Journal of Multidisciplinary Academic Business Studies (JoMABS)
ISSN 2656-2359, Vol 2, No 1, 2024, 1-20 https://doi.org/10.35912/jomabs.v2i1.2393

Determining the best alternative to build and operate a new coal crushing facilities: Analytical hierarchy process approach

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Article History
Received on 04 September 2024
1st Revision on 26 September 2024
Accepted on 14 November 2024

Abstract
Purpose: This study examines the increase in national coal production in Indonesia and its impact on PT. KLM is one of the largest coal producers in Indonesia. With rising production and shifting global market needs, this study aims to analyze the necessity of building a new Coal Crushing Facility next to the South Pinang Extension #2 area, including evaluating costs and the best strategies for its implementation.
Research Methodology: The research methodology involved analyzing problem trees and stakeholders to uncover business complexities and identify the root causes of issues. Qualitative data were collected through semi-structured interviews. All alternatives were evaluated using Value-Focused Thinking (VFT), and the Analytic Hierarchy Process (AHP) method was employed to determine the best alternative assisted by the Super Decision application.
Results: Based on interviews conducted with subject matter experts (SMEs) and analysis, three funding solutions were identified: 1. owned by self-financing, and (2) Own by Leasing 3. Rental Scheme.
Conclusions: The study concludes that building a new Coal Crushing Facility at South Pinang Extension is necessary to support rising production, with three viable financing alternatives self-financing, leasing, and rental identified through systematic analysis to ensure efficiency and competitiveness.
Limitations: The limitations of this study are that it was sourced from an internal company and data were gathered from outside the company. An alternative option was developed based on extensive collaborative discussions and interview sessions with subject matter experts within the company.
Contribution: This study provides valuable guidelines for selecting alternative financing to build and operate new coal-crushing facilities at South Pinang Extension #2.

Keywords: *Alternative, Analytic Hierarchy Process (AHP), Crusher, Economic Evaluation, Life of Mine (LOM), Super Decision Application*

How to cite: Simatupang, K. P., & Wasesa, M. (2024). Determining the best alternative to build and operate a new coal crushing facilities: Analytical hierarchy process approach. *Journal of Multidisciplinary Academic Business Studies*, 2(1), 1-20.

1. Introduction

Indonesia's coal production has increased significantly, reaching 687 million tons in 2022, an increase of 11.9% from the previous year (Setiawan, Puteri, & Pasalli, 2023). This trend is expected to continue until 2023, driven by high global coal benchmark prices and uncertainties in energy transition. Global coal usage is likely to rise owing to energy crises affecting Europe, where several EU nations have reactivated coal-fired power plants to enhance their energy security (Loewen, 2022). Additionally,

extreme weather phenomena are expected to continue impacting renewable energy generation, providing opportunities for coal producers such as PT. KLM to meet market demand (Gonçalves, Costoya, Nieto, & Liberato, 2024).

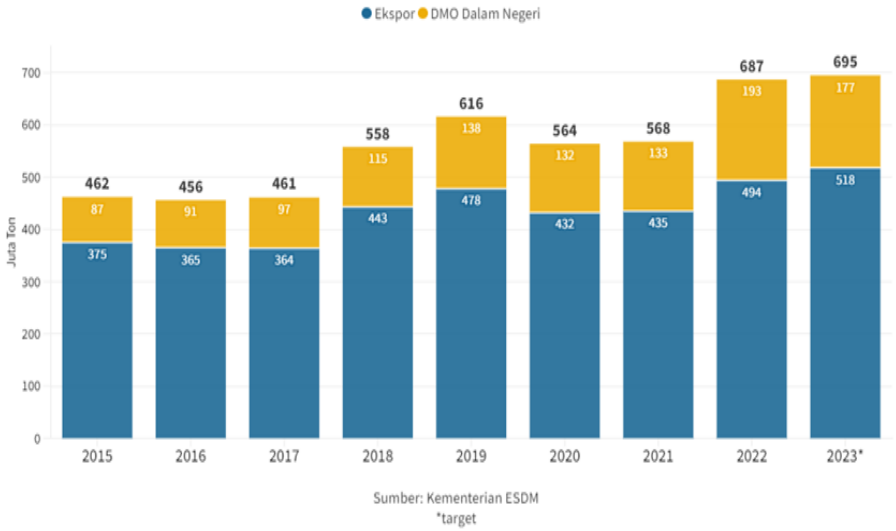

Figure 1. Indonesia Coal Production 2015 - 2023
Source: Dirjen Minerba

1.1. Company Profile

PT. KLM is the largest coal producer in Indonesia and one of the largest globally, with a production capacity of 70 million tons per year. Located in East Kalimantan, the company operates nine open-pit mines across two main areas, Region A and Region B. Coal processing and shipping facilities are integrated across these areas (Nasir, Bakker, & van Meijl, 2023).

1.2. Organizational Structure

PT. KLM's organizational structure includes various divisions that support operations, such as maintenance, processing, development, supply, finance, human resources, and marketing. The organization consists of 14 divisions, each headed by a General Manager and supported by approximately 4,034 permanent employees and 21,000 contractors (Yaschenko, Polyakov, & Sabitova, 2021).

1.3. Business Issue

With the increasing demand for coal, PT. KLM faces challenges in terms of cost efficiency, particularly with respect to the hauling distances. The expansion of mining areas and the need to build new coal-crushing facilities are critical for reducing operational costs and improving efficiency. This research focuses on stakeholder analysis, alternative solutions, and evaluation criteria for constructing a new coal crushing facility at South Pinang Extension (Widodo, Sulistianto, & Ihsan, 2018).

1.4. Research Questions and Research Objectives

PT. KLM expanded the mining area to a new location. Companies must evaluate the operating costs incurred by shifting mining areas to ensure economic viability. The company should identify a new location and business strategy to clarify operational management regarding Coal Crushing Facility issues as follows:

1. What is the root cause of the new coal crushing plant being built next to the South Pinang Extension #2 area?
2. What alternative solutions can effectively determine a strategy for building a new coal-crushing plant?
3. What criteria should be used to evaluate alternative solutions?
4. Which solution is the most effective in resolving this issue?

The objectives of this study are as follows:

1. Identify the stakeholder expectations and values for this project.
2. Identify capital and operational costs to provide relevant alternative scenarios for solving these problems.
3. Determine the best alternative for dealing with current conditions to ensure that there is no disruption to the planned coal production process.

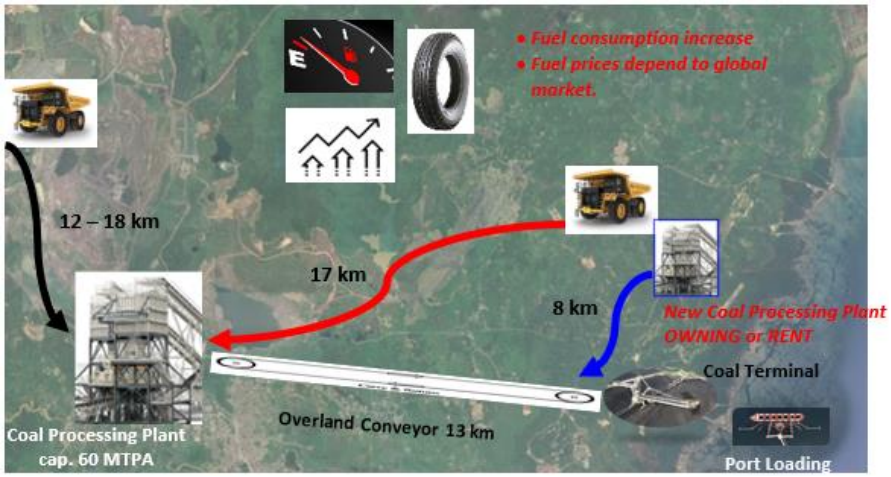

Figure 2. Rich Picture of Coal Hauling Process to CPP
Source: Author

2. Literature review

A literature review is an essential component of this research, as it succinctly describes and scrutinizes prior research on a pertinent topic (Snyder, 2019). This review will facilitate the development of a well-founded justification for this study by offering a comprehensive understanding of the theoretical underpinnings, current research, and existing information. Furthermore, it will facilitate the researcher in recognizing the techniques and fundamental ideas employed in previous studies, thereby helping in the choice of suitable procedures for the present investigation (Xiao & Watson, 2019). This section analyzes the methodological approaches employed in this field, as well as their strengths and weaknesses, based on prior research. This study utilized several specific approaches, namely, the Cynefin Framework, stakeholder analysis, value-focused thinking, analytical hierarchy process, and divergent-convergent thinking model. This review will evaluate the appropriateness of these methodologies with respect to the study's objectives and questions. Therefore, this study is anticipated to address current knowledge deficiencies and offer a more thorough and profound comprehension of the research subject by showcasing a comprehensive awareness of the pertinent literature (Baron, 2023).

2.1. Theoretical Foundation

2.1.1. Cynefin Framework

The Cynefin Framework is a sense-making model that helps individuals and organizations understand complex systems and make decisions in ambiguous and uncertain situations. Developed by Snowden (2021), this framework has been widely used in various fields, including innovation, leadership, and management. The Cynefin Framework consists of five domains: simple, complicated, complex, chaotic, and disordered. Each domain represents a distinct system characterized by different levels of predictability and causality (Nachbagauer, 2021). The framework aids individuals and organizations in determining the domain in which they are operating and the appropriate approach for decision-making and understanding the situation (Hossain, Khatun, & Shanjabin, 2024; Krejci & Stoklasa, 2018; Snowden, 2021).

Simple Domain: Characterized by predictable outcomes and clear cause-and-effect relationships. Standard operating procedures and best practices are effective in this field.

Complicated Domain: Defined by multiple cause-and-effect relationships, requiring expert knowledge and analysis to understand and resolve the issues. Expert advice and sound practices are useful for achieving the desired outcomes.
Complex Domain: Characterized by unpredictable outcomes and nonlinear cause-and-effect relationships. Adaptive strategies, emergence, and experimentation are effective methods for managing complexity and uncertainty.
Chaotic Domain: Marked by complete unpredictability, necessitating immediate action to stabilize the situation. Innovative strategies and rapid experimentation are effective in addressing these crises.
Disorder Domain: This Domain: Defined by confusion and uncertainty regarding the domain to which a situation belongs. Understanding the situation and determining the best course of action depends on making sense of it and making decisions.

Figure 3. Cynefin Framework ver. 2020
Source: Snowden (2021)

The Cynefin Framework has been applied to management, leadership, innovation, and design. Management and leadership help individuals and organizations understand their environments and make appropriate decisions. Innovation and design assist in understanding client needs and creating products and services that meet those needs (Mabhanda, 2022).

Table 1. Cynefin Framework Table

Complexity	Characteristic	Approach	Practice
Clear/Simple	The connections between cause and effect are obvious, can be predicted and repeated, and typically follow a linear pattern.	Sense-Categorise-Respond	Implement best practice
Complicated	There exists rational connection between cause and effect, yet it is not immediately clear and required expert analysis to understand.	Sense-Analyse-Respond	create panel of experts
Complex	Only apparent after the fact, with outcomes that are unpredictable.	Probe-Sense-Respond	experiments that allow patterns to emerge
Chaotic	No relation between cause and effect	Act -Sense - Respond	explore new methodologies
Disorder	The context to which a situation should be allocated is unclear.		

Source: Russo and Camanho (2015)

2.1.2. Stakeholder Analysis
Stakeholder analysis involves identifying relevant stakeholders and assessing their interests, capabilities, and relationships with specific projects or organizations (Que, Wang, Awuah-Offei, Yang, & Jiang, 2019). Effective relationship management and informed decision-making require a

comprehensive understanding of stakeholder perspectives and expectations. Stakeholder analysis aims to identify and understand the interests, strengths, limitations, and positions of stakeholders (Sulaiman, Fitralisma, Fata, & Nawawi, 2024).

Freeman (1984) is the key principle of stakeholder analysis.
Stakeholders: Individuals, groups, or organizations with interests or who may be affected by a project or organization. This includes owners, employees, consumers, suppliers, governments, local communities, and NGOs.
Interest: Items significant to stakeholders that can influence or be influenced by the project or organization, such as financial gain, reputation, and environmental sustainability.
Power: The capacity of stakeholders to influence decisions or actions, derived from factors such as political support, resources, specialized knowledge, and asset ownership.
Dependency: The extent to which an organization depends on a specific stakeholder, or vice versa, affects relationship management.
Analysis and Approach: Various methods were used, including the analysis of communication channels using power-interest matrices, interest-based and impact-based approaches, interest-power analysis, and social network analysis.

2.1.3. Value-Focused Thinking (VFT)
Value-Focused Thinking (VFT) is a systematic approach used to guide complex decision-making by prioritizing desired or anticipated values (Keeney, 1996). Value-focused thinking directs critical resources toward making better judgments by combining thoughtful analysis with a systematic approach that prioritizes the values. It enhances decision-making by generating superior alternatives and recognizing better decision-making scenarios. It is viewed as an opportunity to make choices rather than solve problems.

Figure 4. Central Role of Thinking about Values
Source: Keeney (1996)

Approaching decisions with a value-based attitude helps align decisions with stakeholder interests, leading to higher satisfaction and fulfilment. The key steps in value-focused thinking are as follows:
Identify stakeholders and values: Determine relevant stakeholders and their significant values.
Establish a hierarchy of values: Create a hierarchy to represent the importance and relationships among the values.
Develop a Value Model: Illustrate the structure and connections among the values.
Generate Alternatives: Find and develop potential options to achieve objectives by considering the value model.
Assess Consequences: Evaluate the impact of each alternative on values.
Conduct sensitivity analysis: Analyze how different options respond to variations in key aspects.
Decision-making: Selection based on consequence assessments and sensitivity analyses.

2.1.4. Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a methodology for making judgments in complex, unstructured, multi-attribute situations by ranking options based on specific criteria. Developed by T. L. Saaty (1990), AHP decomposes complex multi-criteria problems into a hierarchical structure, facilitating decision-making in areas like planning, resource allocation, and strategy selection. The key principles of the AHP are as follows:

Decomposition: Breakdown of problems into hierarchical components for detailed analysis.

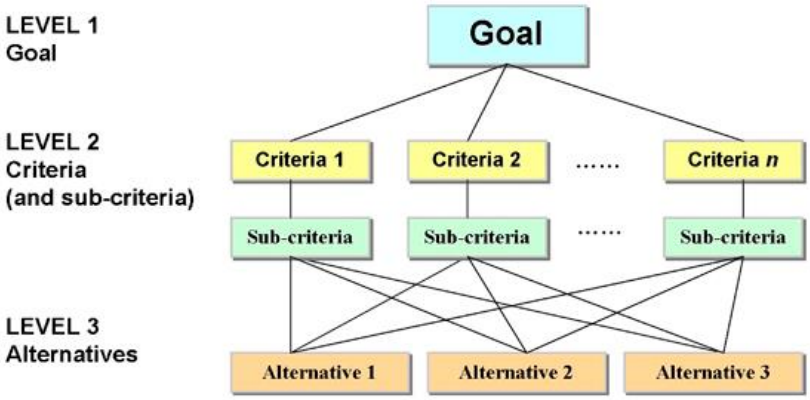

Figure 5. Hierarchy of Goal, Criteria, and Alternatives
Source: T. L. Saaty (1990)

Comparative Judgment: Evaluate and compare elements using a pairwise comparison matrix.

Table 2. Table of Pairwise numerical rating

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one activity over another
5	Essential importance	Experience and judgement strongly favour one activity over another
7	Very strong importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	When compromise is needed between two

Source: R. W. Saaty (1987)

Synthesizing Procedure: Combine the findings to identify the best alternative using priority vectors and consistency measurements.

Consistency Measurement: Consistency ratios were calculated to ensure reliable, pairwise comparisons.

Table 3. Table of Random Consistency Index

N	1	2	3	4	5	6	7	8	9	10
Random consistency index (R.I.)	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Development of Priority Ranking: Determine the priority of alternatives based on the priority vector for each criterion matrix.

2.2. Conceptual Framework

This study aims to develop a comprehensive framework for decision-making in PT KLM using various analytical tools and methodologies. The framework integrates multiple methodological and conceptual approaches, including:

Problem Tree Analysis: An analytical technique used to visualize and understand interconnected problems.

Divergent–convergent Thinking Model: Involves generating a wide range of ideas and refining them.

Stakeholder Analysis: Identifies and assesses those affected by or involved in the project.

Value-Focused Thinking (VFT) assists in complex decision-making by prioritizing values.

Analytical Hierarchy Process (AHP): Organizes and systematically compares alternatives.

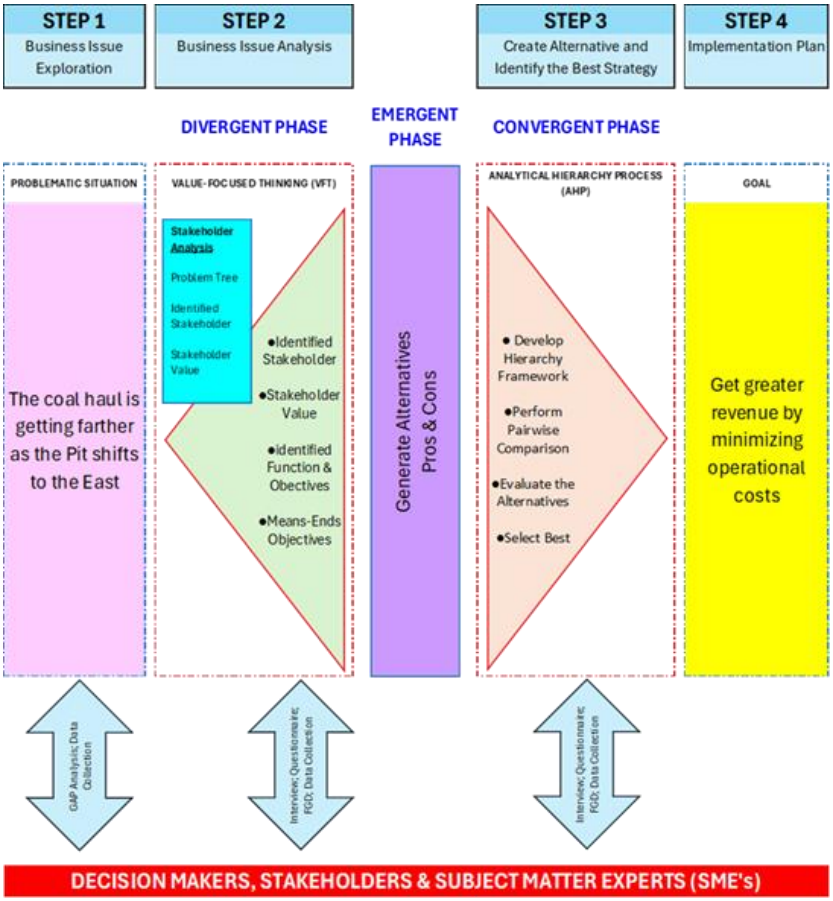

Figure 6. Conceptual Framework
Source: Author

2.3. Marginal Theoretical Contribution

The marginal theoretical contribution table summarizes previous research on decision-making processes using AHP instruments and evaluates the research's contribution to theory development, integration, and enhancement. This illustrates how this study adds value and advances the understanding of complex issue resolution.

The integration of the various theoretical concepts from this study is illustrated in Figure 7.

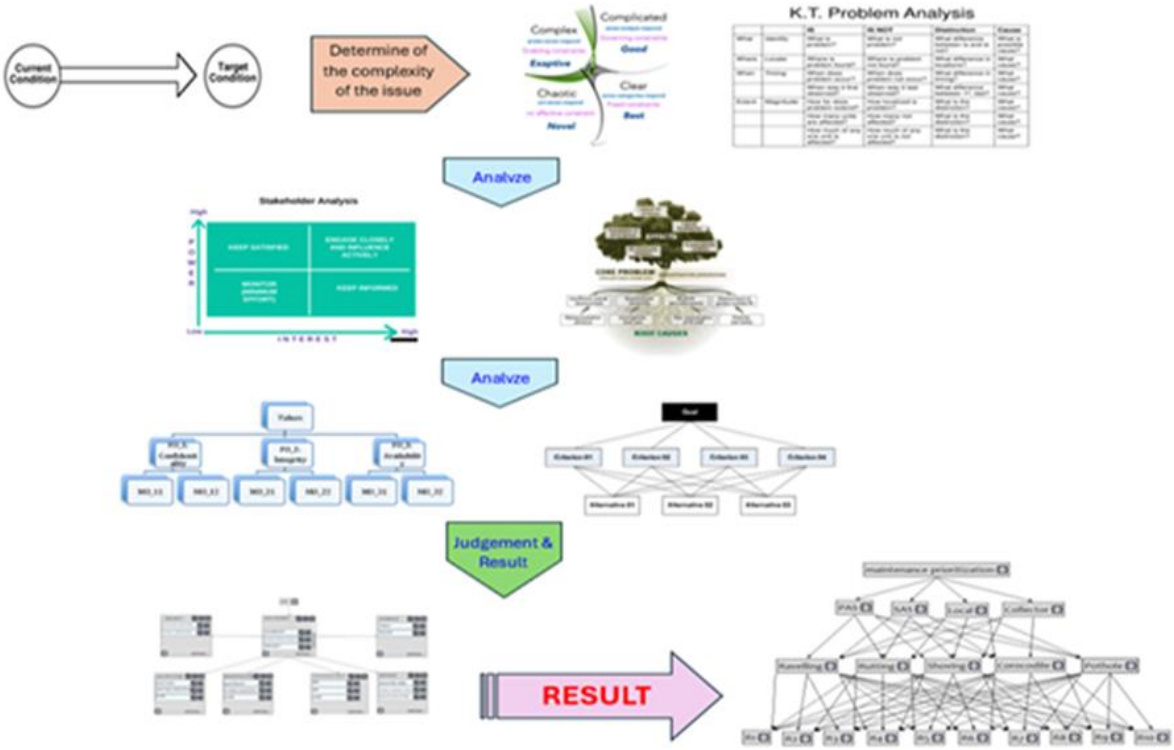

Figure 7. Multimethodological Integration Concept
Source: Author

3. Research methodology

3.1. Research Design

This study was designed to assist the top management of PT. KLM in making informed decisions regarding the South Pinang Coal Crushing Facility project. This study employs a combination of qualitative and quantitative methodologies, specifically the Analytic Hierarchy Process (AHP) approach, to evaluate and select the most suitable strategy for the project. The research design includes several critical stages, such as business issue exploration, problem identification, literature review, stakeholder analysis, alternative generation, and selection of the best alternative using AHP software, followed by recommendations and an implementation plan (Astriani & Siallagan, 2024).

Business Issue Exploration: A thorough examination of business issues to identify potential challenges and opportunities that may impact a company's performance.
Problem Identification: Utilization of problem tree analysis to break down the issue into its components and determine root causes, aiding in the identification of areas that require intervention.
Literature Review and Data Collection: An in-depth review of the existing literature related to the research topic and systematic data collection to address the research questions.
Stakeholder Analysis: Identification and analysis of stakeholders' power and interest levels using a scoring technique, leading to the categorization of stakeholders into quadrants based on their influence and interest.
Generate alternatives: Qualitative data-gathering methods, such as interviews with key stakeholders, are used to identify and analyze possible alternatives.
Select Best Alternatives: Application of the AHP method via Super Decisions software to determine the optimal strategy that aligns with the stakeholder expectations.
Recommendations and Implementation Plan: Development of recommendations based on the selected alternative, followed by a strategic implementation plan.

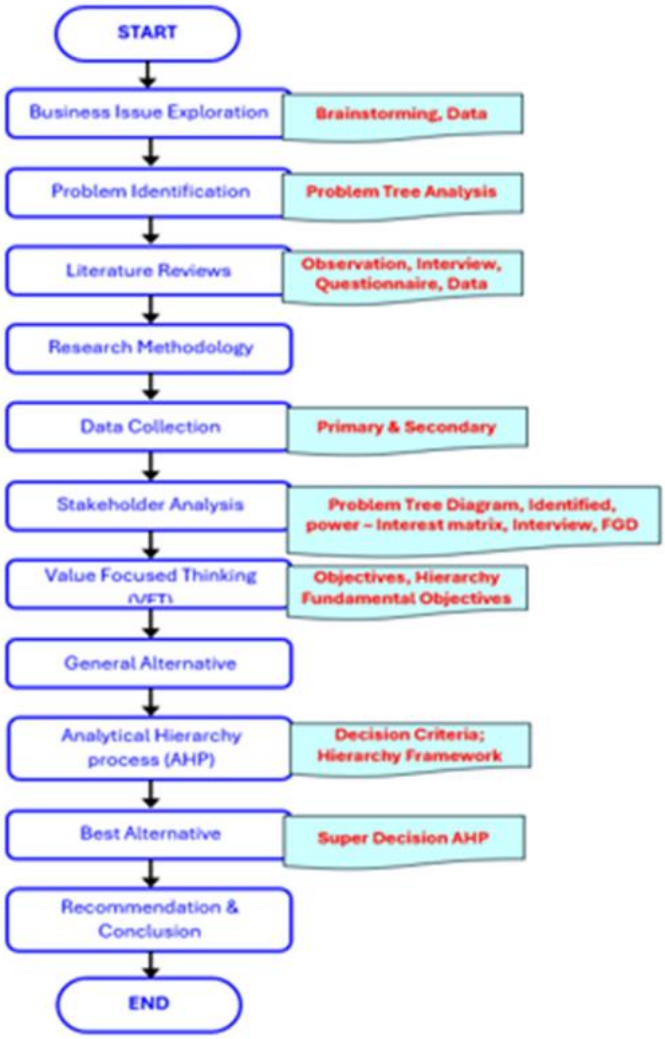

Figure 8. Research Design
Source: Author

3.2. Data Collection Method

This study used various data collection methods to ensure the acquisition of accurate and reliable information. The data collection process included the following steps.

Literature Analysis: Systematic examination of relevant literature, including books, scientific journals, laws, regulations, and internal company documents, such as the South Pinang Extension Development Plan.

Observation: Structured observation of coal-crushing plant operations in Region B to gather insights into the processes and challenges involved.

Semi-structured interviews were conducted with Subject Matter Experts (SMEs) from PT. KLM was selected based on their expertise, involvement in project planning, and knowledge of the South Pinang Extension #2.

Questionnaire: Distribution of structured questionnaires to key respondents from SMEs involved in the project using purposive and snowball sampling techniques to ensure representation.

Table 4. List of Subject Expert (SME)

No.	Subject Matter Expert	Division	Job Description
1.	SME 1	Mining Development	Integration with another related Project.
2	SME 2	Mining Development	Long Term Mine Planning;

3	SME 3	Coal Processing & Handling	Coal Processing Plant Operation
4	SME 4	Coal Processing & Handling	Coal handling Terminal Operation
5	SME 5	Coal Processing & Handling	Plant Engineering & Project Services
6	SME 6	Supply Chain	Contract

The collected data were categorized into primary data (gathered through observations, interviews, and questionnaires) and secondary data (derived from the literature review and company documents).

3.3. Data Analysis Method

The data analysis process in this study followed a systematic approach, combining qualitative and quantitative methods to provide a comprehensive understanding of the research problem.

Qualitative Data Analysis: Analysis of interview and observation data using content analysis techniques. This step includes identifying key behaviors, events, or processes related to the research focus and conducting a problem tree analysis to determine the root causes.

Quantitative Data Analysis: Analysis of numerical data collected through questionnaires using statistical methods. The quantitative analysis involves constructing pairwise comparison matrices and using AHP software to evaluate and rank alternatives.

Table 5. Pairwise Questionnaire of Criteria

Question:

Which one of the following **criteria** do you think is more preferable for new construction of new Coal Crushing Facilities at SPE #2 Project.

Criteria	Pairwise Numerical Rating																			Criteria
Cost	<--	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	-->	Risk
Cost	<--	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	-->	Flexibility
Cost	<--	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	-->	Control
Risk	<--	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	-->	Flexibility
Risk	<--	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	-->	Control
Flexibility	<--	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	-->	Control

Source: Author

Table 6. Pairwise Questionnaire of Criteria

Alternative	Pairwise Numerical Rating																			Alternative
Own by Self Financing	<--	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	-->	Own by Leasing
Own by Self Financing	<--	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	-->	Rental Scheme
Own by Leasing	<--	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	-->	Rental Scheme

Source: Author

The qualitative data inform the construction of the AHP hierarchy, whereas the quantitative data, processed using AHP software, help determine the most efficient strategy for the coal crushing plant project.

4. Result and discussion

This chapter presents the research findings, provides an in-depth analysis of the results, and discusses their implications of the findings. The objective is to critically evaluate the findings in light of the research question and existing theories, thereby contributing new insights to the field of coal crushing plant strategies and financing. This analysis is crucial for making informed decisions that align with the objectives and constraints of the PT. KLM.

4.1. Analysis

4.1.1. Business Issue Exploration

Pit Expansion Plan

The "Life of Mine" (LOM) concept is critical for determining the operational lifespan of PT. KLM mining operations. LOM influences long-term planning, investment decisions, asset management, and financial analyses such as NPV and IRR. Recently, the company's LOM studies have shown that almost all operational pits will be located further from the existing Coal Crushing Plant (CCP), requiring adjustments to coal hauling strategies. Figures 9 and 10 illustrate the existing and proposed pit locations and the corresponding hauling routes, respectively.

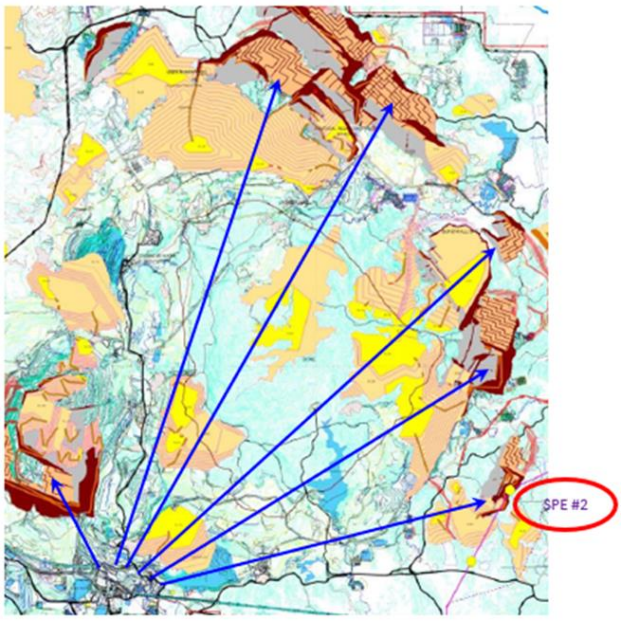

Figure 9. South Pinang Extension #2 Area
Source: Author

Coal Hauling Distance

The coal hauling distance from South Pinang Extension #2 (SPE #2) to the existing CCP is 18.52 km, whereas the distance to the newly proposed crushing facility is only 3.23 km. The operational cost implications of these distances are significant, as shown in the cost breakdown table table. A reduction in the hauling distance would result in considerable savings in hauling costs, road maintenance costs, and fuel consumption.

Figure 10. Existing CPP from South Pinang Extension #2 Area
Source: Author

Problem Tree Analysis

The problem tree analysis below shows the correlation between the causes and effects of the PT KLM Pit expansion plan in the Sout Pinang Extension #2 area.

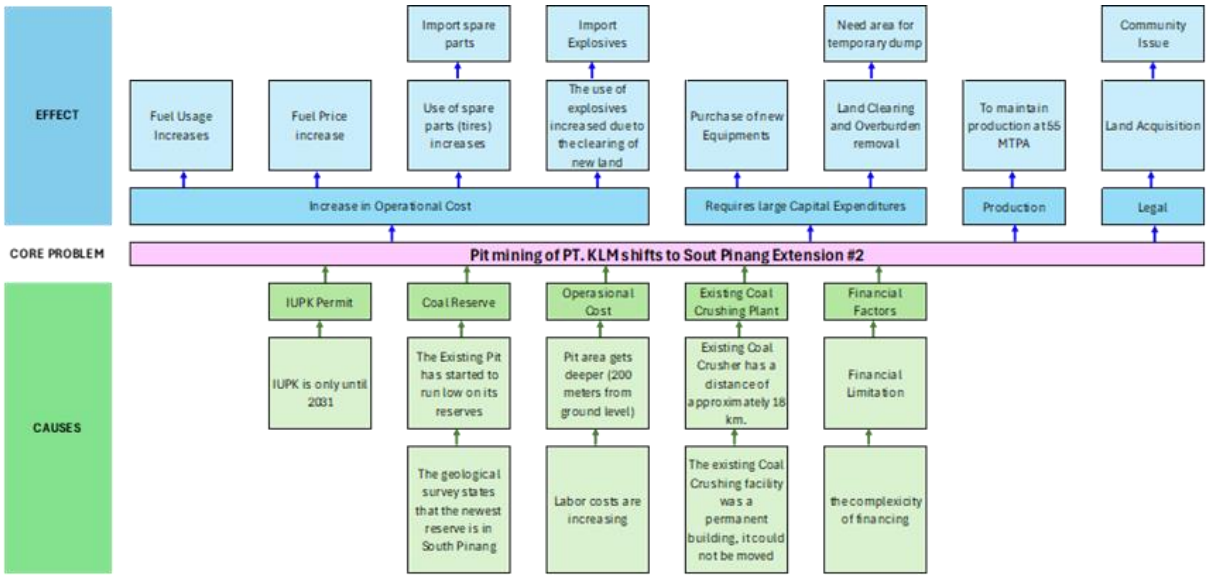

Figure 11. Problem Tree Analysis
Source: Author

4.1.2. Value-Focused Thinking (VFT)

The Value-Focused Thinking (VFT) approach was used to identify and prioritize the values that should guide the decision-making process. Following Françozo and Belderrain (2022) method, the VFT process involves determining key objectives, structuring them hierarchically, and linking them to the desired outcomes. The VFT analysis, illustrated in Figure IV.5, identified four primary objectives for the coal-crushing strategy:

1. Optimization of Coal Hauling Distance
2. Optimization of Coal Crushing Capacity
3. Minimization of Construction Schedule
4. Financial Aspect

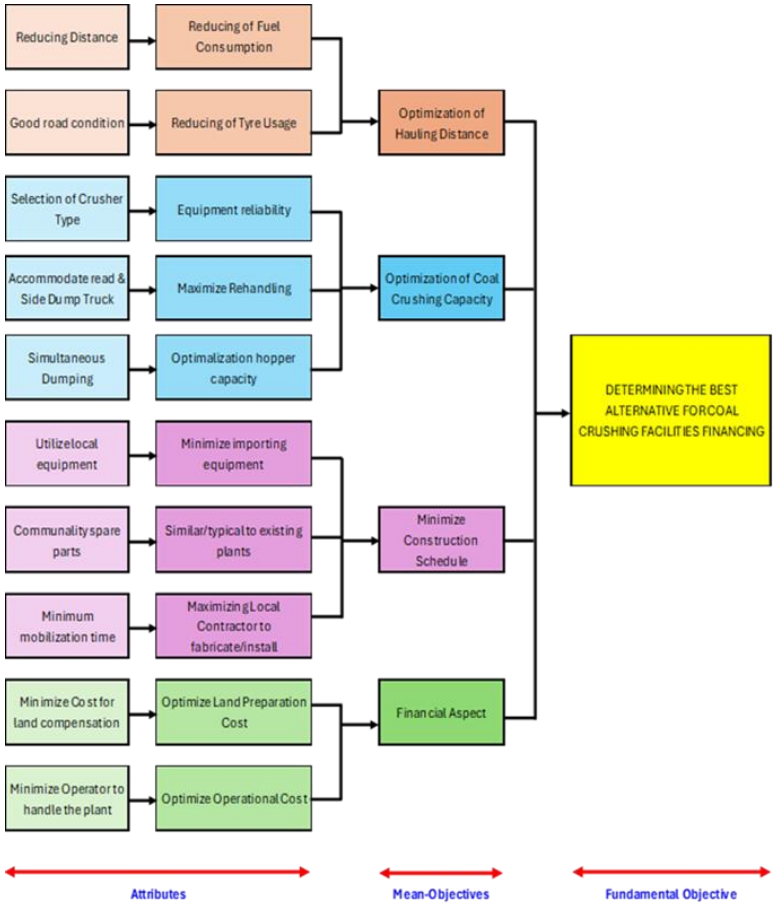

Figure 12. Means-ends Objective Network
Source: Author

4.2. Business Solutions

4.2.1 Analytical Hierarchy Process (AHP)

Objective and Respondent profiles.

The Analytic Hierarchy Process (AHP) was applied to select the most optimal financing strategy for the new coal-crushing facilities project. Three alternatives are identified: self-financing, leasing, and rentals. A group of six Subject Matter Experts (SMEs) from the PT. KLM participates in the AHP process by providing expert opinions via pairwise comparisons.

Modelling of AHP

The AHP model, illustrated in Figure 5, organizes the decision criteria and alternatives into a hierarchical structure. Pairwise comparisons of the criteria and alternatives were conducted using input from SMEs, and the results were synthesized using the Super Decision software. The synthesized results are presented in Figures 13 and 14, which show the priority ranking of the alternatives based on their weighted criteria.

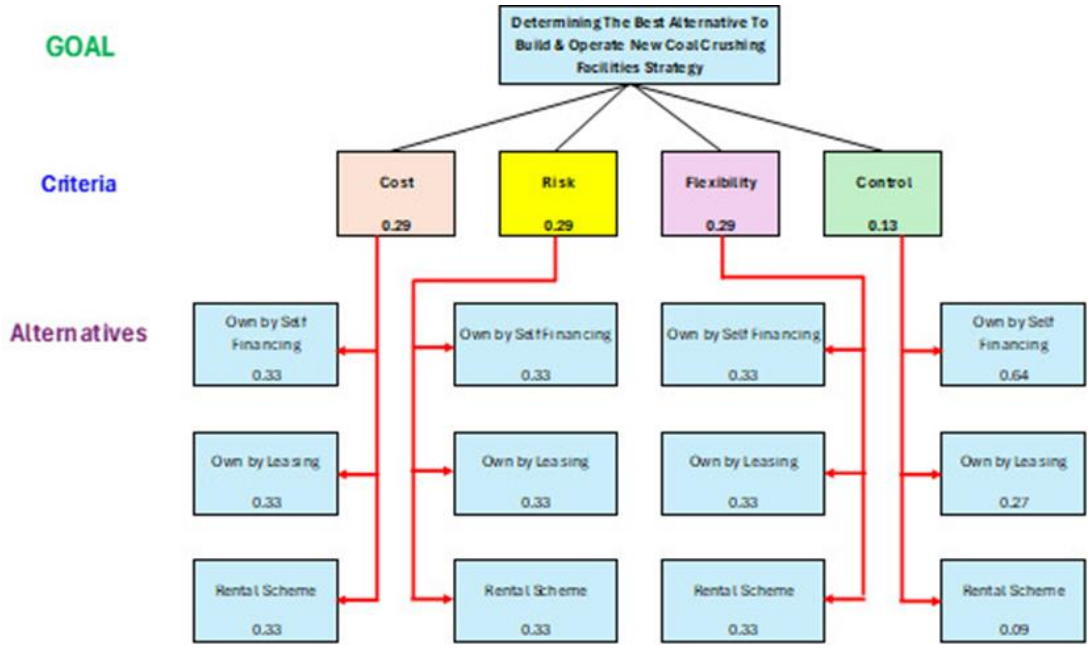

Figure 13. The structure of Hierarchy of AHP Model
Source: Author

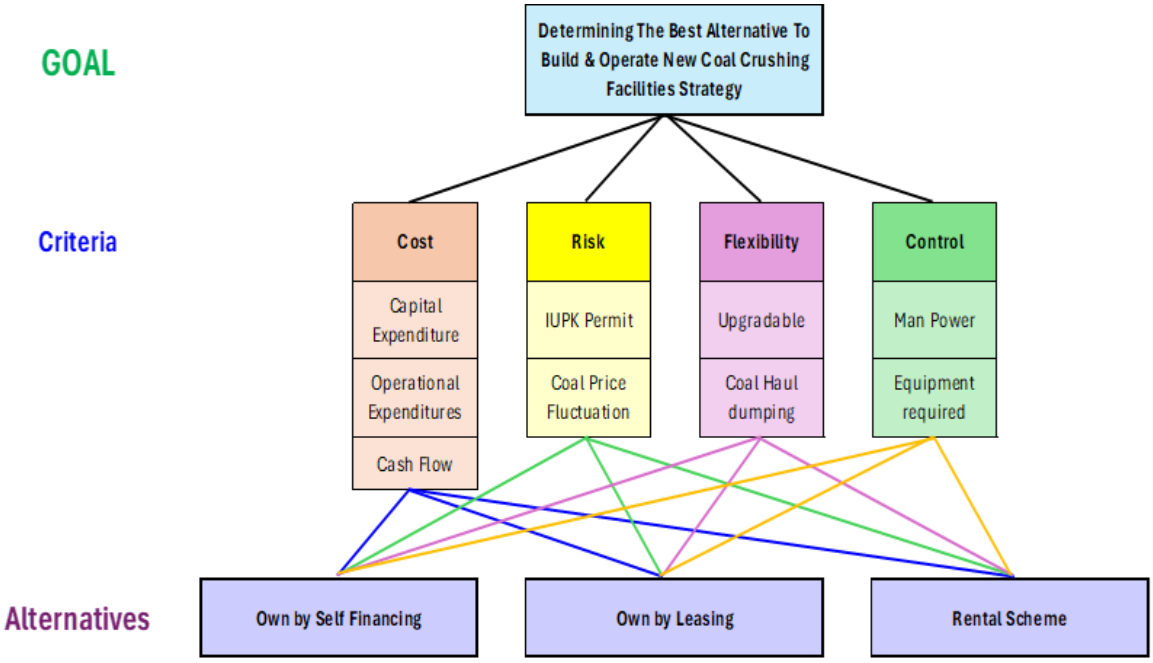

Figure 14. Weigh of Criteria and Alternatives
Source: Author

Results

The AHP analysis ranks the financing alternatives as follows.

1. Own by Self-Financing : 37.8%
2. Own by Leasing : 32.4%
3. Rental Scheme : 29.8%

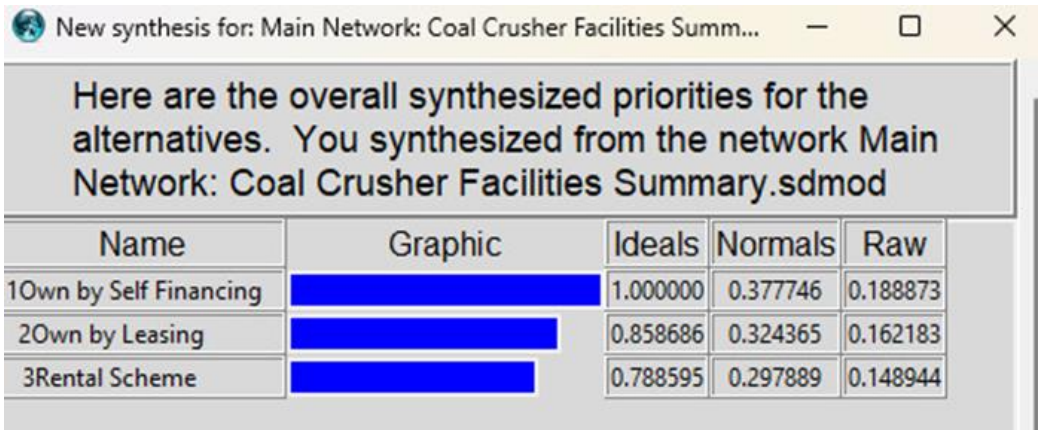

Figure 15. Result from Super Decision AHP Software for Synthesized Result of Alternatives
Source: Author

The consistency ratio, calculated using the Super Decision software, confirmed that the pairwise comparisons were consistent and reliable.

Table 7. Consistency Ratio for All Pairwise Comparison

Item	Consistency Ratio (CR) by *Super Decision*	Parameter	Result
Pairwise Comparison Level - 1	0.000	CR < 0.1	Acceptable
Pairwise Comparison Level - 2			
● Cost	0.000	CR < 0.1	Acceptable
● Risk	0.000	CR < 0.1	Acceptable
● Flexibility	0.000	CR < 0.1	Acceptable
● Ownership & Control	0.052	CR < 0.1	Acceptable

Source: Author

4.3. Implementation Plan & Justification

What

The project involves constructing a new Coal Crushing Plant near the SPE #2 area, designed for a capacity of 3 MTPA, with the potential for expansion. The detailed specifications of the crushing facilities and equipment are presented in Figures 16 and 17 and Table 8.

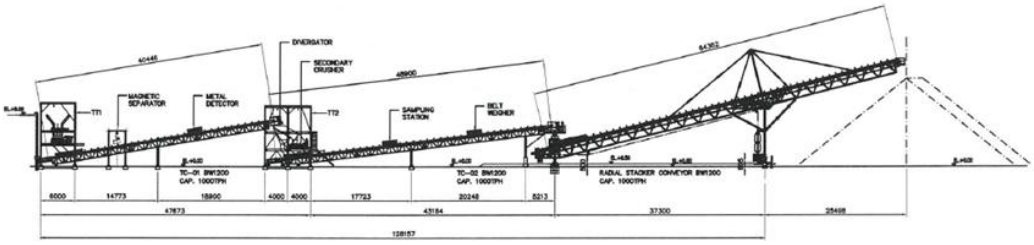

Figure 16. Coal Crusher Conveyor System at SPE #2
Source: Author

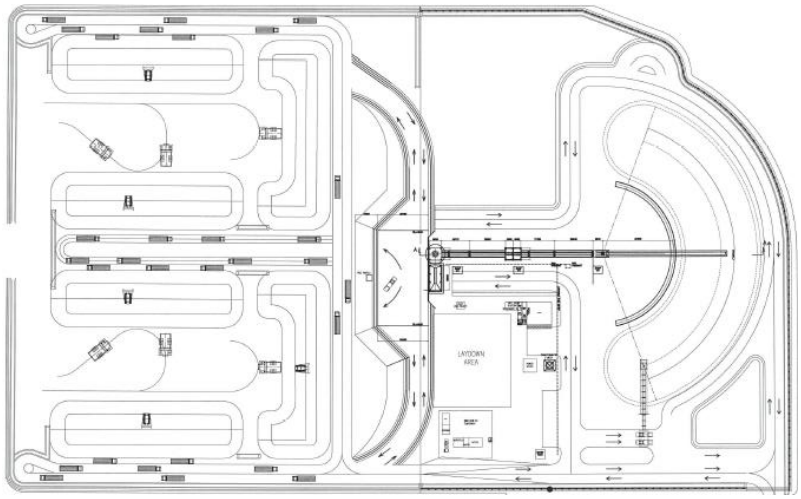

Figure 17. Layout Plan of Coal Crusher Conveyor System at SPE #2
Source: Author

Table 8. Equipment List of Coal Crusher Conveyor Systems at SPE #2

No.	Equipment	Remarks
1.	Retaining Wall	Accommodate for 3 rear dump truck simultaneously
2.	Dump Hopper Station	Accommodate for 3 rear dump truck simultaneously
3.	Coal Breaker (up to 200 mm)	1,000 TPH; crushed sizes up to 200 mm
4.	Conveyor	1,000 TPH
5.	Magnet Separator	Electromagnetic
6.	Metal Detector	Eddy Current – Type
7.	Sizer Station	1,000 TPH; crushed size -50 mm
8.	Belt Scale	Accuracy 99.5%
9.	Sampling system	Double Stage; crushed size -11 mm.
10.	Radial Stacker	1,000 TPH
11.	Stockpile	Minimum capacity 50,000 m3
12.	MCC Building	As per the Company's Standard Specification
13.	Control System	As per the Company's Standard Specification
14.	Conveyors Field Protection Devices	As per the Company's Standard Specification
15.	Earthing and Lightning Protection	As per the Company's Standard Specification
16.	Lighting	As per the Company's Standard Specification
17.	Water Services	As per the Company's Standard Specification

Source: Author

Why

The need for a new Coal Crushing Plant is driven by financial considerations, the desire to reduce operational costs, and the expiration of the IUPK permit in 2031. An economic evaluation, summarized in Table 9, indicates that the project is financially feasible, with a positive NPV, an IRR above the discount rate, and a payback period prior to 2031.

Table 9. Economic Evaluation of Coal Crusher SPE #2

Scenario	1a Rental Crushing Plant + Hauling for SPE #2 Only, Rental crusher $1,5/Ton,	1b Rental Crushing Plant + Hauling for SPE #2 Only, Rental $0.85/Ton	1c Owning Crushing Plant + Hauling for SPE #2 Only,
NPV	$ 4.81 Million	$ 9.51 Million	$ 10.48 Million
Average PI	1.8	2.58	2.35
Payback Period	4.6 years (2028)	3.68 years (2027)	3.91 years (2027)
IRR	34.29 %	50.20 %	45.6 %

Source: Author

Who

The project will be managed by a team dedicated to the PT. KLM includes members from various departments, such as operations, maintenance, engineering, and supply chains. The organizational structure is illustrated in Figure 18.

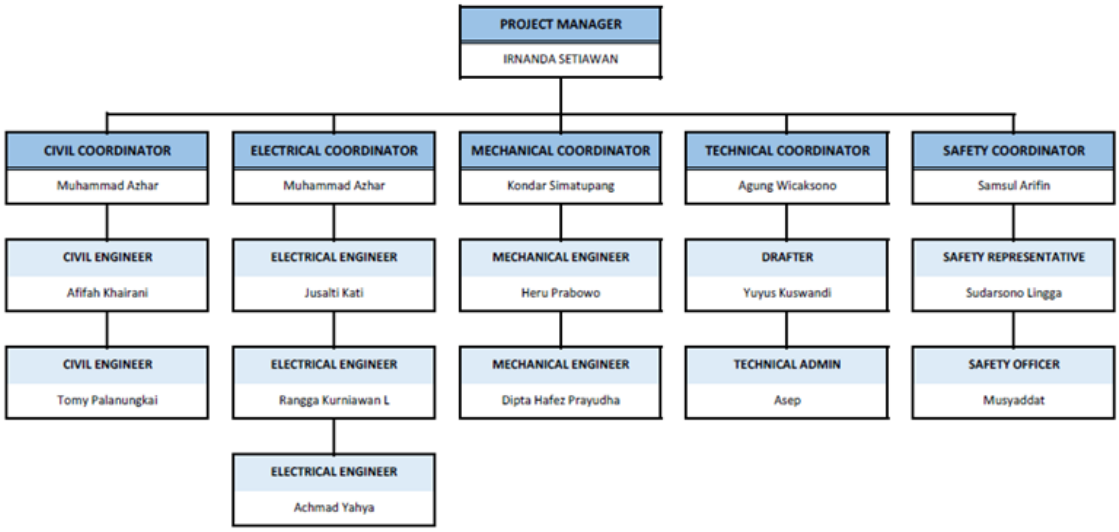

Figure 18. Organization Structure of SPE #2 Project Team
Source: Author

Where

A new facility will be constructed near the SPE #2 area, thereby reducing the hauling distance and operational costs. (Figure 19)

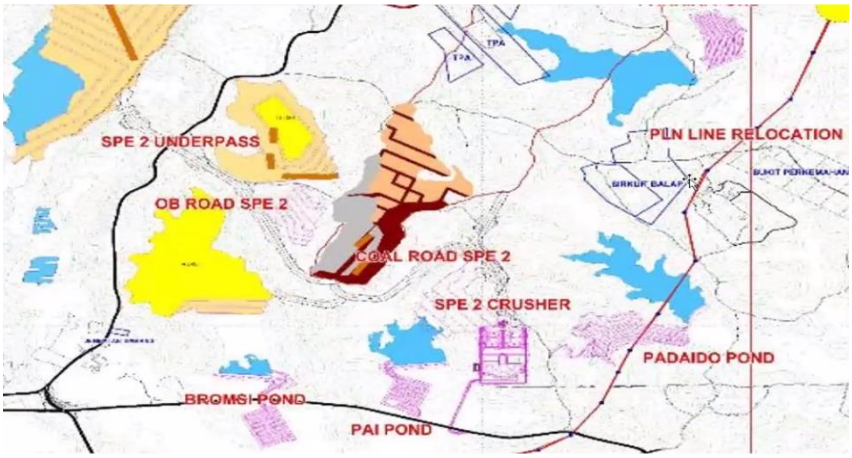

Figure 19. Location of new Coal Crusher next to SPE #2 Pit
Source: Author

When
The project is scheduled for completion and operation by early 2025, in alignment with the company's long-term mine planning.

Table 10. Economic Evaluation of Coal Crusher SPE #2

No	WBS	2023							2024												2025
		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-Dec
1.	Conceptual Study	●	●	●																	
2.	Tenders				●	●	●	●													
3.	Earthwork Crusher								●	●	●	●	●	●	●						
4.	Supply and Installation										●	●	●	●	●	●	●	●	●	●	
5.	Electrical Power Line										●	●	●	●	●	●	●				
6.	Network Infrastructure												●	●	●	●	●	●	●		
7.	Other Works																●	●	●	●	
8.	Operational Readiness																●	●	●	●	●

Source: Author

How
The implementation follows the Project Management Body of Knowledge (PMBOK) framework, ensuring systematic planning, execution, and monitoring. The implementation schedule is detailed in Table 10, covering all phases from the conceptual study to operational readiness.

5. Conclusions

This section provides a concise summary and practical guidance based on the primary findings. These conclusions stem from the core research questions that guided this study's design. To achieve the objectives of this study, a comprehensive approach was adopted, involving a review of the existing literature, collection of primary and secondary data, qualitative and quantitative analysis, and development of an optimal strategy. This multifaceted approach enabled the formulation of more holistic conclusions and actionable recommendations.

5.1. Conclusions

Through rigorous analysis, this study provides a deep understanding of the optimal selection of alternatives to maximize project completion time for the South Pinang Coal Crushing Facilities Project, considering stakeholder expectations. The key findings related to the research questions are summarized below.

1. Root Cause of the Need for a New Coal Crushing Plant in South Pinang Extension #2 Area
   The shift in the mining area towards South Pinang has led to an increase in operational costs. Specifically, the fuel consumption per ton of coal transported has increased, and the cost of tires, which are significant consumables, has escalated. Given that PT. KLM imports tires, and the fluctuating exchange rate of the rupiah against the dollar further exacerbates these costs.
2. Alternative solutions for the construction strategy of the new coal-crushing plant
   The analysis, using Stakeholder Analysis and Value-Focused Thinking (VFT), identified three viable alternatives:
   a. Alternative 1: Construction and operation of new coal-crushing facilities financed by PT. KLM using its internal funds.
   b. Alternative 2: Construction and operation of facilities financed by the PT. KLM through loans.
   c. Alternative 3: Construction and operation of facilities financed by a third party or contractor under a rental scheme.
3. Criteria for Evaluating the Alternative Solutions
   This study identified four key criteria for evaluating alternatives:
   a. Cost: This includes all expenses from the initial land preparation and construction to ongoing operation and maintenance costs.
   b. Risk: Evaluation of various risks, including financial, operational, and sustainability-related risks.
   c. Flexibility: The degree to which each alternative offers flexibility in terms of capital use, operations, and payment schedules.
   d. Control: level of control; PT. KLM retained the operation of its facility.
4. The most Effective Solution is as follows:
   The AHP analysis conducted in Chapter 4 indicates that self-financing is the most efficient approach, offering the highest potential benefits based on economic evaluation. However, if PT. KLM faces financial constraints; particularly, with the existing IUPK only assured until 2031, the rental scheme presents a viable alternative for KLM.

5.2. Recommendations

Based on the findings of this study, the following recommendations are proposed.

1. Proposal and Construction of a New Crushing Facility
   PT. KLM is advised to proceed with the construction of new Coal Crushing Facilities near the expansion pit close to the Coal Terminal. This location minimizes operational costs and improves the efficiency.
2. Securing Additional Capital.
   Given the significant capital required to construct a new facility, PT. KLM should consider securing additional funding from its holding company, recognizing the substantial gains that the new facility will generate.
3. Considering a Rental Scheme if Capital is Limited,
   If PT. KLM's capital is constrained, and considering that the current IUPK is only valid until 2031, the company should explore entering into a cooperation contract under a rental scheme with a third party or contractor for constructing and operating the facilities. This approach would mitigate the financial burden while still achieving operational objectives.

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