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Analysis of Investment Strategy Composition in Rental of Electric Forklift and Diesel Forklift (Case Study of PT XYZ)

Billy Setiawan[1*], Manahan Parlindungan Saragih Siallagan[2]
Institut Teknologi Bandung, Indonesia
Email: setiawanbilly1410@gmail.com[1*]

**Correspondence:Billy Setiawan*

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ABSTRACT

Global initiatives like the Paris Agreement encourage industries worldwide to adopt sustainable practices, including transitioning from diesel-powered to electric-powered machinery. PT XYZ, a company in the logistics sector, faces strategic investment decisions regarding the optimal composition between electric and diesel forklifts. This study aims to determine the most effective investment strategy using the Analytic Hierarchy Process (AHP), supported by a mixed-methods approach combining stakeholder interviews and quantitative pairwise comparisons. The analysis evaluates five primary criteria—Environmental Impact, Economic Efficiency, Operational Performance, Regulatory Compliance, and Market Preference—and fifteen sub-criteria. Findings indicate that Economic Efficiency is the most dominant criterion (52.3%), with Operating Cost (34%) as the leading sub-criterion favoring electric forklifts. The optimal investment ratio is 65.78% electric forklifts and 34.22% diesel forklifts, enabling the acquisition of approximately 67 electric and 51 diesel units with an investment of IDR 30 billion. This composition supports a rental strategy with a potential return on investment in under two years. Diesel forklifts remain advantageous in operational capacity and infrastructure compatibility, especially in remote areas. The AHP model was validated with CR values <0.1, indicating consistent decision-making inputs. The study contributes to strategic investment modeling in the Indonesian industrial sector, aligning business practices with sustainability goals. It also suggests future research exploring dynamic decision-making models, lifecycle cost analysis, and infrastructure readiness assessments for wider adoption of electric forklifts.

Keywords: Investment Strategy; Electric Forklift; Diesel Forklift; AHP; Zero Emission; Sustainability.

INTRODUCTION

The Paris Agreement is an international agreement based on the UN climate change conference in Paris in December 2015 (Bodansky, 2016; Falkner, 2016; Klein et al., 2017). The goal of the Paris Agreement is to limit the temperature rise to below 2 degrees centigrade (United Nation Climate Change, 2015). Countries participating in the congress committed to reducing emissions through nationally determined contributions (NDCs).

The agreement shows a demand for significant change in the industrial sectors, especially those directly affecting carbon emissions, transport, and manufacturing (Green & Stern, 2017; Griffin & Hammond, 2019; Solaymani, 2019). The implementation of the Paris Agreement demonstrates the seriousness of moving towards more efficient and cleaner technologies, including the shift from fuels to electricity (Haszeldine et al., 2018; Kabeyi & Olanrewaju, 2022). PT XYZ sees potential for forklift investment based on benchmarking from PT SML, where they already have 3000 fleets, and PT SML almost rents out all types of forklifts, such as diesel and electric ones. In addition to leasing, PT SML sells new and used forklifts and provides services (https://www.sml.co.id/sewa-forklift-cikarang). Referring to the content of the Paris Agreement related to climate change mitigation and emission reduction, and PT SML as benchmarking, PT XYZ can see the investment in electric forklifts as a strategic move to support sustainability goals and improve the company's environmental performance. This initiative aligns with global commitments to reduce carbon emissions and improve energy efficiency. Considering regulations that support the use of electric vehicles and related incentives, such as those supported by government policies, electric forklifts offer operational benefits through lower maintenance costs and higher efficiency, and position the company as a leader in sustainability and innovation. Therefore, PT XYZ can capitalize on this trend to strengthen its reputation and industry compliance with increasingly stringent environmental regulations.

PT XYZ also aims to expand its business, as evidenced by industries abroad, such as China, India, and Japan, which have already adopted electric forklifts. This highlights a gap between the industry in Indonesia and those in these three countries (Ali et al., 2020; Iyer-Raniga & Dalton, 2019). PT XYZ can leverage this gap by investing in electric forklift projects, although many companies in Indonesia still rely on diesel forklifts. This presents a challenge for PT XYZ as it considers entering the forklift logistics industry, where it must determine whether electric forklifts can compete effectively in Indonesia or if diesel forklifts will still be necessary in the coming years. According to a study (Podgornyy et al., 2024), diesel forklifts consume between 8 to 17 liters of fuel per hour, averaging 12.4 liters during loading. In contrast, electric forklifts operate for 7-8 hours with an electricity consumption of about 31 kWh per hour and can charge up to 70% in just 45 minutes. While electric forklifts are more energy-efficient, diesel forklifts are quicker to refuel. In Asia, rapid economic growth has made the region a global manufacturing hub. Under the Paris Agreement, Asian countries must accelerate economic growth while meeting emission reduction commitments (Bank, 2017). Countries like China, India, and Japan are committed to reducing emissions: China aims for net-zero emissions by 2055, India targets 1,041 billion units of electricity from new energy sources by 2030, and Japan is set to achieve net-zero emissions by 2050, focusing on technological innovation. Meanwhile, Europe strives to become the first carbon-neutral continent by 2050 through the European Green Deal, with companies transitioning to electric equipment and establishing charging infrastructure.

Forklifts play a crucial role in Indonesia's industrial sector, with most companies still relying on diesel forklifts due to their lower purchase prices and attractiveness (Wangsa et al., 2023). However, as the need for net-zero emissions arises, Indonesian companies must prepare to transition to electric forklifts, aligning with PT XYZ's vision of becoming a competent business partner in human resource management. This vision indicates the company's readiness to comply with renewable energy regulations to help reduce emissions, as the Paris Agreement outlines. Unfortunately, the infrastructure for battery recharging remains limited, particularly outside Java. With growing environmental, social, and governance (ESG) concerns, electric forklifts are gaining traction in Asian countries like China, Japan, and India, which is supported by the Paris Agreement's emphasis on green business. The Indonesian government's policies on emission reduction present an opportunity for logistics companies to adopt electric forklift technology, similar to their Asian counterparts. PT XYZ, engaged in logistics and transportation, is committed to reducing carbon emissions through investment in electric forklifts. However, the company faces challenges, particularly the dominance of diesel forklifts in Indonesia, leading to uncertainty in its investment strategy. While PT XYZ has invested in electric forklifts, the appropriate investment composition remains unclear, as all capital has been directed toward electric options without considering diesel forklifts. This research analyzes the investment strategy composition for electric and diesel forklifts. Identifying stakeholder interests based on their power level and interest is crucial to addressing the issues at PT XYZ. Stakeholders are categorized into four quadrants. High-power and high-interest stakeholders include PT XYZ's customers and the President Director, who significantly influence investment decisions regarding electric and diesel forklifts. Their preferences must be actively considered to align decisions with market demands. The President Director, involved in strategic decision-making and budget allocation, ensures that the forklift investment aligns with the company's vision. Customers, as end-users, also have a vested interest in the quality and benefits of the forklifts, which can facilitate market expansion if their needs are met. Forklift suppliers exhibit high investment interest but possess low power, focusing on meeting PT XYZ's specifications and maintaining good relations through quality service and spare parts. The government and investors have high power over project direction but limited direct interest. Investors influence funding decisions based on profit potential, while government regulations shape policies related to electric forklift use and carbon emissions. This analysis informs the decision-making process as PT XYZ navigates the complexities of its investment strategy.

This research aims to formulate an optimal investment strategy using the Analytical Hierarchy Process (AHP) approach. It offers a novel contribution compared to prior studies, such as Atanasković et al. (2013), Mahmutagić et al. (2021), and Ferry (2024), by applying the Analytic Hierarchy Process (AHP) to forklift investment decisions and integrating regulatory, market, and sustainability perspectives in a comprehensive multi-criteria model tailored to Indonesia's logistics sector. While Atanasković et al. (2013) focused on general multi-criteria selection in warehousing and Mahmutagić et al. (2021) on efficiency analysis in warehousing systems, this study uniquely addresses investment strategy composition between electric and diesel forklifts with a quantified ratio (65.78% vs. 34.22%), considering five criteria and fifteen sub-criteria. Additionally, unlike Ferry (2024)This study focused on procurement analysis using AHP and engineering economics, incorporates stakeholder power-interest mapping, regulatory compliance linked to Indonesia's NDC commitment, and environmental externalities like carbon emission penalties. Incorporating realistic investment scenarios (IDR 30 billion) and projected ROI analysis within two years further enhances this study's applied value and decision-making relevance.

RESEARCH METHODOLOGY

This research employs a mixed-methods approach, integrating qualitative and quantitative methods to understand the investment decisions regarding forklifts at PT XYZ comprehensively. Combining these methods allows researchers to explore numerical data and industry experts' practical experiences and insights, ensuring the findings are valid and relevant. Initially, a qualitative approach was taken by developing a topic guide for semi-structured interviews to identify key attributes influencing forklift investment decisions, focusing on operational, cost, and sustainability aspects. Interviews were conducted with experts to uncover the challenges faced by the company and the factors considered most significant in real-world practices. The qualitative data was then analyzed to identify patterns and trends, leading to the establishment of the main criteria for decision-making. Subsequently, the quantitative analysis utilized the Analytical Hierarchy Process (AHP) to assess and weight the criteria, allowing for a structured comparison between diesel and electric forklifts. The AHP method facilitates complex decision-making by organizing the criteria into a hierarchy and enabling pairwise comparisons, resulting in prioritized options based on the established criteria. The outcome of this research is a recommended business solution and implementation plan tailored for PT XYZ, grounded in robust data and analysis that reflect the company's operational context. This blended approach ensures that investment decisions are not only mathematically sound but also aligned with the practical needs and realities of the logistics industry. The data collection involved primary sources through semi-structured interviews and secondary sources such as company reports and regulations, providing a well-rounded foundation for the analysis. The qualitative analysis identified key factors influencing investment decisions, while the quantitative phase employed AHP to derive the optimal investment composition based on priority weights, ultimately guiding PT XYZ in making informed investment choices in the forklift market.

RESULT AND DISCUSSION

Analytic Hierarchy Process

1. **Define criteria for Determining the Investment Composition for Investment Forklift to Achieving Net Zero Emission 2060**

This study determined the main criteria for forklift investment based on a literature review and discussions with the experts from Table 4.1. The main criteria were further elaborated into several sub-criteria based on the literature study. The first questionnaire was administered to the interviewees to obtain their judgment on pairwise comparisons between criteria and sub-criteria. The criteria and sub-criteria set for forklift investment are as described below:

1) Environmental impact

This criterion relates to the impact on the surroundings when the investment is made. Electric forklifts have a significant impact on the environment. The following are sub-criteria regarding environmental impacts, namely:

a. Carbon Emission: Diesel Forklift contributes significantly to carbon dioxide (CO2) emissions, one of the main causes of global warming and climate change. Article “The Carbon Footprint of Electric Forklifts: A Cradle to Grave analysis” (Khabur, 2023) discusses electric forklifts' carbon footprint throughout their lifecycle. Although electric forklifts do not produce emissions directly during their operation, the article emphasizes that some of their carbon emissions come from the electrical products used, such as battery charging, which can account for more than 90% of the total carbon footprint. In addition, emissions associated with the manufacturing process of forklifts and their batteries are estimated to account for around 9% of the total carbon footprint. With passenger EVs, manufacturing of the car and the battery reach 34% of the total emissions (calculated for a 16-year lifespan or 160,000 miles), and energy use adds the other 66%. According to the model used by the European Rental Association, generating the electric energy to charge a forklift's battery exceeds 90% of its total carbon footprint (calculated for a 10-year lifespan). Both calculations are based on the US's average CO2 emissions from electricity-generating plants.

b. Air pollution: Besides carbon emissions, fossil-fueled forklifts produce nitrogen oxides (NOx) and sulfur oxides (SOx), negatively affecting air quality. The article from (Kumar et al., 2019) highlights that these pollutants adversely affect workers' health, especially in enclosed areas such as warehouses and factories. While the focus is not specifically on forklifts, these findings will be relevant to understanding the impact of air pollution on the environment.

c. Noise: Fossil-fueled forklifts generate more noise due to their internal diesel engine, which produces mechanical noise during operation. The paper “Occupational Noise Exposure: A Review of Its effects, epidemiology, and impact with recommendations for reducing its burden” (Theman, 2019) discusses that hazardous noise exposure is one of the most common occupational risks, both in the US and worldwide. Continuous exposure to high noise can cause hearing loss and other health problems.

2) Economic Efficiency

These criteria are developed from a financial point of view to ascertain the impact on the company's economy and implement an optimal investment strategy with the available finances. To optimize the investment, the economic efficiency aspect must be carefully evaluated using the following sub-criteria:

a. Initial Investment Cost: One significant challenge in the adoption of electric forklifts is the higher initial cost compared to diesel forklifts. This is due to the high price of lithium-ion batteries and the need to build supporting infrastructure such as charging stations. This is inversely proportional to diesel forklifts, with lower initial investment costs but more expensive maintenance and operational costs than electric forklifts. Although expensive upfront, electric forklifts offer the potential for long-term savings.
b. Operational Cost: Electric forklifts have advantages in terms of operational costs. Based on the article “How Electric Equipment Reduces Operational Costs” (2024) discusses how electric equipment can reduce operational costs. The article highlights that electric equipment has fewer moving parts, which leads to lower maintenance costs. In addition, the cost of electricity is generally lower than that of diesel fuel or gas, which contributes to overall cost savings.
c. Resale Value: Diesel forklifts have a more established resale value market, especially in countries with limited electricity infrastructure. The battery life of electric forklifts is not as long as diesel forklifts, resulting in lower resale value. However, the global trend towards sustainability may boost electric forklifts in the future, especially in countries with strict emission regulations.

3) Operational Performance

a. Lifting Capacity: Diesel forklifts often have a greater lifting capacity than electric forklifts, especially for outdoor work environments. Diesel forklifts are more flexible for material transport or construction, while electric forklifts are more flexible for indoor use or in warehouses.
b. Operational Reach: Diesel forklifts have an advantage in operational range because they can refuel quickly. In contrast, electric forklifts have time limitations in battery charging, which takes longer, even with fast-charging technology.
c. Resilience in extreme working conditions: Diesel forklifts are more resistant to low temperatures and fairly extreme working terrains. In contrast, electric forklifts are better utilized in indoor terrains such as warehouses.

4) Regulatory Compliance

a. Fulfilment of emission standards: Environmental regulations encourage companies to switch from diesel forklifts to electric ones. Emission standards in the European Union, as stipulated in the EU Emission Standards Directive (2019), demand reduced carbon emissions from industrial equipment. Indonesia is projected to adopt stricter industry emission standards in the period 2026-2027, as part of the implementation of the Nationally Determined Contribution (NDC) in the Paris Agreement. This is expected to encourage companies to shift their investment from diesel forklifts to electric forklifts. This harmonization will strengthen Indonesia's position in global value chains that are beginning to require compliance with environmental standards (KLHK, 2022).
b. Government Incentives: The Indonesian government offers various incentives, such as tax reductions or subsidies, for the adoption of electric vehicles. For example, Peraturan Menteri Perindustrian No. 27/2020 provides tax incentives for electric vehicles with certain TKDN (Tingkat Komponen Dalam Negeri). This encourages companies to switch to electric-based industrial equipment, so incentives for electric-based industrial equipment in Indonesia will be incentivized. https://peraturan.bpk.go.id/Details/167009/permenperin-no-27-tahun-2020

c. Penalty risk due to emissions: Diesel forklifts that do not meet emission standards risk fines, which puts additional pressure on companies to comply with regulations. Under regulation (EU) 2019/631, vehicle manufacturers that do not meet CO2 emission targets are subject to significant financial penalties, which encourages manufacturers to comply with the emission standards set.

5) Market Preference

a. Customer Requests: More and more customers demand environmentally friendly products in the supply chain. This reflects the global trend towards sustainability and ESG (Environmental, Social, and Governance) assessments.

b. Company Reputation for Sustainability: Blum, 2011 research shows that the adoption of green technology can improve a company's reputation in the eyes of customers and stakeholders. Using electricity-based industrial tools can help companies strengthen their image to support sustainability.

c. Infrastructure Readiness: Although electric forklifts have many advantages, limited charging infrastructure is still a bottleneck in developing countries, including Indonesia. An article from the Asian Development Bank 2021, says that inadequate infrastructure could slow the adoption of electric-based industrial tools in the Asian region.

2. Development of the AHP Model

This AHP model aims to determine the investment composition of electric and diesel forklifts to achieve net-zero emissions by 2060. The criteria and sub-criteria were set based on discussions with the president director and the director in charge of forklift investment.

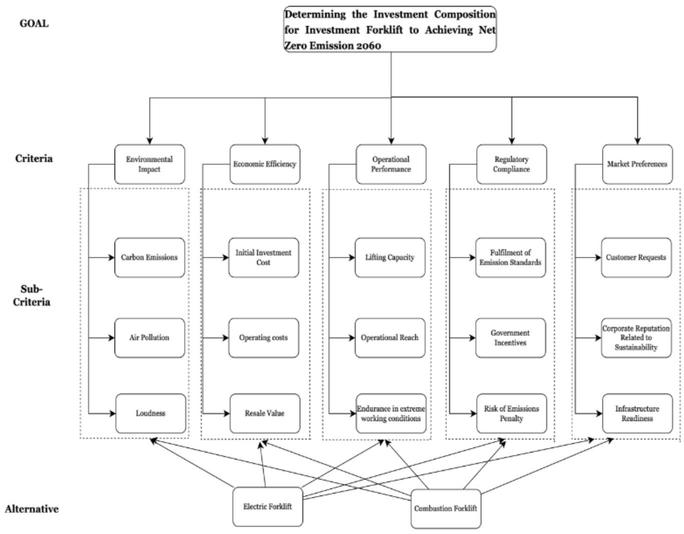

Figure 1. Analytic Hierarchy Process Model

3. Pairwise Comparison of the AHP Model

A pairwise comparison between criteria and sub-criteria in Figure 4.1 was developed into a questionnaire to be filled in by the President Director and Director, who gave a score to each comparison table. The questionnaire was sent to the President Director and the Director, who is in charge of forklift investment. The level of importance of each criterion and sub-criterion was collected from the completed questionnaires. The comparison scale uses a linear scale originated by Saaty (1990), as follows:

Table 1. Scale for Scoring

Intensity of Importance	Definition
1	Equal Importance
3	Moderate Importance

5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2,4,6,8	For a compromise between the above values

Table 2. Scoring for Criteria

Criteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria
Environmental Impact																		Economic Efficiency
Environmental Impact																		Operational Performance
Environmental Impact																		Regulatory Compliance
Environmental Impact																		Market Preference
Economic Efficiency																		Operational Performance
Economic Efficiency																		Regulatory Compliance
Economic Efficiency																		Market Preference
Operational Performance																		Regulatory Compliance
Operational Performance																		Market Preference
Regulatory Compliance																		Market Preference

Scoring for Sub-Criteria

Criteria	Sub-Criteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Sub-Criteria
Environmental impact	Carbon emission																		Air pollution
	Carbon emission																		Noise
	Air pollution																		Noise
Economic Efficiency	Initial Investment Cost																		Operation Cost
	Initial Investment Cost																		Resale Value
	Operation Cost																		Resale Value
Operational Performance	Lifting Capacity																		Operational Reach
	Lifting Capacity																		Resilience in Extreme

Criteria	**Sub-Criteria**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Sub-Criteria**
																			Working Conditions
	Operational Reach																		Resilience in Extreme Working Conditions
Regulatory Compliance	Fulfilment of emission standards																		Government Incentives
	Fulfilment of emission standards																		Risk of Emission Penaly
	Government Incentives																		Risk of Emission Penaly
Market Preference	Customer Requests																		Corporate Reputation Related to Sustainability
	Customer Requests																		Infrastructure Readiness
	Corporate Reputation Related to Sustainability																		Infrastructure Readiness

Before entering into the priority vector calculation process, the first step taken in the AHP method is to compile a Pairwise comparison for the Criteria previously determined. 5 respondents carried out the assessment. This comparison process aims to measure the relative importance of one criterion against another in the context of forklift investment decision-making. Using a 1-9 scale based on Saaty, (1990) each respondent compared criteria such as Environmental Impacts, Economic Efficiency, Operational Performance, Regulatory Compliance, and Market preferences in pairs. The results of these interviews were compiled and averaged and then summarized in Table 4.4, which shows the average score of respondents' preferences for each pair of criteria. For example, Economic Efficiency was rated much more important than Market preference, with a score of 5.80, while Environmental Impact had a moderate advantage over Operational Performance at 1.31. From these values, the next step is to normalize the comparison matrix to produce a priority vector for each criterion. This value will be used to calculate the optimal investment composition between electric and diesel forklifts in the final stage of the AHP analysis.

Table 3. Pairwise Comparison of Criteria

Criteria	Average Point	Criteria	Average Point
Environmental Impact	0.25	Economic Efficiency	4.05
Environmental Impact	1.31	Operational Performance	0.77
Environmental Impact	1.73	Regulatory Compliance	0.58
Environmental Impact	1.80	Market Preference	0.56
Economic Efficiency	4.40	Operational Performance	0.23
Economic Efficiency	4.80	Regulatory Compliance	0.21
Economic Efficiency	5.80	Market Preference	0.17
Operational Performance	2.35	Regulatory Compliance	0.43
Operational Performance	3.27	Market Preference	0.31
Regulatory Compliance	1.95	Market Preference	0.51

After determining the priority weight of each main criterion through pairwise comparison in Table 3, the next step is to conduct a deeper analysis of the sub-criteria of the main category. The aim is to identify specific factors that significantly influence each criterion.

Pairwise comparison between sub-criteria is done using the same approach, which is based on the assessment of 5 expert respondents. The average value of each pair of sub-criteria is presented in Table 4, which illustrates the level of importance between sub-criteria such as carbon emission, operational cost, resale value, lifting capacity, and infrastructure readiness. These values will be used in the normalization process to generate priority weights at a later stage and will be the basis for the final calculation of investment decisions between electric and diesel forklifts.

Table 4. Pairwise Comparison of Sub-Criteria

Criteria	Average Point	Criteria	Average Point
Carbon emission	2.329	Air pollution	0.429
Carbon emission	4.269	Noise	0.234
Air pollution	2.767	Noise	0.361
Initial Investment Cost	0.322	Operation Cost	3.104
Initial Investment Cost	2.425	Resale Value	0.412
Operation Cost	5.100	Resale Value	0.196
Lifting Capacity	1.680	Operational Reach	0.595
Lifting Capacity	1.873	Resilience in Extreme Working Conditions	0.534
Operational Reach	2.183	Resilience in Extreme Working Conditions	0.458
Fulfilment of emission standards	2.480	Government Incentives	0.403
Fulfilment of emission standards	3.800	Risk of Emission Penaly	0.263
Government Incentives	2.167	Risk of Emission Penaly	0.462
Customer Requests	4.267	Corporate Reputation Related to Sustainability	0.234
Customer Requests	3.740	Infrastructure Readiness	0.267
Corporate Reputation Related to Sustainability	1.307	Infrastructure Readiness	0.765

After weighing each sub-criterion in the five main criteria, the next step is to compare the two alternative investment solutions, diesel and electric, against each sub-criteria.

Comparisons were made using the same pairwise comparison approach as before, where decision makers assessed how far each alternative was superior to the other in the context of each sub-criterion. The results of this process are summarized in Table IV.6, which shows the preferences between electric forklifts and diesel forklifts based on the average rating of the five respondents.

Table 5. Pairwise Comparison of Alternatives

Criteria	Average Point	Criteria	Average Point
Carbon Emission			
Diesel Forklift	0.123	Electric Forklift	8.129
Air Pollution			
Diesel Forklift	0.117	Electric Forklift	8.571
Noise			
Diesel Forklift	0.123	Electric Forklift	8.129
Initial Investment Cost			
Diesel Forklift	2.665	Electric Forklift	0.375
Operational Cost			
Diesel Forklift	0.101	Electric Forklift	9.921
Resale Value			
Diesel Forklift	2.340	Electric Forklift	0.427
Lifting Capacity			
Diesel Forklift	2.840	Electric Forklift	0.352
Operational Reach			
Diesel Forklift	1.667	Electric Forklift	0.600
Resilience in extreme working conditions			
Diesel Forklift	1.800	Electric Forklift	0.556
Fulfilment of emission standards			
Diesel Forklift	0.144	Electric Forklift	6.927
Government Incentives			
Diesel Forklift	0.235	Electric Forklift	4.251
Risk of Emission Penalty			
Diesel Forklift	0.133	Electric Forklift	7.522
Customer Requests			
Diesel Forklift	1.833	Electric Forklift	0.545
Corporate Reputation Related to Sustainability			
Diesel Forklift	0.179	Electric Forklift	5.600
Infrastructure Readiness			
Diesel Forklift	3.490	Electric Forklift	0.287

4. Priorities Calculation for AHP Criteria

The priorities for each criterion are calculated using the data collected from all five (5) respondents. The data is arranged in matrix format in accordance with the AHP model. The global priorities of each criterion are calculated using a multiplication formula, along with the calculations of all local priorities.

a. The size of the criteria matrix is 5x5, with the following size of sub-criteria matrices:
b. Environmental Impact with 3x3 sub-criteria matrix size
c. Economic Efficiency with 3x3 sub-criteria matrix size
d. Operational Performance with 3x3 sub-criteria matrix size
e. Regulatory Compliance with 3x3 sub-criteria matrix size
f. Market Preference with 3x3 sub-criteria matrix size

After assessing each alternative forklift based on predetermined sub-criteria, the next step is to calculate global priorities between criteria. This calculation is done by compiling the results of the five respondents' assessments into a Pairwise comparison matrix in accordance with the AHP structure.

Each criterion is compared to determine its importance relative to the different criteria in the context of forklift investment decision-making. This process produces an initial weight for each criterion, which is then used to calculate the global weight of each sub-criterion and alternative. Details of the criteria comparison can be seen in Table 6 below:

Table 6. Pairwise Comparison Matrix of Criteria

Criteria	Environmental Impact	Economic Efficiency	Operational Performance	Regulatory Compliance	Market Preference
Environmental Impact	1	0.25	1.31	1.73	1.80
Economic Efficiency	4.05	1	4.40	4.80	5.80
Operational Performance	0.77	0.23	1	2.35	3.27
Regulatory Compliance	0.58	0.21	0.43	1	1.95
Market Preference	0.56	0.17	0.31	0.51	1
Column Total	6.95	1.85	7.44	10.39	13.82

Step 2: Divide each element of the pairwise comparison matrix in Table 4.7 by its column total and average the elements in each row to get the row average (Priority Vector). The result of the calculation can be seen in Table 7.

Table 7. Priority Vector Calculation of Criteria

Criteria	Environmental impact	Economic Efficiency	Operational Performance	Regulatory Compliance	Market Preferences
Environmental impact	0.14	0.13	0.18	0.17	0.13
Economic Efficiency	0.58	0.54	0.59	0.46	0.42
Operational Performance	0.11	0.12	0.13	0.23	0.24
Regulatory Compliance	0.08	0.11	0.06	0.10	0.14
Market Preferences	0.08	0.09	0.04	0.05	0.07
Column Total	1	1	1	1	1

The result of the row average is usually represented as the priority vector or eigen vector of the solution criteria (Level-1) that can be seen in Table 4.9

Table 8. Priority Vector for Criteria

Solution	Priority Vector
Environmental impact	0.152
Economic Efficiency	0.523
Operational Performance	0.163
Regulatory Compliance	0.096
Market Preferences	0.066

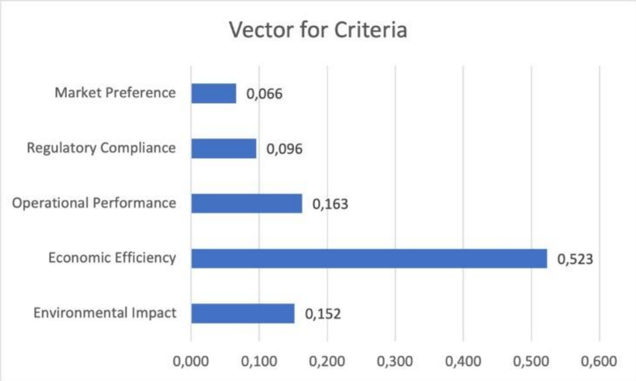

Figure 2. Vector "Criteria"

The calculation results of the priority vector for criteria in Table 4.9 show that the most dominant criterion in making forklift investment decisions at PT XYZ is economic efficiency, with a priority weight of 52.3%. This reflects that decision makers at PT XYZ highly prioritise economic aspects such as operating costs, initial investment value, and resale value in their investment strategy. In Figure 2, the operational performance criterion occupies the second position with a weight of 16.3%, which indicates that technical factors such as lifting capacity and durability are also important to consider in selecting the type of forklift. The environmental impact criterion, with 15.2%, shows that although important, environmental issues such as carbon emissions, noise, and air pollution are still slightly below operational performance. Regulatory compliance (9.6%) and Market Preference (6.6%) criteria are at the bottom of the list, but remain relevant as regulations and changing client preferences remain external factors that influence the direction of investment strategies, especially in the transition to green industries.

After determining the priority weight of each criterion, the next step is to conduct pairwise comparisons between sub-criteria contained in each category. This process aims to discover the internal factors of each criterion that have a dominant influence on decision-making. The assessment is carried out with the same approach and arranged as a pairwise comparison matrix as in Table 9.

Table 9. Pairwise Comparison Matrix of Sub-Criteria

Environmental Impact			
	Carbon emission	Air Pollution	Noises
Carbon Emission	1	2.329	4.269
Air Pollution	0.429	1	2.767
Noises	0.234	0.458	1
Column Total	1.664	3.690	8.035
Economic Efficiency			
	Initial investment Cost	Operating Cost	Resale Value
Initial Investment Cost	1	0.322	2.455
Operating Cost	0.403	1	5.100
Resale Value	0.263	0.462	1
Column Total	4.517	1.518	8.525
Operation Performance			
	Lifting Capacity	Operational Reach	Endurance in Extreme Working Conditions
Lifting Capacity	1	1.680	1.873
Operational Reach	0.595	1	2.183

Endurance in Extreme Working Conditions	0.534	0.458	1
Column Total	2.129	3.138	5.057
Regulatory Compliance			
	Fulfilment of Emission Standards	Government Incentives	Risk of Emission Penalty
Fulfilment of Emission Standards	1	2.480	3.800
Government Incentives	0.403	1	2.167
Risk of Emission Penalty	0.263	0.462	1
Column Total	1.666	3.942	6.967
Market Preferences			
	Customer Requests	Corporate Reputation related to sustainability	Infrastructure Readiness
Customer Requests	1	4.267	3.740
Corporate Reputation related to sustainability	0.234	1	1.307
Infrastructure Readiness	0.267	0.765	1
Column Total	1.502	6.032	6.047

After preparing the pairwise comparison matrix for all sub-criteria in each criterion in Table IV.10, the next process is to normalize the matrix values to calculate each sub-criterion's priority vector. Normalization is done by dividing each value in the column by the total number of columns, then averaged horizontally to obtain the priority weight of each sub-criteria. The results of this calculation process provide an overview of how much influence each sub-criteria has in the overall structure of forklift investment decision making at PT XYZ. The priority vector values obtained are then displayed in Table 10 as follows:

Table 10. Priority Vector for Sub-Criteria

Solution	Priority Vector
Carbon emission	0.589
Air Pollution	0.290
Noise	0.120
Initial Investment Cost	0.238
Operation Cost	0.650
Resale Value	0.112
Lifting Capacity	0.461
Operational Reach	0.343
Endurance in extreme conditions. Working condition	0.197
Fulfilment of emission standards	0.593
Government Incentives	0.268
Risk of Emission Penalty	0.139
Customer Requests	0.666
Corporate Reputation related to sustainability	0.178
Infrastructure Readiness	0.156

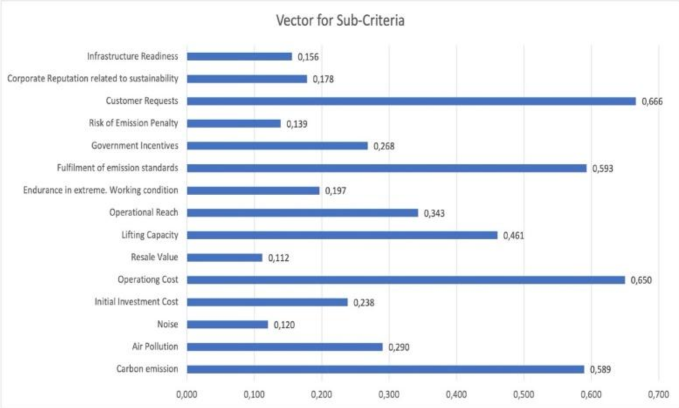

Figure 3. Vector "Sub-Criteria"

Table 10 shows the results of the calculation of the priority vector of each sub-criteria that has been normalized based on the pairwise comparison results in Table 9. These values reflect the level of importance of each sub-criteria in influencing forklift investment decisions at PT XYZ. From the calculation results, several important findings can be highlighted: Consumer requests of 66.6% occupy the position of the most dominant sub-criteria, which shows that market demand, especially PT XYZ clients, significantly influences the direction of investment decisions. This confirms that investment strategies must be adaptive to shifting consumer preferences towards more environmentally friendly technologies. Operating Cost at 65% is the main cost factor in economic efficiency. This reflects the great attention to long-term costs in forklift operations, especially since electric forklifts have significant advantages. Fulfilment of Emission Standards with 59.3% and carbon emission with 58.9% shows that regulatory compliance and environmental contribution are the company's strategic focus in line with the net-zero emission target 2060. Lifting Capacity with 46.1% and Operational Reach with 34.3% are important technical sub-criteria in the operational performance category. This indicates that although environmental and efficiency aspects are very important, the technical capabilities of forklifts remain vital to ensure effective operations. On the other hand, some sub-criteria have lower priorities, such as resale value at 11.2%, Noise at 12%, and infrastructure readiness at 15.6%, which are still relevant, but not the main focus in making strategic decisions on forklift investment at PT XYZ.

Overall, this data shows that forklift investment decisions are influenced by technical and cost aspects as well as current market and regulatory pressures. These findings will be used in the final analysis stage to calculate the prioritization of alternatives between electric and diesel forklifts.

After all sub-criteria and their respective priority weights are obtained, the next step in the AHP process is to assess the two investment alternatives, namely diesel forklifts and electric forklifts, based on previously established sub-criteria. This stage aims to determine the level of excellence of each alternative against each sub-criteria to determine how much each alternative contributes to the overall investment decision. The assessment results are shown in Table 4.12, which shows the priority vector value of diesel forklifts and electric forklifts in each sub-criteria.

Table 11. Priority Vector for Alternative

Sub-Criteria	$\begin{bmatrix} \text{Forklift Diesel} \\ \text{Forklift Electric} \end{bmatrix}$
Carbon emission	$\begin{bmatrix} 0.110 \\ 0.890 \end{bmatrix}$

Air Pollution	$\begin{bmatrix}0.105\\0.895\end{bmatrix}$
Noise	$\begin{bmatrix}0.110\\0.890\end{bmatrix}$
Initial Investment Cost	$\begin{bmatrix}0.727\\0.273\end{bmatrix}$
Operation Cost	$\begin{bmatrix}0.092\\0.908\end{bmatrix}$
Resale Value	$\begin{bmatrix}0.701\\0.299\end{bmatrix}$
Lifting Capacity	$\begin{bmatrix}0.740\\0.260\end{bmatrix}$
Operational Reach	$\begin{bmatrix}0.625\\0.375\end{bmatrix}$
Resilience in Extreme Working Conditions	$\begin{bmatrix}0.643\\0.357\end{bmatrix}$
Fulfilment of emission standards	$\begin{bmatrix}0.126\\0.874\end{bmatrix}$
Government Incentives	$\begin{bmatrix}0.190\\0.810\end{bmatrix}$
Risk of Emission Penalty	$\begin{bmatrix}0.117\\0.883\end{bmatrix}$
Customer Requests	$\begin{bmatrix}0.647\\0.353\end{bmatrix}$
Corporate Reputation related to sustainability	$\begin{bmatrix}0.152\\0.848\end{bmatrix}$
Infrastructure Readiness	$\begin{bmatrix}0.777\\0.223\end{bmatrix}$

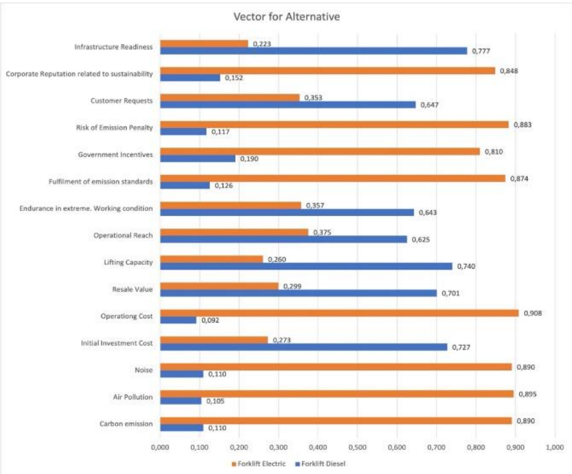

Figure 4. Vector “Alternative”

Table 11 and Figure 4 show each alternative's priority value on each predetermined sub-criterion. These values reflect how strongly each alternative fulfils or excels in each evaluation aspect. It can be seen as follows:

1. Electric forklifts are more dominant in environmental and regulatory aspects

- Carbon emission (11% vs 89%)
- Air Pollution (10.5% vs 89.5%)
- Noise (11% vs 89%)
- Fulfilment of emission standards (12.6% vs 87.4%)
- Risk of Emission Penalty (11.7% vs 88.3%)
- Corporate Reputation (15.2% vs 84.8%)

Based on these results, electric forklifts are significantly favored in environmental aspects, making them an ideal choice to support net-zero emission policies and build a more environmentally friendly corporate image.

2. Electric forklifts are superior in the cost aspect

- Operating Cost (9.2% vs 90.8%)
- Government Incentives (19% vs 81%)

Although electric forklifts are more expensive initially, the long-term operating cost benefits and government incentive support will add significant value in the long run.

3. Diesel forklifts are superior in technical aspects

- Initial Investment Cost (72.7% vs 27.3%)
- Resale value (70.1% vs 29.9%)
- Lifting Capacity (74% vs 26%)
- Operational Reach (62.5% vs 37.5%)
- Resilience in Extreme Conditions (64.7% vs 35.3%)
- Infrastructure Readiness (77.7% vs 22.3%)

Diesel forklifts are still preferred in terms of field practicality, especially for heavy projects or locations that do not yet have battery charging infrastructure.

The initial hypothesis is that electric forklifts are strategically superior in terms of environmental aspects, operational cost efficiency, and regulatory compliance, while diesel forklifts still have operational advantages in capacity, resale value, current infrastructure readiness, and customer preferences.

After obtaining the priority value of each alternative against each sub-criteria, the next step is to determine the most optimal alternative based on the combined local priority of the criteria and the local priority of each sub-criteria. This process is carried out by multiplying the criteria's local priority with the subcriteria's local priority to form a global priority. The complete results of the calculation process are shown in Table 12.

Table 12. Combined Alternative Solution for All Respondents

		Priority calculation of Sub-Criteria				
Criteria	**Local Priority**	**Sub-Criteria**	**Local Priority**	**Global Priority**	**Diesel Forklift**	**Electric Forklift**
Environmental Impact	0.152	Carbon emission	0.589	0.090	0.110	0.890
		Air Pollution	0.290	0.044	0.105	0.895
		Noise	0.120	0.018	0.110	0.890
Economic Efficiency	0.523	Initial Investment Cost	0.238	0.125	0.727	0.273
		Operation Cost	0.650	0.340	0.092	0.908
		Resale Value	0.112	0.059	0.701	0.299
Operation Performance	0.163	Lifting Capacity	0.461	0.075	0.740	0.260
		Operational Reach	0.343	0.056	0.625	0.375
		Resilience in Extreme Working Conditions	0.197	0.032	0.643	0.357
Regulatory Compliance	0.096	Fulfilment of emission standards	0.593	0.057	0.126	0.874
		Government Incentives	0.268	0.026	0.190	0.810
		Risk of Emission Penalty	0.139	0.013	0.117	0.883
	0.066	Customer Requests	0.666	0.044	0.647	0.353

	Priority calculation of Sub-Criteria				
Market Preference	Corporate Reputation related to sustainability	0.178	0.012	0.152	0.848
	Infrastructure Readiness	0,156	0,010	0.777	0.223

Based on the results in Table IV.13, it can be interpreted that each sub-criteria has a different level of contribution to the final decision in selecting alternative forklift investments. The global priority value obtained reflects how much influence each sub-criteria has on the decision. The sub-criteria with the highest value is operating cost with 34%. This shows that operational cost efficiency is a significant consideration in PT XYZ's investment strategy. It also indicates that long-term usage and maintenance costs are the main focus of PT XYZ in determining the direction of sustainable investment. These advantages contributed the most to the final positioning of the electric forklift as the most recommended alternative.

Furthermore, initial investment cost occupies the second position with a global priority value of 12.5%. Although diesel forklifts are superior in this aspect, the contribution of this aspect to the final decision is not as significant as operating costs. This shows that although the initial investment cost is still considered, it is not the main determining factor in choosing an alternative.

Environmental aspects also emerge as an important consideration in investment decisions, as indicated by the high global priority of 9% on carbon emissions. Electric forklifts scored high in this aspect, reflecting PT XYZ's awareness of the urgency of reducing carbon emissions and support for Net Zero emissions by 2060. This contribution also strengthens the position of electric forklifts as a strategically superior alternative.

Several other sub-criteria, such as resale value, lifting capacity, and operational reach, contributed moderately to the final decision. Diesel forklifts dominate in these aspects, especially in the operational performance dimension, which confirms that diesel forklifts remain relevant in the context of field needs and projects that require large lifting forces and fast refueling flexibility. However, as the global priority of this dimension is lower than the cost aspect, its contribution to the overall ranking is more limited.

Meanwhile, the sub-criteria with the least contribution to the decision are infrastructure readiness, corporate reputation related to sustainability, risk of emission penalty, and noise. Despite the small weights, it is interesting that electric forklifts still excel in almost all sub-criteria. This shows that the advantage of electric forklifts lies not only in the main aspects but also consistently in the supporting aspects.

After analyzing all criteria and sub-criteria in Table IV.13, the next step in the AHP method is to calculate the priority ranking between alternatives to determine the optimal investment solution for PT XYZ. This step is done by multiplying the entire priority vector of the alternative with the global priority of each sub-criteria. This process will produce an investment composition for each alternative that can be compared quantitatively.

CONCLUSION

This study, using the Analytic Hierarchy Process (AHP), determined that the optimal forklift investment composition for PT XYZ is 65.78% electric and 34.22% diesel, based on five main criteria—Economic Efficiency, Operational Performance, Environmental Impact, Regulatory Compliance, and Market Preference—along with fifteen sub-criteria. Economic Efficiency emerged as the most influential factor (52.3%), with Operating Cost (34%) being the most critical sub-criterion, favoring electric forklifts. While electric forklifts are prioritized for their cost-effectiveness and environmental benefits, diesel forklifts remain relevant for specific operational needs. With an investment of IDR 30 billion, the company can procure 67 electric and 51 diesel units, aligning with a rental business model and a projected ROI in under two years. All AHP calculations were validated with CR values <0.1, indicating strong consistency. A dynamic optimization framework that incorporates technological developments, fluctuating energy prices, and real-world performance data is recommended for future research. This could involve advanced decision models such as dynamic or fuzzy AHP, lifecycle cost analysis, and simulations. Further exploration into infrastructure readiness and user adaptability is essential for supporting strategic investment in electric forklift adoption.

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