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Determination of Business Location by Using Analytical Hierarchy Process (AHP) and Weighted Product (WP)

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Abstract

Information technology that is currently developing provides opportunities for business actors to develop their business. One of the factors that make a business grow is the location of the business. It is not easy to determine the appropriate business location, so various selections are needed so as to be able to measure the feasibility of the location. The existence of a decision support system can assist in making decisions about determining the location. The method chosen is the AHP method combined with the WP method. To get the value calculated by the AHP method, data collection by interview and observation was used. The literature study is used in the calculation stages with the AHP and WP methods. The use of a combination of AHP and WP methods in determining the location of the business gives a ranking result, with the highest score achieved by the Royal location of 0.617 and the lowest value achieved by the Poris location of 0.094. After observing the new location, Royal for 3 months, there was an increase in sales in the first month by 3 million/15%, in the 2nd month by 4 million/19% and in the 3rd month by 7 million/30%.

Keywords: *AHP, WP, business location, decision support system, criteria.*

1. Introduction

The application of information technology has been widely implemented in various aspects of life [1]. Information technology that is currently developing provides opportunities for business actors to develop their business. One of the roles of information technology is to provide support for organizational management in making business decisions, for example by applying certain computational models in the field of business prediction [2]. Before setting up a business, an entrepreneur must think carefully about the strategy that will be used, of course with a long process and a long time [3]. Location is a crucial thing in starting a business. Many factors and criteria can influence in determining or choosing a business location. In determining the location, criteria are needed that are in accordance with the wishes of consumers [4]. Because of the many criteria used, the calculations used are also more [5]. Therefore, the Multi-attribute Decision Making (MADM) approach can be used [6]. MADM is a decision support system method that can be used to solve problems [7]. Maximize profits and minimal expenses can be obtained from the accurate selection of business locations [8]. It is not easy to determine the appropriate business location, so various selections are needed so as to be able to measure the feasibility of the location.

Based on this, a decision support system is needed that functions for entrepreneurs in determining the appropriate location, of course with the system being able to provide consideration of which location will provide more benefits with less burden. [3]. The existence of a decision support system can turn complex manual calculations into computerized calculations. The information generated by the decision support system in this case is the best location, aiming to support the company's leadership in making a decision [9]. Decision Support Systems are made to support every stage of decision making, starting from identifying or analyzing problems, determining relevant data, and using the approach used in the sample-making process in terms of providing results or decisions [10].

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The method chosen is the AHP method combined with the WP method. The Analytical Hierarchy Process (AHP) method has stages of completion of compiling problems in a sequential hierarchy and then comparing them in pairs [11]. The reason the AHP method was chosen is because it is able to analyze criteria that have a good consistent value. While the Weighted Product (WP) is a structured decision method [12]. The weighted product (WP) method is one of the methods commonly used in site selection systems, the advantage of this method is the concept of weight improvement used for each criterion. [13]. Both methods were chosen because they were able to select the best alternative from a number of available alternatives [14]. The combination concept used is the AHP method used to find the priority weight of each criterion which will then be used in calculating the Weighted Product (WP) method with the aim of finding the best ranking [15]. The use of the weight criteria obtained with the AHP method is used in the process of calculating the vector S in the WP method [16]. The comparison of the importance ratio of the criteria processed using the AHP method is taken by weight [17]. The weights are derived from AHP and calculated by the WP method to get a list of recommended locations. Based on the results of the analysis of the combination of AHP and WP that has been carried out in previous researchers [18], The AHP method is able to produce priority factors which become the weight values for the WP method ranking.

2. Research Methodology

Data collection uses 3 techniques or methods, namely :

1) Interviews with business owners.
2) Observation of alternative locations that have been determined.
3) Study literature by collecting references from previous journals that have similar titles or methods.

2.1. Analytical Hierarchy Process (AHP)

AHP is a method for creating a sequence of alternatives that aims to choose the best at the time of decision making. The steps and procedures in solving problems using the AHP method are as follows: [15] :

Defining the problem, then determining the solution and compiling a hierarchy of the problems encountered.

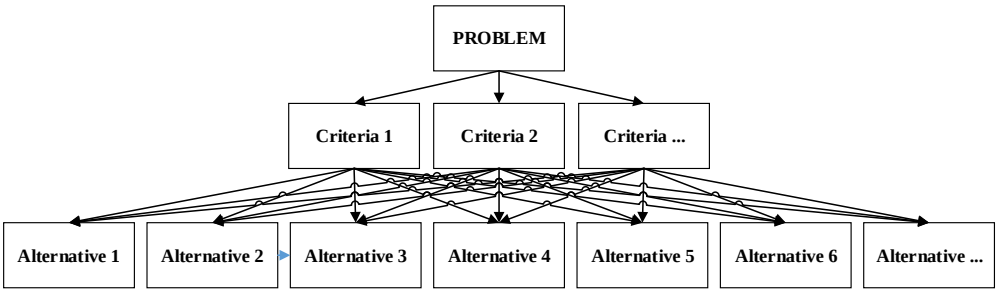

Figure 1. AHP Hierarchy Structure

Determine the weight of the criteria by comparing each criterion in pairs. This comparison process uses a priority scale or a quantitative scale in table 1 to construct a pairwise comparison matrix for site selection using the equation.

Table 1. Quantitative Scale

Intensity of Interest	Definition	Explanation
1	Both elements are equally important	Two elements have the same effect big
3	One element a little more	Little experience and judgment

Intensity of Interest	Definition	Explanation
	important than elements that other	support one element compared other elements
5	One element is more important than on others	Very strong experience and judgment support one element compared other elements
7	One element is definitely more absolute important than elements other	One strong element is supported and dominant seen in practice
9	One element is absolutely essential than other elements	Evidence in favor of one element against other elements has a level highest affirmation possible strengthen
2, 4, 6, 8	Values between two values close consideration	This value is given when there are two compromises between 2 choices
Opposite	If for activation i gets one digit compared to activation j, then j has the opposite value compared to i.	

Normalization of the pairwise comparison matrix. The matrix normalization steps are as follows:

a) Sum the values of each column in the pairwise comparison matrix.
b) Divide each value from the column by the sum of the corresponding columns to obtain a normalized matrix. The matrix normalization calculation formula uses equation (1).

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{l=1}^{m} a_{lk}} \quad (1)$$

Information :

$\bar{a}_{jk}$ = The value of pairwise comparison matrix normalization result

a_{jk} = The value of the jth row, kth column pairwise comparison matrix

a_{lk} = The value of the pairwise comparison matrix of the lth column of the kth column

m = End of matrix row

c) Calculating the synthetic weights by adding up each column in the same row from the normalized comparison matrix using equation (2)..

$\sum$ column = c1 + c2 + c3 + cn (2)

d) Calculate the eigenvalues by multiplying each column of the pairwise comparison matrix in the same row, then to the power of a number of criteria (-number of criteria) using equation (3).

$\lambda 1 = (c1 \times c2 \times c3 \times cn)^{-w}$ (3)

e) Calculate the priority weight of each criterion by dividing the eigenvalues for each criterion by the total number of eigenvalues.
f) Calculating the importance of each criterion by dividing the synthesis weight by the priority weight.
g) Calculate the maximum eigenvalue (λ max) by means of the total number of importance values divided by the number of criteria.
h) Measuring consistency to ensure that the considerations for decision making are of high consistency. The steps in measuring consistency are:
i) Calculate the Consistency index (CI) shown by the equation (4).

$$CI = (\lambda_{maks} - n)/(n-1) \quad (4)$$

Information:

CI = Consistency Index

λ_{maks} = Eigen Maximum
n = Number of Elements

j) Calculate the Consistency Ratio (CR) shown in equation (5).

$$CR = \frac{CI}{RI} \quad (5)$$

Information:
CR = Consistency Ratio
CI = Consistency Index
RI = Index Random Consistency

Checking the consistency of the consistency ratio hierarchy (CI/IR) is less than or equal to 0.1 then the calculation results can be declared correct.

2.2.Weighted Product (WP)

The Weighted Product (WP) method requires a normalization process because this method combines the results of the assessment of each attribute. The multiplication result is not meaningful if it has not been compared (divided) with the standard value. The weight for the benefit attribute functions as a positive power in the multiplication process, while the cost weight functions as a negative power. The Weighted Product method uses multiplication as a link to attribute ratings, where the rating of each attribute must be raised to the first power with the corresponding weight [19].

The calculation steps with the Weighted Product (WP) method are as follows:

a) Improvement of criterion weight, with equation (6).

$$\text{new } W_j = \frac{old\ W_j}{\sum W_j} \quad (6)$$

b) Calculating the vector S. This step is the same as the normalization process, with equation (7).

$$S_i = \prod_{j=1}^{n} X_{ij}^{W_j} \quad (7)$$

Information:
S = Expressing alternative preferences is analogized as a vector S
X = Declare the value of criteria
W = Declare the weight of the criteria
i = Declare alternative
j = Declare criteria
Wj is a positive value for the rating attribute, and a negative value for the number attribute..

c) Calculate the vector V, or the relative preference of each alternative, for ranking by equation (8).

$$V_i = \frac{\prod_{j=1}^{n} (X_{ij})^{W_j}}{\prod_{j=1}^{n} (X_j{}^{*})^{W_j}} \quad (8)$$

Information:
V = Expressing Alternative Preferences Analogous to Vector V
X = Declare Criteria Value
W = Declare Criteria Weight
i = Express Alternative
j = Declare Criteria
n = State the number of criteria.

The data is processed using 2 methods, namely Analytical Hierarchy Process (AHP) and Weighted Product (WP). The AHP method is used to find the priority weights that will be used in the WP method. While the WP method is used to find the value of the V vector and determine the ranking of locations. The results can be

seen and will be sorted based on the value of the vector V of each alternative location which is calculated using the WP method.

3. Results and Discussion

The data used in determining alternative locations were taken from past research data [8] only with different methods. Past research in determining the location of the business using the AHP and SAW methods, while in the current study using AHP and WP. Seven areas that will be used as alternative locations are Gondrong, Sipon, Poris, Royal, Rawa Cipondoh, Dadap, and Teluk Naga. Determination of the location using three criteria, namely the area of the shop, the cost of rent, and the crowd.

3.1. Data processing with AHP

a) Hierarchical Structure

The picture of the alternative hierarchical structure of business locations with several criteria can be seen in figure 1 below.

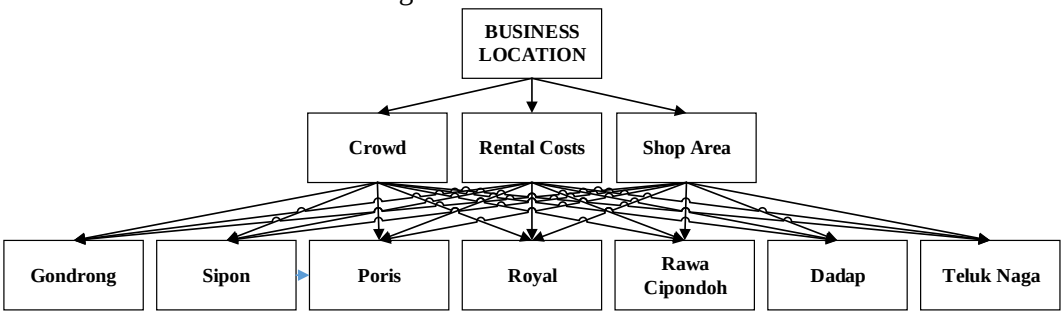

Figure 2. Struktur Hirarki Alternatif Lokasi Usaha

b) Criteria Comparison Matrix

The results of the comparison of the criteria matrix that have been calculated in the form of values in each column. The values obtained from interviews with shop or business owners are shown in table 2.

Table 2. Value of Criteria Comparison Matrix

Criteria	Crowd	Rental Costs	Shop Area
Crowd	1	3	5
Rental Costs	0,33	1	3
Shop Area	0,2	0,33	1

c) Matrix Normalization

Calculating the normalization of the comparison matrix obtained from each column of criteria divided by the value of the number of columns can be seen in table 3.

Table 3. Matrix Normalization

Criteria	Crowd	Rental Costs	Shop Area	Criteria
Crowd	0,65	0,69	0,56	1,9
Rental Costs	0,22	0,23	0,33	0,78
Shop Area	0,13	0,08	0,11	0,32

d) Measuring Consistent Value

Check the consistency of the consistency ratio (CI/IR) hierarchy with the following steps::

1) Synthesis Weight
   Calculate the synthetic weight by adding up each column as follows:
   $\sum C1 = 0,65 + 0,69 + 0,56 = 1,9$
2) Priority Weight

Calculating priority weights by means of each column of the pairwise comparison matrix in the same row then divided by the number of criteria used as follows:
∑ C1 = (0,65 + 0,69 + 0,56)/3 = 0,63

3) Eigen
Calculating the eigenvalues of the importance of each criterion by means of each column of the comparison matrix multiplied by the priority weight as follows:
∑ C1 = (1*0,63) + (3*0,26) + (5*0,11) = 1,96

The results of the calculation of consistent values consisting of synthesis weights, priority weights and eigenvalues can be seen in table 4..

Table 4. Consistent Value

Criteria	Synthesis Weight	Priority Weight	Eigen	Eigen Sum
Crowd	1,9	0,63	1,96	1,96/0,63=3,11
Rental Costs	0,78	0,26	0,8	0,8/0,26=3,08
Shop Area	0,32	0,11	0,32	0,32/0,11=2,91
Eigen Max Sum				9,1

e) Eigen maximum (λ max)
Calculate the maximum eigenvalue (λ maximum) by dividing the total number of eigenvalues divided by the number of criteria used in the following way:
λ max = 9,1/3 = 3,03

1) Calculating Consistency index (CI)
CI = (3,03-3) / (3-1) = 0,015
2) Calculating *Consistency Ratio* (CR)
The IR value depends on the number of criteria in table 5.

Table 5. Index Random Consistency

Size	1 and 2	3	4	5	6	7	8	9	10	11
RI	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49	1,51

CR = 0,015/0,58 = 0,03.

Based on the CR results, the value is less than 0,1 then the calculation results can be declared correct (consistent).

3.2. Data processing with WP

a) Criteria and Weights
The value of the criterion weight or priority weight can be seen in table 4.

b) Match Rating
The compatibility rating values that have been collected based on the results of interviews with business or shop owners can be seen in table 6.

Table 6. Match Rating Value

Alternative Location	Criteria		
	Crowd	Rental Costs	Shop Area
Teluk Naga	2	1	2
Poris	3	3	2
Dadap	2	2	2
Gondrong	3	2	1
Royal	2	3	2
Rawa	1	2	2
Sipon	2	3	3

c) Vector Value S

Calculation of the value of the vector S using the equation 7.

$S1 = (2^{-0,63})*(1^{-0,26})*(2^{-0,11}) = 0,599$
$S2 = (3^{-0,63})*(3^{-0,26})*(2^{-0,11}) = 0,349$
$S3 = (2^{-0,63})*(2^{-0,26})*(2^{-0,11}) = 0,582$
$S4 = (3^{-0,63})*(2^{-0,26})*(1^{-0,11}) = 0,418$
$S5 = (2^{-0,63})*(3^{-0,26})*(2^{-0,11}) = 0,450$
$S6 = (1^{-0,63})*(2^{-0,26})*(2^{-0,11}) = 0,901$
$S7 = (2^{-0,63})*(3^{-0,26})*(3^{-0,11}) = 0,430$

d) Vector Value V

Calculation of the value of the vector V using the equation 8.

$$V1 = \frac{0,599}{0,599+0,349+0,582+0,418+0,450+0,901+0,430} = 0,161$$
$$V2 = \frac{0,349}{0,599+0,349+0,582+0,418+0,450+0,901+0,430} = 0,094$$
$$V3 = \frac{0,582}{0,599+0,349+0,582+0,418+0,450+0,901+0,430} = 0,156$$
$$V4 = \frac{0,418}{0,599+0,349+0,582+0,418+0,450+0,901+0,430} = 0,112$$
$$V5 = \frac{0,450}{0,599+0,349+0,582+0,418+0,450+0,901+0,430} = 0,617$$
$$V6 = \frac{0,901}{0,599+0,349+0,582+0,418+0,450+0,901+0,430} = 0,242$$
$$V7 = \frac{0,430}{0,599+0,349+0,582+0,418+0,450+0,901+0,430} = 0,115$$

The value of Vector 5 or V5 reached the highest value of 0,617 and the lowest value was generated by the value of Vector 2 or V2 of 0,094. Based on the results of the above calculations, the best location for business is location 5, namely Royal with the largest final value of 0,617. The process is continued with final observations by looking at the results obtained after the implementation of sales at location 5. This observation process was carried out for 3 months by comparing the average sales obtained between businesses at the initial location with businesses that have been moved to location 5. The following is a table 7 with comparative data on average sales.

Table 7. Average Sales Comparison

Month	Average Sales at Initial Location (million)	Average Sales at Location 5 (million)	Increase (million)
1	20	23	3
2	21	25	4
3	23	30	7

Based on the data above, there was an increase in the first month of 3 million or 15% and in the second month there was an increase of 4 million or 19% and in the 3rd month an increase of 7 million or 30%.

4. Conclusion

The use of a combination of AHP and WP methods in determining the location of the business gives a ranking result, with the highest score achieved by the Royal location of 0,617 and the lowest value achieved by the Poris location of 0,094. After observing at the new location, Royal for 3 months, there was an increase in sales in the first month by 3 million or 15% and in the 2nd month there was an increase of 4 million or 19% and in the 3rd month an increase of 7 million or 30%.

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