

Optimization of Factory Location Selection Using the AHP Method Based on Operational Cost Criteria, Logistics Accessibility, and Labor Availability

Angger Styo Yuniarti¹, Muhammad Arif Kurniawan², Andi Rukmana³, Samsul Makin⁴

Universitas Insan Pembangunan Indonesia, Tangerang, Indonesia

Email: anggerstyoyuniarti06@gmail.com¹, awan.insanpembangunan@gmail.com², rukmana.andy@gmail.com³, samsulmakin25@gmail.com⁴

Factory location selection represents a strategic decision that significantly impacts the long-term operational success of manufacturing companies. This research aims to optimize the factory location selection decision-making process by applying the Analytical Hierarchy Process method, considering three fundamental criteria: operational costs, logistics accessibility, and labor availability. A quantitative approach was employed involving five expert respondents consisting of industrial practitioners and academics to conduct pairwise comparison assessments of four alternative industrial estate locations in West Java. The analysis results indicate that operational costs have the highest priority weight of 0.540, followed by logistics accessibility with a weight of 0.297, and labor availability with a weight of 0.163. Cikampek Industrial Estate emerged as the optimal location with a global priority weight of 0.300, excelling in operational cost efficiency despite having limitations in logistics accessibility. Consistency testing shows Consistency Ratio values ranging from 0.035 to 0.046, confirming the validity of respondent assessments. This research provides practical contributions in the form of a structured decision model that can assist manufacturing company management in making strategic production facility location decisions more objectively and measurably.

Keywords: Factory Location Selection, Analytical Hierarchy Process, Operational Costs, Logistics Accessibility, Labor Availability.

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Corresponding Author:

Angger Styo Yuniarti
Universitas Insan Pembangunan Indonesia
Tangerang
anggerstyoyuniarti06@gmail.com

1. Introduction

The decision to select a factory location is a strategic one that has a long-term impact on the operational success and profitability of a manufacturing company [1]. In an era of globalization and increasingly competitive industries, determining the optimal location for production facilities is a crucial factor influencing a company's competitiveness in the market. Selecting the right location not only impacts operational cost efficiency but also determines a company's ability to access resources, distribute products, and maintain a long-term competitive advantage [2].

According to the perspective put forward by [3] Inappropriate factory location decisions can result in increased transportation costs of up to 25% and a significant decrease in operational productivity. The complexity of factory location decision-making involves a variety of interrelated, multi-criteria factors that often have conflicting interests. The site evaluation and selection process requires a systematic approach that integrates quantitative and qualitative aspects simultaneously. One method that has proven effective in addressing multi-criteria decision-making problems is the Analytical Hierarchy Process (AHP) [4].

The AHP method developed by Thomas L. Saaty offers a structured framework for analyzing complex decisions through hierarchical decomposition and pairwise comparisons between criteria [5]. Research conducted by [6] shows that the use of the AHP method in selecting industrial facility locations can increase decision accuracy by up to 35% compared to conventional approaches that only rely on managerial intuition.

2. Literature Review and Problem Statement

The three fundamental criteria that are the main focus of this research are operational costs, logistical accessibility, and labor availability. Operational costs encompass various components such as land prices, utility rates, local taxes, and infrastructure maintenance costs, which vary significantly across potential locations. Empirical research conducted by [7] revealed that operational costs can contribute up to 40% of total production costs, making optimizing this aspect a strategic priority. Logistics accessibility relates to ease of access to transportation networks, proximity to suppliers and markets, and supply chain efficiency, which influence distribution speed and responsiveness to market demand. Locations with good logistics accessibility can reduce lead times by up to 30% and substantially increase customer satisfaction.

The availability of a qualified and adequate workforce is the third critical factor determining the sustainability of factory operations. This aspect includes the number of available workers, their skill and education levels, regional wage levels, and employee turnover rates. A study conducted by [8]. Research shows that locations with an adequate talent pool can increase productivity by up to 28% and significantly reduce recruitment and training costs. Indonesia's demographic bonus presents a strategic opportunity for manufacturing companies to capitalize on the availability of a productive workforce across various regions. However, disparities in the quality and distribution of labor across regions require careful analysis in the location selection process [9].

The integration of the AHP method in the context of factory site selection, taking these three criteria into account, is expected to provide optimal solutions that are measurable and objective. This study seeks to fill the literature gap by developing a comprehensive and practical decision model for application in the Indonesian manufacturing industry [10].

The systematic approach offered through this research is expected to assist decision makers in conducting more structured, transparent, and accountable evaluations of alternative locations, resulting in strategic decisions that support operational efficiency and long-term business sustainability [11].

Based on the background outlined above, this study formulates several key issues that require in-depth study. First, how to identify and quantify the relative importance of each criterion—operational costs, logistical accessibility, and labor availability—in the context of factory location selection using the AHP approach.

Second, how to systematically implement the AHP method to evaluate and compare available factory location alternatives based on predetermined criteria. Third, how to generate the most optimal factory location recommendations by considering trade-offs between criteria and decision-makers' preferences, thereby supporting operational efficiency and the long-term business sustainability of manufacturing companies.

This study aims to develop a systematic and structured decision-making model for selecting an optimal factory location using the AHP method, focusing on three main criteria: operational costs, logistical accessibility, and labor availability. Specifically, this study aims to determine the relative importance of each criterion through a pairwise comparison process involving expert judgement, conduct a comparative evaluation of available alternative factory locations based on established criteria, and produce a ranking and recommendation for the most optimal factory location. By achieving these objectives, this research is

expected to provide a practical contribution to manufacturing companies in making strategic factory location decisions that are more objective, measurable, and scientifically accountable.

3. Method

This study uses a quantitative approach with the Analytical Hierarchy Process (AHP) method to optimize factory location selection based on predetermined criteria. The initial stage of the study begins with identifying and establishing a decision hierarchy consisting of primary objectives, evaluation criteria, and alternative locations to be evaluated [12]. Primary data collection was conducted through in-depth interviews with industry practitioners and academics who have expertise in the field of operations management and production facility planning to obtain a pairwise comparison assessment between criteria and alternatives.

Data analysis used a pairwise comparison matrix with a Saaty rating scale ranging from 1 to 9, where the value represents the relative importance of one element to another. The rating scale used in this study is presented in the following table [13].

Table 1. Saaty Paired Comparison Rating Scale

Intensity of Interest	Definition	Explanation
1	Equally important	Both elements have the same influence.
3	A little more important	Experience and judgment slightly favor one element over another.
5	More important	Experience and strong judgment favor one element over another.
7	Much more important	One element is strongly supported and its dominance is visible in practice.
9	Absolutely more important	Evidence that supports one element over another has the highest level of affirmation.
2, 4, 6, 8	Middle value	A compromise value between two adjacent assessments

Priority weighting was calculated using the eigenvector method to determine the importance level of each criterion and the ranking of alternative locations. Based on the pairwise comparison matrix in Table 2, the priority weights for each criterion were obtained as shown in Table 3, with operational costs receiving the highest weighting of 0.540, followed by logistics accessibility at 0.297, and labor availability at 0.163. The consistency of the assessment was verified through the calculation of the Consistency Ratio with a maximum tolerance limit of 0.10 to ensure the validity of the analysis results, as recommended in the study of multicriteria decision-making methodology. [14] Data processing is carried out with the help of decision support software to improve the accuracy and efficiency of the computational process in determining the most optimal factory location.

4. Results and Discussion

Decision Hierarchy Structure

This study develops a systematic three-level decision hierarchy structure to optimize factory location selection. The first level is the main objective, which is to determine the most optimal factory location. The second level consists of three main evaluation criteria, namely operational costs, logistical accessibility, and labor availability. The third level includes four alternative locations evaluated, namely Location A (Karawang Industrial Estate), Location B (Cikarang Industrial Estate), Location C (Cikampek Industrial Estate), and

Location D (Purwakarta Industrial Estate). This hierarchical structure allows the decomposition of complex problems into simpler elements that are easier to analyze systematically.

Pairwise Comparison Results of Criteria

The pairwise comparison process involved five expert respondents: three manufacturing industry practitioners and two academics with at least ten years of experience. The aggregated assessment results using the geometric mean method produced the comparison matrix presented in Table 2.

Table 2. Pairwise Comparison Matrix Between Criteria

Criteria	Operating costs	Logistics Accessibility	Availability of Labor
Operating costs	1,000	2,000	3,000
Logistics Accessibility	0.500	1,000	2,000
Availability of Labor	0.333	0.500	1,000

Based on calculations using the eigenvector method, priority weights were obtained for each criterion as shown in Table 3. The results show that operational costs have the highest weight with a value of 0.540, followed by logistics accessibility with a weight of 0.297, and labor availability with a weight of 0.163.

Table 3. Criteria Priority Weight

Criteria	Priority Weight	Ranking
Operating costs	0.540	1
Logistics Accessibility	0.297	2
Availability of Labor	0.163	3

The consistency test yielded a value of $\lambda_{max} = 3.054$, Consistency Index (CI) = 0.027, and Consistency Ratio (CR) = 0.046. A CR value smaller than 0.10 indicates that the paired comparison assessment has an acceptable level of consistency [15].

Evaluation of Alternative Locations Based on Operational Cost Criteria

The operational cost evaluation includes several sub-criteria: land price, electricity rates, water rates, land and building tax, and infrastructure maintenance costs. The results of pairwise comparisons of alternative locations based on the operational cost criteria are presented in Table 4.

Table 4. Alternative Local Priority Weights on Operational Cost Criteria

Alternative Locations	Local Priority Weight	Ranking
Location A (Karawang)	0.188	3
Location B (Cikarang)	0.142	4
Location C (Cikampek)	0.412	1
Location D (Purwakarta)	0.258	2
CR	0.038	Consistent

Location C received the highest priority weighting on the operational cost criteria because it offers competitive land prices and lower utility rates compared to other alternatives.

Evaluation of Alternative Locations Based on Logistics Accessibility Criteria

The logistics accessibility assessment takes into account proximity to toll roads, ports, airports, as well as access to raw material suppliers and distribution markets. The evaluation results are presented in Table 5.

Table 5. Alternative Local Priority Weights on Logistics Accessibility Criteria

Alternative Locations	Local Priority Weight	Ranking
Location A (Karawang)	0.318	2
Location B (Cikarang)	0.437	1

Alternative Locations	Local Priority Weight	Ranking
Location C (Cikampek)	0.156	4
Location D (Purwakarta)	0.089	3
CR	0.042	Consistent

Location B shows the best performance on the logistics accessibility criteria with superior connectivity to national and international transportation networks.

Evaluation of Alternative Locations Based on Labor Availability Criteria

The labor availability evaluation takes into account workforce quantity, education level, technical skill level, regional minimum wage level, and employment stability. The assessment results are presented in Table 6.

Table 6. Alternative Local Priority Weights on Labor Availability Criteria

Alternative Locations	Local Priority Weight	Ranking
Location A (Karawang)	0.276	2
Location B (Cikarang)	0.338	1
Location C (Cikampek)	0.194	3
Location D (Purwakarta)	0.192	4
CR	0.035	Consistent

Location B received the highest weight because it has sufficient availability of skilled labor with a high level of productivity.

Synthesis of Results and Final Ranking

The global priority weight calculation is performed by multiplying the criterion priority weight by the local priority weight of each alternative, then summing the results for each location alternative. The final results are presented in Table 7.

Table 7. Global Priority Weight and Final Ranking of Alternative Locations

Alternative	Operation Cost (0.540)	Logistics Accessibility (0.297)	Labor Availability (0.163)	Global Weight	Ranking
Location A	0.102	0.094	0.045	0.241	2
Location B	0.077	0.130	0.055	0.262	3
Location C	0.222	0.046	0.032	0.300	1
Location D	0.139	0.026	0.031	0.196	4

5. Conclusion

This study successfully developed a systematic decision-making model for optimal factory location selection using the Analytical Hierarchy Process method by considering three main criteria. The analysis revealed that operational costs were the dominant factor with a priority weight of 0.540, reflecting the manufacturing industry's high sensitivity to cost efficiency in maintaining competitiveness. Logistics accessibility ranked second with a weight of 0.297, indicating the importance of supply chain connectivity in company operations, while labor availability had a weight of 0.163 indicating relatively even availability across West Java's industrial areas. Cikampek Industrial Estate was selected as the most optimal location with a global priority weight of 0.300, leveraging competitive advantages in operational cost efficiency that include affordable land prices and economical utility tariffs. Although Cikarang Industrial Estate demonstrated superior performance in logistics accessibility and labor availability, its high premium cost caused this location to be ranked second. The validity of the research results was confirmed through a consistency test

with the Consistency Ratio value of all comparison matrices being below the threshold of 0.10, ensuring the reliability of expert respondents' assessments. The research findings provide a practical contribution in the form of a structured framework that manufacturing companies can adapt to formulate strategic decisions on production facility locations in a more objective and measurable manner, supporting operational efficiency and long-term business sustainability.

Based on the results and discussion of this study, several recommendations can be put forward for practical implementation and further research development. First, for manufacturing companies considering the Cikampek Industrial Estate as a factory location, it is recommended to develop strategies to compensate for limited logistics accessibility through investment in an efficient transportation management system, the development of an integrated distribution network, or strategic collaboration with local logistics service providers to minimize the impact of longer lead times. Second, company management needs to conduct periodic sensitivity analyses for changes in criteria weights along with the dynamics of regional business and infrastructure conditions, considering the development of toll roads and logistics facilities in West Java that can change the relative attractiveness of each location in the medium to long term.

Third, for further research, it is recommended to expand the number of expert respondents and involve more diverse stakeholders, including representatives of local governments and local communities, to increase the representativeness and external validity of the analysis results. Fourth, future research can integrate additional criteria such as local government fiscal incentives, environmental sustainability aspects, natural disaster risks, and the quality of digital infrastructure to provide a more comprehensive evaluation in the context of Industry 4.0. Fifth, the development of a hybrid model that combines the AHP method with other optimization techniques such as Fuzzy AHP, TOPSIS, or PROMETHEE can be considered to handle more complex uncertainty and ambiguity in the decision-making process. Sixth, the implementation of a web-based decision support system or mobile application that adopts this research framework can facilitate faster and more accessible decision-making for industry practitioners at various business scales.

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