Measurement of Criterion Weight to Determine Industrial Area Location Using AHP for Economic Growth

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Abstract. Industrial area is an infrastructure for the process of industrialization as a source that can trigger economic growth. Industrial areas that are structured and can support production operations are an appeal to foreign investors. However, the development of industrial areas requires careful planning because it impacts on the environmental carrying capacity and land loss. Therefore, industrial area development needs attention to a variety of important criteria as considerations in determining the location of an industrial area. This study aims to determine the criteria and measure the importance of each relative criterion to other criteria. The method used is Analytical Hierarchy Process (AHP). The results show that there are four important factors that need to be considered with each of the importance level, namely Infrastructure by 33.97\%, Distance to Access by 31.74\%, Land & Soil by 19.57\%, and Production Factors by 14.72\%. The four factors have ten important criteria that need to be considered in making decisions to determine the location of an industrial area where the two highest criteria are electricity infrastructure with a significance level of 19.05\% and telecommunications infrastructure with an importance level of 14.92\%.

1. Introduction
Economic growth as a process of increasing output from time to time becomes an important indicator to measure the success of a country development [1, 2]. One of the efforts made by Indonesia is industrialization to increase economic growth. Although it is not the final goal of economic development, industrialization is an effort to achieve high and sustainable growth rates which in turn will create high per capita income. The growing industrial revolution convinced many countries that the dominant criterion in economic development was an increase in per capita income caused by industrialization [3, 4, 5]. Therefore, it can be concluded that industrialization is a process of interaction between technological development, innovation, specialization of production, and trade among countries which in turn is in line with the increase in community income which drives changes in economic structure [6, 7].

Considering the current economic growth in Indonesia despite being affected by COVID-19, it was recorded in the Central Statistics Agency that economic growth in the first quarter of 2020 was 2.97\% (year on year / yoy) and the industrial sector still contributed the most to the structure of the national Gross Domestic Product (GDP) up to 19.98\% in the first quarter of 2020 [8]. The following data proves that the more the industries are built, the faster it can increase income per capita. The growth of this
industry requires infrastructure and careful planning of industrial area location which is provided to support the operational activities of the manufacturing industry [9]. Building an industry requires structured and integrated planning so that it does not only pursue the target to realize building as many Industrial Areas as possible but also meets the infrastructure needs of a country.

At this time, Indonesia only has 108 industrial areas that have been established. In order to realize the mission of increasing the role of the national industry as a pillar and driver of the national economy, the government has planned to build 36 national industries in RIPIN 2015-2035 [10]. In order to maintain the performance of industry in Indonesia, the government is attracting investment especially in the import substitution sector, export-oriented, labor-intensive, and high-tech-based industries. In order to facilitate and equalize the economy, the Government of Indonesia through the development of priority industrial areas has prioritized the spread of industries outside Java. There are 27 priority industrial areas that have been planned for 2020-2024, namely 14 on the island of Sumatra, six in Kalimantan, three in Sulawesi, one in Madura, one in Java, and one in Maluku, one in West Nusa Tenggara, and one in Papua [11].

The development of an Industrial Area is also inseparable from the location selection of the industrial area to be developed because it is strongly influenced by several factors/variables in the location. In addition, the development of an Industrial Area will also have an impact on several functions around the location. Several criteria were taken into consideration in the selection of Industrial Area locations, including; Distance to City Center, Distance to settlements, Road system that serves, Network system that serves, Transport Infrastructure, Topography/Land Slope, Distance to River, Carrying capacity, Land fertility, Land use, Land availability, Land prices, Location orientation, and Multiplier Effects [12].

The problem is that the criteria to be considered are quite a lot, and moreover various sources set different criteria. The right decision making is needed to obtain maximum results on important criteria that are considered to determine the location of industrial area. This paper aims to determine important criteria in determining the location of industrial areas as well as measuring the importance of each criterion. The application of AHP method is used to provide an assessment of the number of criteria needed to be considered in selecting suitable and sustainable industrial park locations.

2. Method

2.1 Industrial Area

Industrial Area is a central location of industrial activities that is equipped with supporting facilities and infrastructure developed and managed by industrial area companies. According to Indonesian Government Regulation No. 2 of 2017, Industrial Area is a processing industry activity center equipped by infrastructure, facilities, and other supporting facilities provided and managed by the Industrial Park Company. According to the National Industrial Zoning Committee's (USA) 1967, Industrial Park is an industrial area on a sufficient land, which is administratively controlled by a person or an institution suitable for industrial activities because of its location, topography, proper zoning, availability of all infrastructure (utilities), and ease of transportation accessibility.

2.2. Survey Method and Level of Importance

In the data collection process, it is necessary to establish survey methods that will be used in data processing using Analytical Hierarchy Process (AHP) method. The survey tool was designed using a questionnaire that was distributed to respondents who were experts in determining the industrial area. The process of collecting data was done by comparing two criteria in sequence from all criteria in the study. If the score given is higher on the left scale, then the criteria on the left are more important than the criteria on the right, and vice versa. The number of respondents who will fill out the questionnaire is as many as 5 experts who understand about important criteria in the development of industrial areas.
2.3. Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) was developed by Dr. Thomas L. Saaty [13, 14] from the Wharton School of Business in 1970 which is a decision support model that will break down complex multi-factor or multi-criteria problems into a hierarchy.

The decision-making process in AHP method [15] is basically as follows:

- Determine the types of criteria used.
- Arrange these criteria in a paired matrix.

\[ a_{ij} = w_i w_j, i, j = 1, 2, \ldots, n \]  

(1)

Where n states the number of criteria compared, wi weights for the i-th criteria, and aij is the comparison of weights of the i-th and j criteria.

- Normalize each column by dividing each value in the i-th column and in the j-row with the largest value in column i.

\[ a_{ij} = \frac{a_{ij}}{a_{ij}} \]  

(2)

- Add up the values in each i-th column, i.e.:

\[ a_{ij} = \sum a_{ij} \]  

(3)

- Determine the priority weight of each i-th criterion by dividing each value a by the number of criteria compared (n), i.e.:

\[ w_i = \frac{\sum_{j=1}^{n} b_{ij}}{n} \]  

(4)

- Calculate the value of lamda max (eigen value) with the formula:

\[ \lambda_{\text{max}} = \sum a_{n} \]  

(5)

- Calculate the consistency index (CI)

Consistency calculation is counting deviations from value consistency, and this deviation is called the consistency index with the equation:

\[ CI = \frac{\lambda_{\text{max}} - n}{n-1} \]  

(6)

where \( \lambda_{\text{max}} \) is the main eigenvalue of the valuation matrix, and n is the order of the matrix

- Calculate Consistency Ratio (CR) with the formula:

\[ CR = \frac{CI}{RI} \]  

(7)

Random Index (RI) is a constant depending on the number of elements compared where if the number of elements is 10, the RI value is 1.49.

- Test the consistency of hierarchy. If it does not meet CR <0.100, then the evaluation must be repeated.

3. Result and Discussion

Industrial area is one of the infrastructures in enhancing economic growth because in addition to being a means of business location for domestic industries, the industrial area is one of the attractions for foreign investors. At present, there are more than 12,000 industrial zones throughout the world in which 893 of them are approximately located in ASEAN [16]. The development of industrial areas in ASEAN
which ranks the 3rd best for foreign investors is Singapore followed by Malaysia and Thailand. Intense competition is pushing the country to build an efficient and promising industrial area for investors.

In developing industrial areas, there are four important things that need to be considered: land conditions, distance to access, availability of infrastructure, and factors of production. This study will break down each of the four variables into more structured criteria and pay attention to Government Regulation Number 142 of 2015 concerning industrial areas [17]. Land conditions consist of 3 criteria, namely (1) Slope, (2) Land Use, and (3) Soil Type. Distance to access consists of 3 criteria, namely (1) Distance of land to roads and access, (2) Distance of land to rivers, and (3) Distance of land to public facilities. Infrastructure consists of 2 criteria, namely (1) Availability of electricity infrastructure and (2) Telecommunications infrastructure while the production factor consists of 2 criteria, namely (1) the level of labor wages and (2) the price of land per m2. Therefore, the overall criteria that need to be considered in determining the location of an industrial area consist of 10 criteria as shown in figure 1.

The results of AHP method from five expert respondents in the field of industrial area development were used to determine the criteria in the assessment of industrial areas based on the ten criteria. Data was collected by determining the scale using the pairwise comparison method so that the relative importance of one criterion and the other criteria can be seen. The results of the pairwise comparison of five expert respondents on the ten criteria are shown in table 1.

| Criteria             | Slope | Land use | Soil type | Distance to road (accessibility) | Distance to water source | Distance to public facilities | Labor cost | Land prices | Availability of electricity infrastructure | Telecom infrastructure |
|----------------------|-------|----------|-----------|----------------------------------|--------------------------|-------------------------------|------------|------------|-------------------------------------------|------------------------|
| Slope                | 1.000 | 0.333    | 0.500     | 1.000                            | 3.000                    | 0.200                         | 3.000      | 2.000      | 1.000                                     | 0.200                  |
| Land use             | 3.000 | 1.000    | 0.200     | 1.000                            | 0.500                    | 5.000                         | 2.000      | 3.000      | 0.500                                     | 0.500                  |
| Soil type            | 2.000 | 5.000    | 1.000     | 1.000                            | 0.500                    | 0.250                         | 4.000      | 5.000      | 1.000                                     | 1.000                  |
| Distance to road     | 1.000 | 1.000    | 1.000     | 1.000                            | 0.200                    | 5.000                         | 4.000      | 7.000      | 4.000                                     | 4.000                  |
| (accessibility)      |       |          |           |                                  |                          |                               |            |            |                                           |                        |
| Distance to water    | 0.333 | 2.000    | 2.000     | 5.000                            | 1.000                    | 3.000                         | 0.250      | 5.000      | 1.000                                     | 1.000                  |
| source               |       |          |           |                                  |                          |                               |            |            |                                           |                        |
| Distance to public   | 5.000 | 0.200    | 4.000     | 0.200                            | 0.200                    | 1.000                         | 1.000      | 1.000      | 3.000                                     | 5.000                  |
| facilities           |       |          |           |                                  |                          |                               |            |            |                                           |                        |
| Labor cost           | 0.333 | 5.000    | 0.250     | 0.250                            | 4.000                    | 1.000                         | 1.000      | 0.250      | 1.000                                     | 5.000                  |

Figure 1. Criteria to determine industrial area

Table 1. Matrix criteria
Furthermore, the values in each row of the normalized matrix were summed up and then divided by the total elements so as to get the Priority vector. The determination of Weighted Sum Vector (WSV) was done by multiplying each element of the paired comparison matrix with Priority vector. The calculation of Consistence Vector (CV) was done by dividing the results of WSV with the Priority vector value of pairwise comparison matrix while the Lamda value is the average value of CV. Table 2 is a normalization table that shows the overall results of calculations that have been carried out in the matrix.

| Criteria                          | Slope | Land use | Soil type | Distance to road (accessibility) | Distance to water source | Distance to public facilities | Labor cost | Land prices | Availability of electricity infrastructure | Telecom infrastructure |
|-----------------------------------|-------|----------|-----------|----------------------------------|--------------------------|-------------------------------|------------|-------------|---------------------------------|------------------------|
| Land prices                       | 0.500 | 0.333    | 0.200     | 0.143                            | 0.200                    | 1.000                         | 4.000      | 1.000       | 1.000                           | 1.000                  |
| Availability of electricity       | 1.000 | 2.000    | 1.000     | 0.250                            | 1.000                    | 0.333                         | 1.000      | 1.000       | 1.000                           | 1.000                  |
| infrastructure                    | 5.000 | 2.000    | 1.000     | 0.250                            | 1.000                    | 0.200                         | 1.000      | 1.000       | 1.000                           | 1.000                  |

| Criteria                          | Slope | Land use | Soil type | Distance to road (accessibility) | Distance to water source | Distance to public facilities | Labor cost | Land prices | Availability of electricity infrastructure | Telecom infrastructure |
|-----------------------------------|-------|----------|-----------|----------------------------------|--------------------------|-------------------------------|------------|-------------|---------------------------------|------------------------|
| Slope                             | 1.000 | 0.382    | 1.496     | 0.525                            | 1.303                    | 0.187                         | 1.165      |
| Land use                          | 2.616 | 1.000    | 2.627     | 1.108                            | 0.910                    | 1.246                         | 0.964      |
| Soil type                         | 0.668 | 0.381    | 1.000     | 0.286                            | 0.561                    | 0.240                         | 0.894      |
| Distance to road (accessibility)  | 1.904 | 1.000    | 3.500     | 1.000                            | 1.108                    | 2.371                         | 1.914      |
| Distance to water source          | 0.768 | 1.037    | 1.783     | 0.903                            | 1.000                    | 0.654                         | 1.100      |
| Distance to public facilities     | 5.348 | 0.725    | 4.618     | 0.422                            | 1.380                    | 1.000                         | 1.035      |
| Labor cost                        | 0.859 | 1.644    | 1.118     | 0.522                            | 0.909                    | 0.966                         | 1.000      |
| Land prices                       | 0.879 | 0.582    | 0.966     | 0.457                            | 0.622                    | 1.332                         | 0.556      |
| Availability of electricity       | 4.904 | 1.783    | 4.427     | 0.891                            | 2.667                    | 2.141                         | 1.783      |
| infrastructure                    | 5.711 | 1.272    | 3.737     | 0.944                            | 2.667                    | 1.933                         | 1.292      |
| TOTAL                             | 24.656| 9.805    | 25.272    | 7.058                            | 13.127                   | 12.071                        | 11.703     |

| Criteria                          | Land prices | Availability of electricity infrastructure | Telecom infrastructure | Total | Priority vector | WSV | CV |
|-----------------------------------|-------------|---------------------------------------------|-------------------------|-------|-----------------|-----|----|
| Slope                             | 1.138       | 0.204                                       | 0.175                   | 7.575 | 0.052           | 0.575| 11.076|
| Land use                          | 1.719       | 0.561                                       | 0.786                   | 13.536| 0.104           | 1.110| 10.717|
| Soil type                         | 1.035       | 0.226                                       | 0.268                   | 5.559 | 0.040           | 0.444| 11.024|
| Distance to road (accessibility)  | 2.187       | 1.122                                       | 1.059                   | 17.165| 0.139           | 1.484| 10.703|
| Distance to water source          | 1.607       | 0.375                                       | 0.375                   | 9.601 | 0.074           | 0.807| 10.984|
| Distance to public facilities     | 0.750       | 0.467                                       | 0.517                   | 16.262| 0.105           | 1.104| 10.492|
| Labor cost                        | 1.797       | 0.561                                       | 0.774                   | 10.151| 0.085           | 0.920| 10.849|
| Land prices                       | 1.000       | 0.467                                       | 0.467                   | 7.329 | 0.062           | 0.662| 10.609|
| Availability of electricity       | 2.141       | 1.000                                       | 2.537                   | 24.273| 0.190           | 2.016| 10.586|
| infrastructure                    | 2.141       | 0.394                                       | 1.000                   | 21.092| 0.149           | 1.577| 10.568|
| TOTAL                             | 15.515      | 5.377                                       | 7.958                   | 132.543| 1.000          |      |    |
Table 3 shows the calculation of the Consistency Ratio (CR) which is a measure of errors in making decisions or an indication of the level of consistency or inconsistency depending on the Consistency Index (CI) and Random Index (RI). From the calculation of consistency ratio, it is known that the comparison of pairs has a Consistency Ratio (CR) value of 0.0567 which is smaller than the standard of 0.1000, so the weighted values for the ten criteria are stated to be quite consistent and can be used in the assessment of criterion weights in determining and selecting an efficient industrial area.

Table 3. Consistency

|                      |   |
|----------------------|---|
| Lamda max            | 10.7607 |
| CI                   | 0.0845  |
| CR                   | 0.0567  |

The results of importance weight measurement on the ten criteria in determining and evaluating an industrial area are shown in Figure 2. The four main variables obtained the importance of each level, namely: (1) Land & Soil by 19.57%, (2) Distance to Access by 31.74%, (3) Infrastructure by 33.97%, and (4) Production Factors by 14.72%.

![Figure 2. Measurement of criterion weight](image)

The overall order of importance level on the ten important criteria in determining the location of an industrial area is shown in Table 4 obtained from the results of data processing using the Analytical Hierarchy Process (AHP) method.

Table 4. Importance level of criteria

| No | Criteria                      | Level of Importance |
|----|-------------------------------|---------------------|
| 1  | Electricity                   | 19.05%              |
| 2  | Telecommunication             | 14.92%              |
| 3  | Distance to road              | 13.86%              |
| 4  | Distance to public facilities | 10.53%              |
| 5  | Land Use                      | 10.36%              |
| 6  | Labor Cost                    | 8.48%               |
| 7  | Distance to river             | 7.35%               |
| 8  | Land Price                    | 6.24%               |
| 9  | Land Slope                    | 5.19%               |
| 10 | Soil Type                     | 4.02%               |
|    | Total                         | 100.00%             |
Infrastructure with an importance level of 33.97% is the variable that has the highest level of importance among the four other variables. From the top ten criteria, infrastructure occupies the two highest order, namely (1) electricity infrastructure of 19.50% and (2) telecommunications infrastructure of 14.92%. The availability of electricity and telecommunications infrastructure is the first priority that must be considered in determining the location of industrial areas. This is because in general, industries operating in an industrial area are manufacturing industries that require high supply of electricity and telecommunications networks.

Distance to access with an importance level of 31.74% becomes the second most important variable needed as a condition for the existence of industrial area. This variable consists of three criteria with each of the importance level, namely (1) Distance to road of 13.86%, (2) Distance to public facilities of 10.53%, and (3) Distance to river of 7.35%. Proximity factors related to the ease of industrial operational access include the access to the flow of production goods, suppliers, marketing, and ease of access for labor.

The condition of land with an importance level of 19.57% is the third important factor for the sustainability of an industrial area. This factor consists of three criteria with each order of relative importance, namely (1) Land Use of 10.36%, (2) Land Slope of 5.19%, and (3) Land Type of 4.02%. Soil conditions are very important regarding the feasibility of carrying capacity of land for industrial areas. Land limitation and the conversion of land into industrial areas need to pay attention to the balance of natural ecosystems so as to avoid damage and natural disasters. Therefore, the condition of land that will be used as industrial areas related to natural and environmental carrying capacity needs to be carefully considered.

Production factor with an importance level of 14.72% becomes the fourth important factor which is considered in the selection of industrial area locations. This factor consists of two criteria with each of the importance level, namely (1) Labor Cost of 8.48%, and (2) Land Price of 6.24%. The factor of production becomes one of the attractions for foreign investors to invest their capital in the industrial area of a country. This is because there is a direct relationship with the production cost which is one of the main considerations. In general, foreign investors will move their production to the countries with low labor costs but skilled labor and low land prices so that the production can be more efficient.

4. Conclusion
Industrial area is an infrastructure for industrial growth which will ultimately increase economic growth. One attraction for foreign investors to move their production is the availability of industrial areas that support industrial operations efficiently.

The main factor in determining the sustainability of industrial area becomes a consideration in choosing the location of industrial area. In this study, there are four (4) variables with each of the importance level, namely Infrastructure of 33.97%, Distance to Access of 31.74%, Land & Soil of 19.57%, and Production Factors of 14.72%. Infrastructure is a top priority for the sustainability of industrial areas.

The four main factors are then broken down into 10 criteria for determining the efficient industrial areas. It obtained the weight of importance level on the ten criteria from the highest to the lowest, namely Electric Infrastructure of 19.05%, Telecommunications Infrastructure of 14.92%, Distance to road access of 13.86%, Distance to public facility access of 10.53%, Land use of 10.36%, Wages of labor of 8.48%, Distance to rivers of 7.35%, Land prices of 6.24%, Land slope of 5.19%, and Land type of 4.02%.

This research is the initial stage of determining the criteria and measuring the importance level of the criteria needed in making decisions to determine the location of industrial areas. In the future research, the ten criteria with each of the importance level will be used to assess the suitability of the location to be an industrial area. This will also be performed by mapping an area using a Geographic Information System (GIS).
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