. The average value is calculated to combine decision making within uncertainty.

III. METHODOLOGY

Data collection was done by interviewing and distributing questionnaires to three experts in the sales and operation department of PT Pos Logistic Bandung. The experts were chosen based on several predetermined criteria such as, having insight and knowledge, age and historical depth in decision making, and therelevance level of the experts to the knowledge related to the problem of decision making. The data that has been obtained is collected and calculated in the next step. FAHP is an additional hypothesis on AHP developed by Thomas Saaty (1980). AHP is used as a tool that results in decision making on multi-criteria issues. Expert Choice is the software that is currently used to calculate AHP because of its practical use. Next, the implementation of the approach using the Pairwise comparison with alternative comparisons related to various criteria. The FAHP model has some levels, the first level is objective, second is criteria, third is sub-criteria, and alternative research as the fourth level. The basic of the FAHP model does not involve differences for personal assessment, with this the Fuzzy approach is included in the AHP model for model improvisation. In the FAHP the Pairwise comparison and alternative comparisons are performed using a linguistic variable based on TFN.Steps in the level of analysis can be conveyed, as follows (Izhar, *et al*., 2019):

Step 1: Determining the pairwise matrix comparison with the TFN scale as shown in Table 1.

Table 1.Linguistic terms and the corresponding TFN

Triangular Fuzzy Number (TFN)	Reciprocal of Triangular Fuzzy Number	Linguistic Variable
1 = (1,1,3)	(1/3,1/1,1,1)	Equally Important (EI)
3 = (1,3,5)	(1/5,1/3,1/1)	Weakly Important (WI)
5 = (3,5,7)	(1/7,1/5,1/3)	Fairy Important (FI)
7 = (5,7,9)	(1/9,1/7,1/5)	Strongly Important (SI)
9 = (7,9,9)	(1/9,1/9,1/7)	Absolutely Important (AI)
2 = (1,2,4) 4 = (2,4,6) 6 = (4,6,8) 8 = (6,8,9)	(1/4,1/2,1/1) (1/6,1/4,1/2) (1/8,1/6,1/4) (1/9,1/8,1/6)	The Intermittent Value Between Two Adjacent Scales

Based on the comparable TFN of these linguistic circumstances from Table 1, for instance if the decision maker says, "Criterion 1 (C1) is Strongly Important (SI) than Criterion 2 (C2)", then the fuzzy triangular scale used is (5, 7,9). In contrast, the comparison comparability of C2 to C1 will obtain the fuzzy triangular scale as$\left(\frac{1}{9},\frac{1}{7},\frac{1}{5}\right)$.

Step 2: Determining the value of priority fuzzy synthesis (S_i) with the formula,

$S_i = \sum_{j=1}^{m} M_{gi}^{j} \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$ .....(2.1)

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$perform the fuzzy addition operation of m extent analysis values for a particular matrix such that

$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j , \sum_{j=1}^{m} m_j , \sum_{j=1}^{m} u_j\right)$ .....(2.2)

and to obtain $[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1}$, perform the fuzzy addition operation of M_{gi}^{j} (j=1,2,…,m) values such that

$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = (\sum_{j=1}^{n} l_j , \sum_{j=1}^{n} m_j , \sum_{j=1}^{n} u_j)$ .....(2.3)

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and then compute the inverse of the vector in Eq. (2.1) such that

$[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1}\left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right)$.....(2.4)

Step 3: Determining the vector value (V) and the defuzzification ordinate value (d').

The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as:

$V(M_2 \geq M_1) = \sup [\min(\mu M_1(x), \mu M_2(y))]$ .....(2.5)

and this can be equivalently expressed as follows:

$V(M_1 \geq M_2)$ = highest $(M_1 \Omega M_2)$

$$\mu M_2(d) \begin{cases} 1, & \text{if } m_1 \geq m_2 \\ 0, & \text{if } l_1 \geq l_1 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{Otherwise} \end{cases}$$

where d is the ordinate of the highest intersection point D between μM_1 and μM_2. In figure 2, the intersection between M_1 and M_2 can be seen.

To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

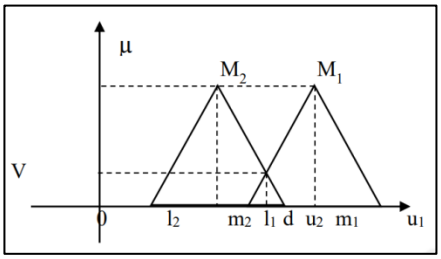

Figure 2: The interaction between M_1 and M_2

Step 4: If the resulting fuzzy value is greater than k, M_i, (i = 1,2, ..., k) then the vector value can be defined as follows:

$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } (M \geq M_k)] = \min V(M \geq M_i)$, i= 1, 2, 3,….,k….....(2.7)

Assume that

$d'(Ai) = \min V(S_i \geq S_k)$ .....(2.8)

For k = 1, 2,…, n; k ≠ i. Then the weight vector is given by μ

$W' = (d'(A_1), d'(A_2), \ldots\ldots, d'(A_n))T$ ….....(2.9)

where A_i (i = 1, 2,…., n) are n elements.

Step 5: Normalization of the weight value of fuzzy vectors (W)

$W = (d(A_1), d(A_2), \ldots, d(A_n))\ T$ ….....(2.10)

where W is a non-fuzzy number. That gives the priority weights of one alternative over another.

I. Findings and Discussion

To determine the criteria, three experts have been chosen to express their opinions about the criteria needed through the questionnaire. The results of the questionnaire were collected and then the AHP calculation was performed using the Expert Choice application. For FAHP calculation, the results of the questionnaire are converted to TFN before then processed using Microsoft Excel software. The results of the three experts were averaged, then a paired comparison matrix of all factors was made. The updated Fuzzy evaluation matrix with respect to TFN is shown in Table 2. The criteria represent the criteria and sub-criteria for vendor selection based on numbers. Table 3 shows the labels on each factor involved in the study.

Table 2.The labels of the criteria and sub-criteria

No	Criteria	Sub-criteria
1	Administration	Have a Company Registration Certificate

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		Have a Trading Business License
2	Flexibility	Flexibility in vehicle changes
		Flexibility in delivery time changes
3	Vendors Experience	Experienced driver
		The number of consumers
		The level of success
4	Financial	Enough capital
		Payment method
		Ease in negotiating prices
5	Service	The speed and accuracy of responding to customer requests and complaints
		Speed and accuracy in communication
6	Quality	Warranty for Defective Goods
		Vehicle compatibility
		Delivery timeliness

a. Calculation with AHP

Based on Table 2 above, the AHP calculation is done using the Expert Choice application as shown in Figure 3 below, it is known that the results of the calculation using the Expert Choice application by filling in the criteria weights, sub-criteria and alternatives from the three respondents anddoing 'combined'or combining the weights of each respondent, got an inconsistency total of <1, which is 0.09 top weight owned by PT X with a weight of 0.452.

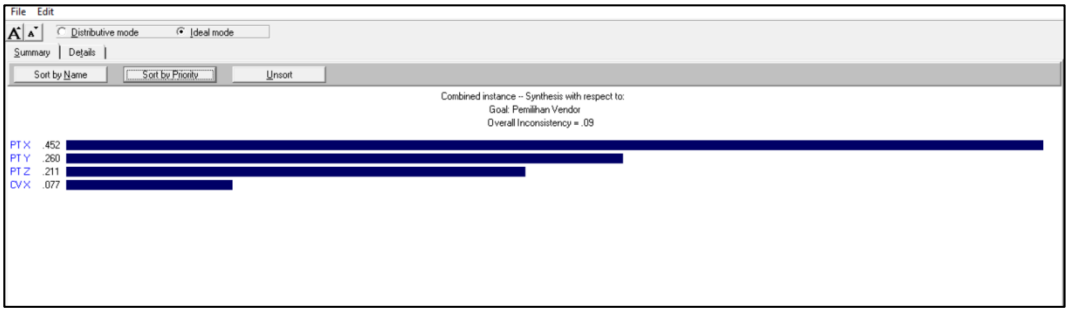

Figure 3.The results of weighting usingexpert choice

b. FAHP calculation

Tabel3.Pairwise comparison matrix of each criterion

	Respondent	Administration			...			Quality		
		l	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*
Administration	1	1,00	1,00	3,00	....	....	....	1,00	3,00	5,00
	2	1,00	1,00	3,00	....	....	....	0,14	0,20	0,33
	3	1,00	1,00	3,00	....	....	....	1,00	1,00	3,00
Flexibility	1	0,14	0,20	0,33	....	....	....	0,20	0,33	1,00
	2	0,20	0,33	1,00	....	....	....	0,20	0,33	1,00
	3	0,11	0,14	0,20	....	....	....	0,11	0,14	0,20
Vendors Experience	1	0,20	0,33	1,00	....	....	....	1,00	1,00	3,00
	2	1,00	3,00	5,00	....	....	....	1,00	3,00	5,00

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	3	0,14	0,20	0,33	....	....	....	1,00	1,00	3,00
Financial	1	1,00	1,00	3,00	....	....	....	1,00	3,00	5,00
	2	1,00	1,00	3,00	....	....	....	0,20	0,33	1,00
	3	1,00	1,00	3,00	....	....	....	0,20	0,33	1,00
Service	1	1,00	1,00	3,00	....	....	....	1,00	3,00	5,00
	2	1,00	1,00	3,00	....	....	....	1,00	1,00	3,00
	3	3,00	5,00	7,00	....	....	....	1,00	1,00	3,00
Quality	1	0,20	0,33	1,00	....	....	....	1,00	1,00	3,00
	2	3,00	5,00	7,00	....	....	....	1,00	1,00	3,00
	3	1,00	1,00	3,00	....	....	....	1,00	1,00	3,00

The data collected is then analyzed according to the purpose of the study, using the FAHP method to get the geometric mean value of the fuzzy pairwise comparison values between the criteria. The results of processing the geometric mean values of the fuzzy pairwise comparison values for each criterion are calculated using the help of Microsoft Excel Software. Table 4 shows the processing results of the geometric mean values, each criterion has a TFN denoted by *(l,m,u)*.

Table4.The geometric mean value of the fuzzy pairwise comparison value

Criteria	Geometric Mean		
	l	*m*	*u*
Administration	0,910	1,259	2,812
Flexibility	0,234	0,312	0,599
Vendors Experience	1,028	1,416	3,003
Financial	0,580	0,809	1,868
Service	1,449	2,062	4,192
Quality	0,813	1,218	2,933
Total	5,014	7,077	15,406
Inverse	0,199	0,141	0,065
Increasing Order	0,065	0,141	0,199

Based on the fuzzy weight value of each criterion that is calculated using equation (2.8), and the results are shown in Table 5.

Table5.Fuzzy relative weights and normalization criteria

Criteria	Relative Fuzzy Weights			Mi	Normalized	Ranking
Administration	0,059	0,178	0,561	0,266	0,181	4
Flexibility	0,015	0,044	0,119	0,060	0,041	6
Vendors Experience	0,067	0,200	0,599	0,289	0,197	2
Financial	0,038	0,114	0,373	0,175	0,119	5
Service	0,094	0,291	0,836	0,407	0,278	1
Quality	0,053	0,172	0,585	0,270	0,184	3

Table 5 shows the results of the calculation of the fuzzy relative weights for each criterion. Finding the average fuzzy value for each criterion is calculated based on equation (2.3). Normalization is performed on the fuzzy average value for

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each criterion based on equation (2.10). The next step is done using equation 2.1 to equation 2.10 to calculate the alternatives, the final results obtained for alternative calculations are shown in Table 6 below:

Table 6.The final result of the calculation

Final Weight					Final Score			
Criteria	Score	Sub-criteria	Score	Global Weight	PT X	PT Y	PT Z	CV X
Administration	0,181	Company registration certificate	0,500	0,091	0,030	0,020	0,020	0,020
		Trading business license	0,500	0,091	0,029	0,021	0,021	0,021
Flexibility	0,041	Flexibility in vehicle change	0,374	0,015	0,004	0,004	0,004	0,004
		Flexibility in delivery time changes	0,626	0,025	0,008	0,006	0,006	0,006
Vendors Experience	0,197	Experienced driver	0,315	0,062	0,017	0,015	0,015	0,015
		The number of consumers	0,371	0,073	0,022	0,017	0,017	0,017
		The level of success	0,315	0,062	0,018	0,015	0,015	0,015
Financial	0,119	Enough capital	0,318	0,038	0,012	0,009	0,009	0,009
		Payment method	0,365	0,044	0,013	0,010	0,010	0,010
		Ease in negotiating prices	0,318	0,038	0,012	0,009	0,009	0,009
Service	0,278	Responding to customer requests and complaints	0,634	0,176	0,052	0,041	0,041	0,041
		Speed and accuracy in communication	0,366	0,102	0,028	0,025	0,025	0,025
Quality	0,184	Warranty for defective goods	0,317	0,058	0,017	0,014	0,014	0,014
		Vehicle compatibility	0,366	0,067	0,020	0,016	0,016	0,016
		Delvery timeliness	0,317	0,058	0,019	0,014	0,014	0,014
Total	1,000		6,000	1,000	0,300	0,234	0,234	0,234
Ranking					1	2	3	4

Several criteria are used in the vendor selection of PT. Pos Logistic Bandung, including: administration, flexibility, vendor experience, finance, services, and quality. It should be noted that any change in the value of the criteria can change

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the final result. For example, the service criteria are the best criteria, if the vendor has a problem with the service provided, then the optimal results can move to other criteria. Application of FAHP method at PT. Pos Logistic Bandung can provide decision support for the company to choose PT X vendors as partners with the final result of 0.300.

IV. CONCLUSIONS

Vendor selection is the most important task for the company, determining the criteria used is depended on the company by going through several stages. The decision making process at PT. Pos Logistic Bandung involves many criteria, the FAHP method can be used to overcome weaknesses in criteria that have a subjective nature compared to the AHP method and can determine the priority weights on each criterion on which to base the analysis.

Based on the results of calculations performed, the vendor that has the highest weight value is PT X with the results of 0.300 using FAHP and 0.452 using Expert Choice. This shows that FAHP and Expert Choice both chose PT X as the most suitable vendor that is in accordance with the requirement of PT Pos Logistic Bandung, but with different weights. Future studies are expected to be able to combine the FAHP method with several other decision selection system methods, and consider the level of customer satisfaction with vendors.

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