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Proposed Factory Area Location Alternative Selection Based on Multiple Criteria Decision Making Using Analytical Hierarchy Process Method (Case Studi PT. SKI)

Riana Magdalena*, Agustinus Silalahi, Su Fendi

Program Studi Teknik Industri, Fakultas Teknik, Unika Atma Jaya Jakarta
Kampus 3 BSD, Cisauk, Tangerang, Banten

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Abstract

PT. SKI is a manufacturing company engaged in the production of hair and skin beauty products such as hair masks, shampoos, conditioners and others. Demand for beauty products that are increasing every day requires companies to produce more than inventory. One solution is to expand the production area in an increase large-scale production processes. However, the current production area which cannot optimally support this due to the absence of vacant land or expansion of the area that can be carried out. Based on the results of interviews with the head of the production section, the plan to move locations in several alternative places is the right solution for the company. In the specific task studied, the need for this location transfer will be related to multiple decision making taken by the company. One technique to identify these problems is using the Analytical Hierarchy Process or AHP method where this method is a simplification of complex problems that are not structured, strategic, and dynamic into their parts, and organize in a hierarchy. The level of importance of each criterion that supports decision support is relatively compared to other criteria by considering various considerations and then synthesizing to determine criteria that have high priority and play a role in influencing the results of the system. Based on the results, it is found that there are several criteria which plays an important role in the selection of factory location alternatives obtained in the mathematical equation. The first criterion namely Investment and Operations has a value of around 55.84% indicating that the first best alternative location in the sub criteria is land price, land area, expansion and employee salaries (UMR). Continued around 58.47% in the second general criteria, namely facilities with sub criteria of water, electricity, transportation and service which showed the best selection was in the first location alternative and 73.51% in the criteria for ease of licensing and transportation access at the first alternative location. By comparing the three data multiplication matrices and assessment criteria, it was found that a large comparison of the three general criteria had a total of 60.91% of the first alternatives being the priority of PT. SKI to choose the location of the new factory area, which is located in Padurenan, Gunung Sindur, Bogor, West Java.

1. INTRODUCTION

In the development of daily needs, in survival increases along with global growth as indicated by the demand for materials for the body's need for survival. Likewise with manufacturing companies that will increase production in line with consumer demand. PT. SKI is a company engaged in manufacturing, especially in beauty products and cosmetics, and has plans to move factory locations to industrial estates.

The factor that caused the displacement of the location was due to the current location not permanent or rented land and which could not be expanded.With these problems, a special application is needed to facilitate the company in determining the new factory location in expanding the production process using the AHP (Analytical Hierarchy Process) method.

This method is used by selecting criteria that are mutually different so that the criteria can be processed using the AHP method in producing a desired alternative. The principle of the method used is the simplification of a complex problem that

*Corresponding author. Riana Magdalena
Email address: riana.magdalena@atmajaya.ac.id

is unstructured, strategic and dynamic in its components and will also be arranged in a hierarchy. After that, the importance of each variable is subjectively assigned a numerical value about the existing qualitative variables compared to the existing quantitative variables.

Consideration of these variables can be done by synthesis to determine variables that have high priority values and can provide an alternative to the location obtained in this problem.

2. RESEARCH METHODOLOGY

2.1 Theoretical Background

PT. SKI is a company engaged in manufacturing specialized in beauty products and cosmetics. It also has a plan to move the factory location to an industrial area. Factors that cause location displacement are caused by the current location not permanent or land transportation and which cannot be supported (expansion area). With the existence of these problems, special application is needed for companies in determining the location of new factories in the production process by using applications from Multi Criteria Decision Making in the selection of the desired location alternatives. This method can also consider a variety of criteria both from quantitative and qualitative data combined with the selection of opinions given qualitatively so that the desired decision making achieved in the company can be processed in a systematic processing.

Decision Making

According to Marimin (2005), there are two sets of work in decision making, namely, decision making without trial and decision making based on an experiment. Decision-making without being based on experiments is done by systematically compiling the way public works before finding solutions to the expected problems. This theory was developed in line with a statistical approach where, in simple terms, the resulting decision was attempted to have the minimum effect of errors.

Decision making means choosing between various ways of doing or getting things done. The above implies that decision making is more oriented to problems that arise or may arise. In contrast to this, Drumond states that decision making is an attempt to create future events and formation (Syafaruddin, 2004).

Another definition that explains that "decision making is the process of generating and evaluating alternatives and making choices among them" (Syafaruddin, 2004). This opinion confirms that decision making is a process when there are a number of steps that must be done and evaluates alternatives to make decisions from all alternatives. Every decision making process is a system of action because there are several components in it.

According to Prayudi (Syafaruddin, 2004), the framework in decision making is as follows:

1. Position of the person authorized to make decisions;
2. Problems, namely deviations from what is desired and planned or intended;
3. The situation of the decision maker is;
4. Conditions of decision makers;
5. Objectives, namely what is desired or achieved by decision making.

From the above definition, it can be concluded that decision making is a process of selecting one or more of the existing decision alternatives.

Multi Criteria Decision Making

Decision-making without being based on experiments is done by systematically compiling the way public works before finding solutions to the expected problems. This theory was developed in line with a statistical approach where, in simple terms, the resulting decision was attempted to have the minimum effect of errors.

In the approach to decision analysis with this multiple criterion that is through the initial stage (deterministic) the initial information collected were defined and linked with the variables that influences the decision. The second stage is probabilistic where the quantitative value of uncertainty determines which includes mutually influential variables. The last stage is the informational stage to determine the economic value of each variable that is quite influential, so that a decision is obtained.

Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is a method of simplifying a complex problem that is unstructured, strategic, and dynamic into its parts, and arranges it in a hierarchy. The level of importance of each variable is relatively compared to other variables by considering various considerations and then synthesizing to determine variables that have high priority and play a role in influencing the results of the system.

Some of the advantages of using the AHP method in making this decision are that it can explain the retrieval process that is graphically illustrated so that it is easily understood by all parties involved in making these decisions. In addition, complex decisions can be broken down into smaller decisions that can be resolved easily.

AHP can also test the consistency of assessment, the value of occurrence of deviations that are far from the value of perfect consistency. It

can show the assessment must be corrected or rearrange the hierarchy.

The working principle of AHP is as follows:

1. In compiling this hierarchy, all criteria and alternatives are arranged in a hierarchical structure where they can present all the elements in decision making.
2. Criteria and alternatives are assessed through pair comparison. According to Saaty (1983), on a variety of issues the scale of 1-9 is the best number in expressing opinions. The values and definitions of qualitative opinions from the Saaty scale are as follows:

Table 1.
Saaty scale

Value	Information
1	Criteria / Alternative A is equally important with the criteria / alternative B
3	A little more important than B
5	A is clearly more important than B
7	A is clearly more important than B
9	Absolute more important than B
2,4,6,8	When in doubt between two adjacent values

3. Determination of Priority
   Each criterion and alternative needs to be carried out in pairs. Relative comparison values are then processed to determine the relative ranking of all available alternatives. Both quantitative and qualitative criteria can be compared according to predetermined judgment to produce the weight and priority calculated in the matrix table with mathematical solutions.
4. Logical Consistency
   All elements are grouped logically and ranking accordingly consistently according to a logical criterion. The application of consistency in the selection of the Analytical Hierarchy Process method includes two main stages, namely the measurement of consistency in each comparison matrix which is declared 100% if each number in the comparison matrix is a ratio. This is because the numbers obtained are the result of a comparison between 2 elements. The second logical consistency is the consistency of the whole hierarchy where it shows thoughts that are categorized according to the homogeneity of their relevance and where the intensity of the relations after each idea logically justifies the search for Eigen value.

Calculation of Consistency Vector (λ) is done in determining priority vectors in the search for Eigen value.

$$\lambda = \frac{\text{WSV}}{Average} \ldots\ldots\ldots(1)$$

Consistency Index is the consistency of answers that will affect the success / perfection of results with the Consistency Index calculation formula, namely:

$$\text{CI} = \frac{\lambda_{max} - \text{n}}{\text{n} - 1} \ldots\ldots(2)$$

Where n is the number of criteria. In knowing whether the CI with a certain amount is good enough or do not need to know the ratio that is considered good is by calculating the Consistency Ratio with the requirement that CI < 0.10.

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

RI or random index issued by Oarkridge Laboratory in the form of Table 2 as follows:

Table 2.
Random index

N	1	2	3	4	5	6	7
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32

Secondary data obtained from several sources related to the alternative locations studied are area, the land price, area expansion and minimum employee salary.After all data is obtained, the next step is to process existing data to change the data that has been collected into results that can support analysis of decisions and can help in making conclusions about the problems that occur. Data processing is done by using one of the multiple criteria decision support methods, Analytic Hierarchy Process.

2.2 Preliminary Studies

In the initial stage, it is done by taking data PT. Indonesia from June 20, 2018 to July 20, 2018 to see the condition of the company directly and by conducting interviews with the heads of the production division and to the HR division there to find out the actual condition of the company.

2.3 Problems Identification

After conducting a preliminary study and knowing the actual condition of the company, the identification of the problems that existed at PT. SKI through interviews and advanced data searches also carried out to obtain information relating to existing problems.

2.4 Data Collection and Processing

At the stage of data collection, researchers conducted interviews with parties related to the selection process of the new alternative factory location decisions. Primary data obtained directly includes water facilities, electricity facilities, transportation facilities, ease of licensing, ease of access to transportation and service facilities.

2.5 Analysis and Evaluation

At this stage, an analysis of the results of data processing is carried out by knowing alternative outputs that can be compared in the selection of initial locations. Data obtained results obtained, then the researcher can provide a proposal for the location of the plant which is feasible to consider in several factors that have been obtained.

2.6 Analysis and Evaluation

The last stage in this study is to make conclusions and suggestions where conclusions are made from the results of data processing that has been done to answer the existing research objectives. Then based on what can be concluded, the researcher can also provide appropriate advice about the problems faced along with the solutions in the alternative selection of new plant locations to PT. SKI.

3. RESULTS AND ANALYSIS

In Table 3, all data related to the selection criteria for alternative locations are divided into 3 groups A, B, C. Each group are then divided again and symbolized as A1, A2, A3, A4, B1, B2, B3, B4, C1, and C2. The amount of alternative 1 will be added to the amount of alternative 2. The end result it will be classified as Higher Better (HB) or Lower Better (LB). Data that has real numbers are presented in Table 3, while Data from questionnaires about interest each criteria are presented in Table 4.

In the Figure 1 above, it can be seen that the goal to be achieved by PT. SKI is the selection of new factory location alternatives with levels below, namely General Criteria covering Investment & Operations, Facilities and Easiness. Each general criterion consists of several criteria which include area, land price, area expansion, minimum employee salary, water, electricity, transportation and service facilities as well as easy access to transportation as well as ease of licensing. Alternatives at the lower level include 2 places, namely Gunung Sindur, Bogor and Jalan Raya Ciputat, Depok.

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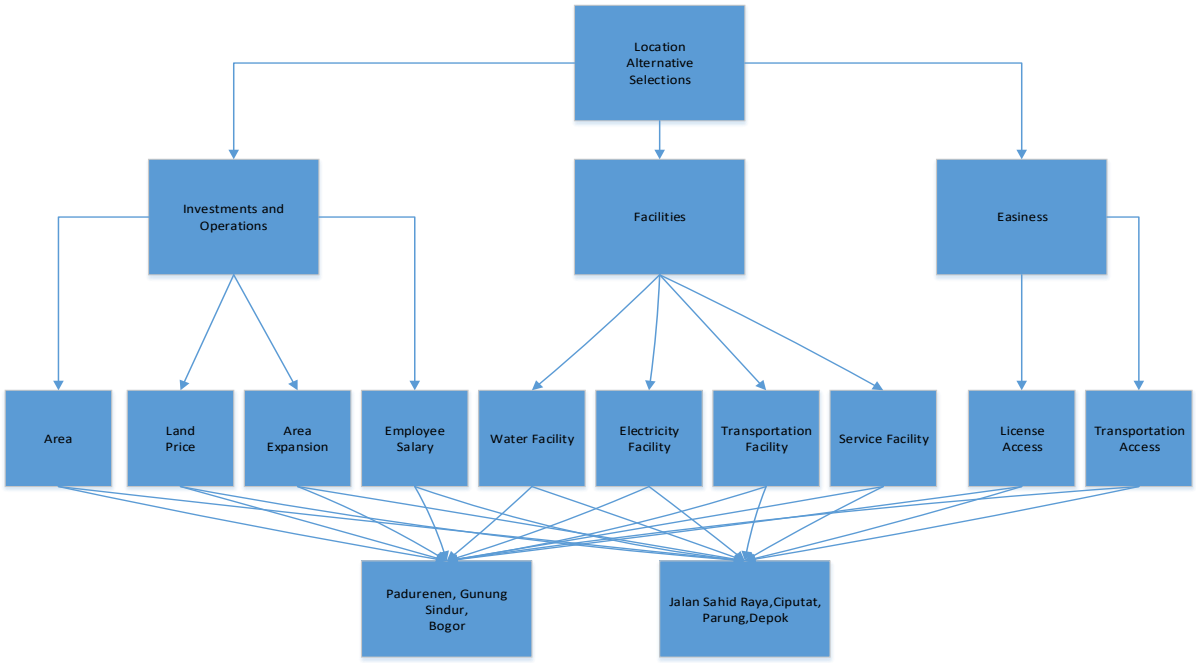
Table 3.
Data selection criteria for alternative locations

No.	Criteria	Symbol	Alternative 1	Alternative 2	Total	Attribute
1	Area	A1	2000	1500	3500	HB
2	Land price	A2	5334000	7500000	12834000	LB
3	Area Expansion	A3	2200	1665	3865	HB
4	Minimum Employee Salary	A4	3557146.66	3584700.29	7141846.95	LB
5	Water Facilities	B1	4	3	7	HB
6	Electricity Facilities	B2	5	4	9	HB
7	Transportation Facilities	B3	4	2	6	HB
8	Services Facilities	B4	4	3	7	HB
9	Access to Transportation	C1	5	4	9	HB
10	Ease of Licensing	C2	5	5	10	HB

Table 4.
Interest data each criteria

Comparison			R1	R2	R3	R4	R5	Total	RG
A1	X	A2	5	5	7	6	5	28	1.9473
A1	X	A3	5	4	5	5	4	23	1.8722
A1	X	A4	3	5	3	3	7	21	1.8384
A2	X	A3	5	5	5	5	6	26	1.9186
A2	X	A4	5	3	4	3	5	20	1.8206
A3	X	A4	2	2	4	3	3	14	1.6952
B1	X	B2	5	5	5	5	4	24	1.8882
B1	X	B3	5	7	7	7	6	32	2
B1	X	B4	6	5	3	5	4	23	1.8722
B2	X	B3	5	7	7	7	6	32	2
B2	X	B4	6	5	5	7	5	28	1.9473
B3	X	B4	1	1	2	1	2	7	1.4758
C1	X	C2	1	1	2	1	2	7	1.4758
A	X	B	5	3	5	3	5	21	1.8384
A	X	C	2	1	2	1	2	8	1.5157
B	X	C	1	2	1	2	1	7	1.4758



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Figurel 1.
Hierarchy diagram selection of alternative locations of PT. SKI

Table 5.
Score recapitulation of each criteria

	Investment and Operations	Facilities	Simplicity	*Overall* Criteria Weight
Alternative 1	0.5645	0.5847	0.5331	0.6091
Alternative 2	0.4355	0.4153	0.4669	0.4881

Table 3.
Consistency ratio

	A	**B**	**C**	**Average**	**WSV**	**Λ**	**λ_{maks}**	**CI**	**CR**
A	1	1.8384	1.5157	1.4514	4.4828	3.0887			
B	0.5439	1	1.4758	1.0066	2.9459	2.9266	3.1044	0.0522	0.0900
C	0.6598	0.6776	1	0.7791	2.4187	3.1044			

Table 5 shows the recapitulation of the results of each criterion that has been processed by showing the weighted values of the overall criteria and Table 6 shows the ratio of concessions to data processing that has been processed.

Regarding Table 3, the calculation for *Consistency Ratio* as follows:

$$CR = \frac{CI}{RI} = \frac{0,0522}{0,58} = 0,0900$$

Where RI or Random Index is a random index issued by Oarkridge Laboratory for CR calculation, with an N value equal to 3 having RI value of 0.58. The results of CR are 0.09 where the value does not exceed 0.1 eating consistency of expert opinion is still accepted and continued in the decision making of multiple criteria

4. ANALYSIS AND EVALUATION

Based on the problems that are being experienced by PT. SKI, choosing an alternative area of the new factory location requires some supporting data to process the data into better selection. In the Figure 1, there are 2 alternative locations proposed by the factory, namely the industrial area in Padurenan, Gunung Sindur, Bogor, West Java and the second alternative, Jalan Sahid Raya Ciputat Parung, Cinangka, Depok.

This location selection also has several criteria that have been obtained based on interview with the head of the production division at PT. SKI where data consists of 2 types, namely quantitative and qualitative data. Quantitative data includes 4 main criteria, namely land area, land price, expansion (area expansion) and minimum employee salary where the data is obtained from secondary data that has been traced by researchers and experts. Furthermore, qualitative data includes water, electricity, transportation, service and facilities for licensing and transportation access. The data is obtained directly from the results of interviews with assessments using a Likert scale that has a range of values 1-5 where the largest value is the top priority in determining the qualitative criteria. In data collection, higher better conversion needs to be done on land price data and employee salaries.

After obtaining supporting data for alternative decisions, it is also necessary to assess the importance of the comparison of each existing criteria. The initial step in the comparative assessment of interests is divided into 3 general criteria obtained from the hierarchical structure that has been made, namely general criteria, namely Investment and Operations which include land area, land price, area expansion and minimum employee salary. Second, namely facilities which include water facilities, electricity facilities, transportation facilities and service facilities and the last criteria, namely Ease, which includes ease of licensing and ease of access to transportation.

Determination of the criteria used in the selection of location alternatives was obtained from several literature studies such as Rahmayanti (2010) and Cahyadi and Sekarsari (2012). The three general criteria will be assessed through pairwise comparisons. According to Saaty (1983), for various issues of alternative selection, the scale of 1 to 9 is the best scale in giving opinions where qualitative opinions of the scale have been given in data collection in Table 1. This qualitative opinion has also been obtained based on interviews with five respondent experts / observers who knew well the problem in the selection of the decision. The number of respondents will produce opinions that are different from each other. In this method, it requires one answer for the comparison matrix. Therefore,

the answers that have been obtained from the respondents must be averaged. The leveling uses geometric averages. This geometric average is used because the averaged number is a ratio of numbers whose properties are ratio. This geometric average can also reduce the error caused by one number that is too large and too small.

The qualitative opinion interview data obtained will then be processed in testing the Reliability Test using SPSS software. The results of the processing show that Cronbach's Alpha is 0.949, which is more than the value of r table at a significance of 5%, which is 0.497, which means that the opinion data can be said to be realistic as a data collection tool in subsequent studies. The three general criteria that have been processed will then be compared again with each other using the current scale. The results of the assessment of the criteria obtained geometric averages which will be continued in the matrix of multiplication of criteria and assessment criteria with mathematical equations.

The results obtained in these mathematical equations, namely the first general criteria, namely Investment and Operations have a value of around 55.84%, indicating that the first best alternative is in the criteria of land prices, land area, expansion and also minimum employee salaries. Continued around 58.47% on the second general criteria, namely facilities which showed the best selection was in the first alternative and 73.51% in the criteria for ease of licensing and transportation access in the first alternative.

By comparing the three data multiplication matrices and assessment criteria, it was found that logical consistency. The logical consistency in question is all elements that are grouped logically and ranked consistently according to logical criteria. This important characteristic in the AHP will produce the parameters used to check whether the paired comparisons have been carried out consequently or not, often called the consistency ratio where the processing results show that the CR is 0.09 and does not exceed the provisions of 0.1. This means that the assessment of criteria has been done consistently (Table 6).

Based on data processing using the Analytical Hierarchy Process Method, there were several advantages in the direct application of problems that occurred at PT. SKI where broad and unstructured problems become a model that is flexible and easily understood by anyone, this method can also handle the interdependence of elements in a system that do not impose linear thinking.

In addition, the AHP provides a scale to measure things and realize a method for setting priorities and can also track the logical consistency of considerations in determining those priorities. But on the weakness of this method requires a qualitative opinion assessment criteria and alternatives that are truly in accordance with their fields (experts) which means people who have broader knowledge in the problems faced in decision support by seeing whether the expert's level of subjectivity is a perception that can be used or not and also in improving the decision must start from the initial stage. In future research, it is expected that researchers can provide other methods of comparison with current processing, so that can provide a comparative method for better decision making.

4. CONCLUSIONS

Based on the research that has been done, the following are conclusions that can be taken:

- Analytical Hierarchy Process explains the decision making process that is graphically drawn so that it is easily understood by all parties involved in decision making.
- Criteria in determining the location of the factory area at PT. SKI includes: area, land price, area expansion, minimum employee salary, water facilities, electricity facilities, transportation facilities, service facilities, easy licensing and easy transportation access.
- The results of qualitative opinions on pairwise comparisons between criteria show that they are reliable after reliability testing is carried out.
- Alternatives chosen in choosing a new factory location PT. SKI, namely in Padurenan, Gunung Sindur, Bogor, West Java.

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