

Strategic Decision Analysis in Disposal Selection to Manage Production Continuity at Pit KGB PT BIB

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ABSTRACT

PT BIB, one of Indonesia's largest coal companies, aims to increase its production capacity annually, with a coal production target of 46.8 million tons approved by the Ministry of Energy and Mineral Resources (ESDM). Achieving this target has become increasingly challenging due to operational delays and environmental constraints, particularly the limited disposal capacity at the KGB Pit. This research focuses on identifying the best decision-making strategies to optimize mining operations, specifically addressing the disposal capacity issues caused by poor materials, landslides, and spatial limitations for disposal locations. The Kepner-Tregoe and Fishbone (Ishikawa) Diagram methods were employed to identify the root causes of these limitations systematically. Three alternative solutions emerged from expert discussions: maintaining the fleet, relocating the fleet, and improving the sequence of operations. The SMART method was applied to determine the best course of action, evaluating each alternative against criteria such as production volume, haulage distance, stripping ratio, preparation time, safety, and environmental impact. The findings provide a clear path forward for optimizing operational efficiency at PT BIB, ensuring that production targets can be met sustainably and effectively.

Keywords: Coal Production; Disposal Management; Fishbone Diagram; Kepner-Tregoe; SMART Method; Decision Making.

INTRODUCTION

Indonesia's economic growth is inseparable from the importance of the availability and distribution of domestic energy. In 2023, coal remained the most significant contributor at 39.69% in the mix of primary energy consumption, besides oil, natural gas, and other renewable energies (Ministry of Energy and Mineral Resources, 2023). Since the Paris Agreement was signed in 2015, Indonesia has remained focused on increasing domestic coal production, with a projection of 922.14 million tons in 2024, an increase of 19.6% from the coal production achievement in 2023 (Figure 1).

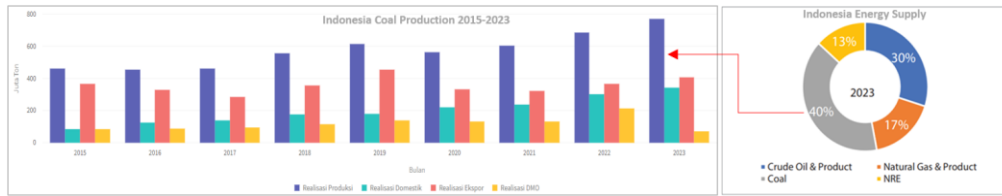


Figure 1. Overview Indonesia Primary Energy Supply & Coal Production 2023

In 2024, through the approval of the RKAB that has been obtained, PT BIB has set ambitious production targets for its mining operations, particularly from the KG block, one of the most significant blocks in the company's concession area. Pit KGB, as one of the pits located in the KG block area, began its mining operations in 2011 and is projected to continue operating until 2036, in accordance with the mine's determined life of mine (LOM) (Hadi et al., 2021; Sudjiman & Sudjiman, 2018; Winahyu et al., 2013). Pit KGB plays an important role in achieving the company's production goals with a target of overburden stripping of 47.68 million BCM and a coal production target of 10.95 million tons (Figure 2).

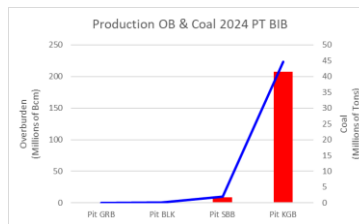


Figure 2. Production Target Overburden & Coal PT. BIB 2024

However, as of July 2024, the production achievement of Pit KGB year to date, July 2024, has not met expectations, with overburden production reaching only 24.37 million BCM or 92.7% of the plan, and coal production reaching only 5.46 million tons, or 91.6% of the plan. It is recorded that there has been a loss of 344 work hours or 11.83% of the total planned work hours. The most significant contribution to the loss of working hours is the preparation and maintenance of disposal, with a loss of 128 hours or 37.21% of the total working hours lost. In addition, the landslide conditions in the KGB disposal area worsen the situation, making the availability of disposal capacity increasingly difficult when it is necessary to repair the current disposal conditions (Figure 3).

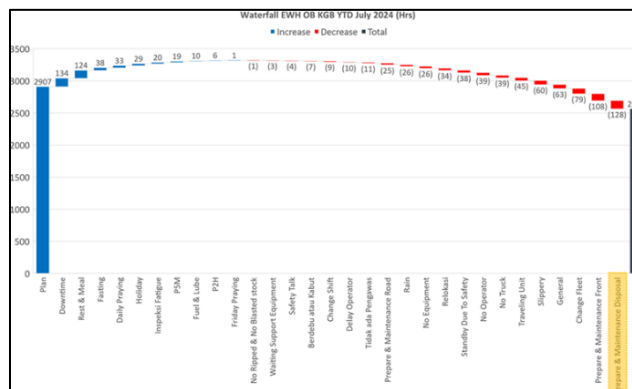


Figure 3. Production Target Overburden & Coal PT. BIB 2024

Achieving the 2024 production target is very important for PT BIB, as the company is preparing and submitting a revision of the Feasibility Study (FS) and Environmental Impact Analysis (AMDAL) to increase the coal production target to 54 million tons by 2025. To grant approval to the company to increase its production target, the Ministry of Energy and Mineral Resources (ESDM) will consider the success of achieving the 2024 production target as one of the key indicators required. Therefore, immediate action is necessary to resolve the current issues immediately as they will impact the company's business sustainability in the future.

Every company in the coal sector faces significant challenges to remain competitive in a dynamic and often unpredictable environment. Therefore, the development of strategies becomes very important not only to maintain competitiveness but also to effectively address the increasingly pressing continuity challenges (Nenavani et al., 2018). This strategy not only ensures the survival of the company but also encourages growth and adaptation in the face of ongoing changes (Djunaedi et al., 2024; Effendi, 2024; Gallego-García et al., 2022; Surya et al., 2021). In addition, good collaboration among stakeholders is needed in implementing the strategy to support the company's production continuity and operational success in the long term (Franciosi et al., 2021). In achieving the company's goals, it is important first to identify the critical issues that hinder progress so that a proper analysis can be conducted by considering the necessary criteria. Thus, each stakeholder can determine the best alternative to solve the problems faced by the company (Frejowski et al., 2021).

Previous research has examined the importance of strategic decision-making in mining operations, particularly in overcoming production delays and optimizing resource management. For example, Nenavani & Jain (2018) highlighted the need for strategic planning in the mining industry to navigate challenges and ensure competitiveness, emphasizing the role of decision-making frameworks in addressing operational delays. Similarly, Franciosi et al. (2021) explored the significance of collaboration among stakeholders to implement effective strategies for production continuity in the mining sector. While these studies have contributed valuable insights into decision-making strategies, they did not specifically address the application of the Kepner-Tregoe and Fishbone methods to optimize mining operations in the context of coal disposal capacity issues (Kharat et al., 2019; Kibira et al., 2016; Korucu & Erdagi, 2012; Shahba et al., 2017). The novelty of this study lies in the use of these methods to systematically identify and evaluate alternatives for managing disposal capacity limitations at PT BIB, focusing on criteria such as production volume, haulage distance, and environmental impact, which has not been explored in depth in previous research (Jiskani et al., 2019).

The main objective of this research is to determine the best decision-making strategies for optimizing mining operations at PT BIB, with a specific focus on addressing disposal capacity limitations at the KGB Pit (Franciosi et al., 2021; Hawley, 2017; Herdyanti et al., 2022). The research seeks to identify and evaluate alternatives to enhance operational efficiency and meet production targets. This study's expected benefit is to provide PT BIB with actionable strategies that can help resolve current operational challenges, improve production performance, and support the company's sustainability and growth targets. Furthermore, the findings will contribute to the broader mining industry by providing insights into decision-making frameworks that can be applied to similar operational challenges.

RESEARCH METHOD

Research Design

In this research, the author will use both qualitative and quantitative approaches. The qualitative approach is conducted to obtain a broad overview of the business problems faced by PT BIB so that the stakeholders involved in preparing this research can determine which factors most influence the continuity of production in Pit KGB and what actions need to be taken to address these issues. Then, through a quantitative approach, the author will provide measurable data from each action choice given by each stakeholder so that it can correlate with the qualitative approach.

The research design is divided into two stages: data collection and data analysis. At the data collection stage, the types of data collection are divided into primary data, which consists of technical data and information obtained through interviews. Secondary data is a collection of previously existing data that has been reprocessed to obtain relevant information and data for further analysis. After all the data has been collected, the research enters the analysis stage, which includes grouping the existing problems using the Kepner-Tregoe method, then determining the root cause using a fishbone diagram to prioritize the problems that need to be resolved first. Then, the decision-making process to choose the best alternative is carried out using the SMART method by measuring the utility value of each available alternative against each criterion being considered.

In implementing the chosen alternative, an analysis of potential problems that may arise if the alternative is carried out is first conducted as a precautionary measure in case issues occur in the future. And finally, creating a step-by-step implementation plan to achieve the desired solution (Figure 4).

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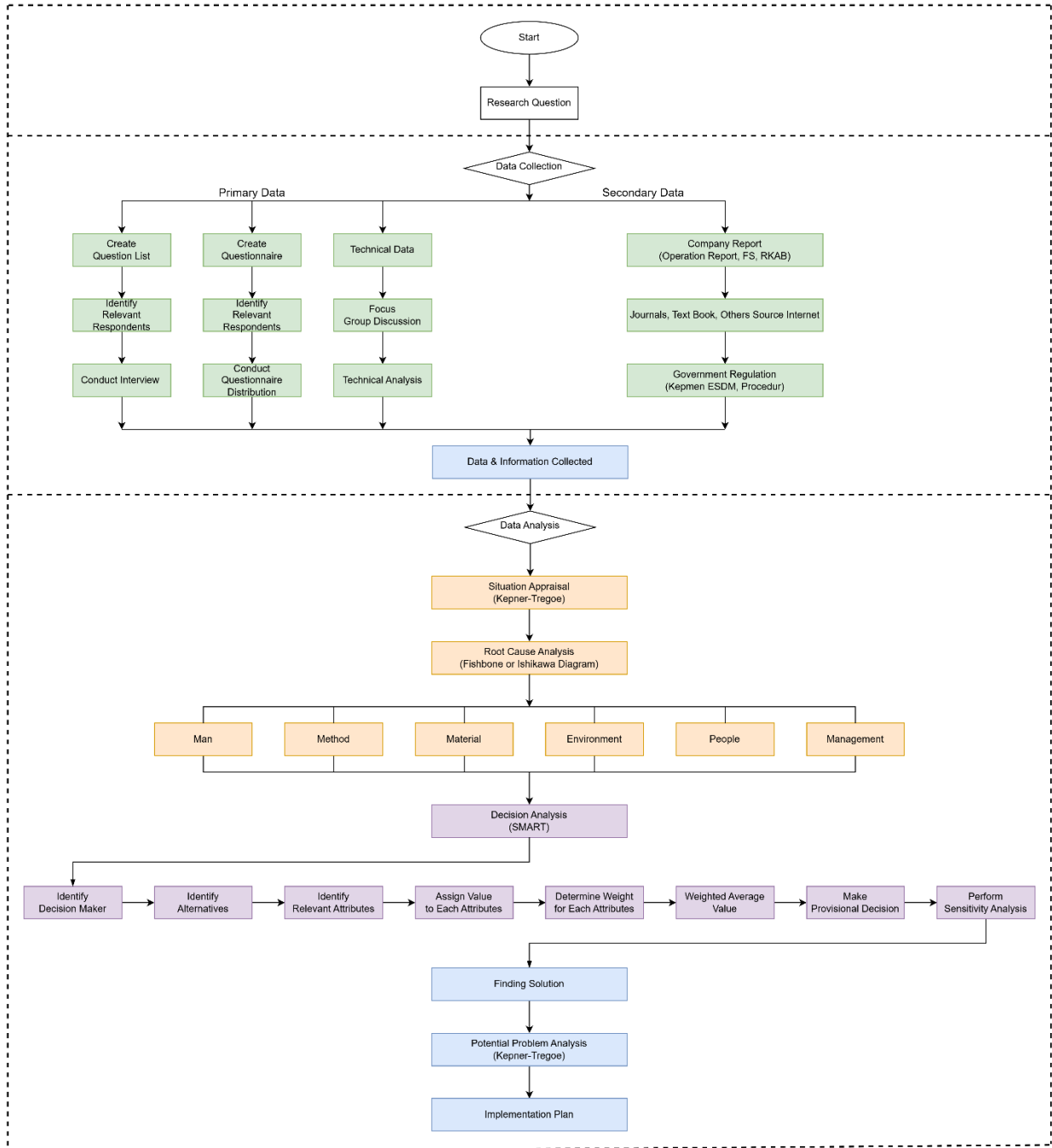


Figure 4. Kepner-Tregoe, Fishbone Diagram, & SMART Research Design (Author, 2024)

Situation Appraisal Phase

Situation Appraisal is used to recognize and identify problems or situations that require more attention. The analysis creates a priority order based on urgency, impact, and complexity considerations. Thus, the initial action can be determined as a quick step to handle the situation.

Root Cause Analysis Phase

After analyzing the problem faced by the company, the next stage is to analyze the root causes of the problems and the main obstacles to be resolved. Analysis using the Fishbone or Ishikawa Diagram has the advantage of being able to systematically identify possible causes of problems, able to break down any discrepancies in improving internal processes within the company, having a broader perspective by connecting processes from various departments so that it can be used in complex situations with various possible causes, and helping users visualize through a structured arrangement making it easier to understand. Applying the fishbone diagram to problem-solving methodology is a strategic step that can be adopted in various research and operational management practices (Yazdani et al., 2012).

Root cause analysis using the Fishbone or Ishikawa method is carried out through the stages of determining the main problem to be solved, creating an outline of the diagram in the form of a long horizontal line (referred to as the "fishbone") that depicts the causes of the problem and the 'fish head' at the end that represents the problem to be solved, identifying categories of causes consisting of Human-Machine-Material-Method-Environment-Management factors, identifying the root cause of the problem, and evaluating the root cause to generate alternative solutions.

Decision Analysis (SMART) Phase

After analyzing the main causes that contribute significantly to a problem, an analysis is carried out to determine what decisions must be taken and selected to overcome the causes of existing problems. In this research, the author uses the SMART method because the problem at hand needs to be solved by considering each desired interest, as well as each alternative produced, so that the decision chosen is considered the best choice in answering the problems that occur (Ozdemir & Kumral, 2019). The selection of alternatives is obtained from the assessment results using measurable parameters so that decision makers can directly compare each aspect that is the basis for consideration (Sakdiyah et al., 2022). Through a systematic and rational process, SMART produces measurable and accountable decisions and helps decision-makers understand the structure of the problem at hand thoroughly. The method is sensitive to the critical factors of a problem and supports analytical and data-driven decision-making even if they do not all reflect the full complexity of reality (Taherdoost & Mohebi, 2024).

Identification of decision makers

In the implementation of its corporate activities, PT BIB has established a carefully crafted organizational framework to facilitate the execution of responsibilities and efficient reporting mechanisms between the central administration and operational units in the field. The organizational structure of PT BIB is characterized by a clear separation of functions among divisions and departments, ensuring comprehensive support for mining operations. The organizational structure is an important phase in understanding the issues that arise within the context of an organization or project, including mining activities. In the case of mining operational activities, there are several key stakeholders involved, each with different perspectives and interests regarding the issues that arise, including the Short-Term Planning Department, Pit Operation Department, Strategic Long-Term Planning & Optimization Department, Health-Safety-Environment Department, Geotechnical Department, and Finance Department. Every decision and interest must be integrated to provide an assessment that becomes a mutual

agreement. Then, the chosen agreement needs someone to decide whether to implement it. Therefore, it is necessary to determine a decision-maker who is an individual or party with the authority and responsibility to make decisions related to the choices to achieve a specific goal.

Identify Alternatives

Each alternative, developed to address the ongoing issues, is summarized and processed based on the results of FGD with relevant stakeholders. To determine the appropriate sources, the author obtained candidates based on the organizational structure implemented by PT BIB and their relevance to the emerging issues, ensuring that the information produced is aligned with the competencies and experiences they have acquired during their careers at the company.

After identifying the available alternatives, to understand the details of each alternative, a simulation is used with the help of Minescape software. Before conducting the simulation, the author collected data in the form of actual mining and disposal situation data (DXF format) from the Survey Team, Forest Area Utilization Permit (IPPKH) boundary data (DXF format), as well as drone photos or satellite imagery to assist the author in conducting technical analysis. Then, each alternative design scenario, considered based on discussions with experts, was created and simulated to obtain measurable parameters such as dump capacity in bank cubic meters (BCM), overburden volume in BCM, coal volume in tons, and transport distance in meters.

Identify Relevant Attributes

After a number of alternatives are determined based on the results of discussions with the parties and Minescape software simulations, the next stage is to identify and determine the relevant attributes or criteria to be used to determine the level of importance of each attribute to each alternative. The various attributes used by the author were obtained from the literature study results and discussed during the interview. The attributes are then divided into three categories: cost criteria, Technical criteria, and Compliance criteria.

Technical factors are all related to the use of resources in a production process. Inappropriate selection of disposal placement criteria can hinder smooth operations, increase operating costs and even pose safety risks. Therefore, technical factors must be considered to ensure the selection process of mining operations is efficient and sustainable (Tubis et al., 2020).

Economic factors are all costs, benefits, values, and resources that affect economic decision-making at the individual, organizational, and government levels. In determining the optimal disposal site, economic factors are a significant consideration that determines the project's overall feasibility. The economic success of a disposal site selection plan is strongly influenced by a number of conditions, including disposal area preparation costs, operational costs, and reclamation costs after the disposal has been finalized (Shariati et al., 2014).

Compliance factor in mining is a system that emphasizes health, safety, and environmental protection in the mining workplace. The goal is to prevent occupational accidents, diseases, and environmental pollution and to increase productivity. According to KEPMEN 1827 K/30/MEM/2018, every IUP (Mining Business License) holder is obliged to apply the compliances of good mining techniques (Good Mining Practice), which includes the management of occupational safety and health (K3), operational safety, and management and monitoring of the mining environment in a planned, measurable and sustainable manner.

Assign a Value to Each Attribute

After each criterion is determined, the next step in considering the alternatives to be selected is to measure the level of importance of each existing criterion using a measurable scale. To determine the scale value of each attribute, the author uses the direct rating method so that the value of an attribute has clear boundaries and does not cause errors in interpreting the level of importance of each attribute.

Determine Weight for Each Attribute

After the scores for each criterion are determined, the next step is to determine the original weight. The original weight is obtained from the distribution of questionnaires to each respondent involved to understand the benefits of each alternative against the criteria. After that, the Normalized Weight value is determined using the following formula:

$$\text{Normalized Weight} = \frac{\text{Original Weight}}{\text{Total Original Weight}} \times 100\% \quad (1)$$

Weighted Average Value

After the normalized weight is obtained, the aggregate weight value is calculated by multiplying the normalized weight of each attribute by the Original Weight of Each Alternative.

Make Provisional Decision

The next step is to make a provisional decision by comparing the costs and benefits of each alternative. This will assist the author in choosing the most efficient frontier point.

Perform Sensitivity Analysis

After the utility value of each alternative and the preliminary decision are determined, the next step is to calculate the robustness level of each existing alternative if the importance level of each existing attribute changes. This stage is performed by repeatedly changing the utility value of each criterion to be considered unimportant (valued at 0) and comparing each change made.

Potential Problem Analysis Phase

After the decision-making analysis and alternative solutions were obtained, the author performed a potential problem analysis to identify any obstacles and issues that may arise while implementing the chosen alternative program. This is done as a mitigation step in the initial phase of the implementation plan so that if obstacles or problems occur, anticipatory actions can be taken to maintain the implementation of the alternative program and achieve the company's goals.

Implementation Plan Phase

The Implementation Plan is carried out by identifying the necessary aspects using the 5W + 1H concept, setting up work plan stages, and reporting the justification to management as a consideration for approval.

RESULT AND DISCUSSION

Identify Problem Situation

To achieve the planned targets in the KGB Pit, which include overburden removal production of 47.68 million BCM, coal production of 10.95 million tons, a stripping ratio of 4.3 BCM/Ton, an overburden transport distance to the disposal site of 3,166 m, and a reclamation

target of 126.8 Ha, several challenges need to be addressed that are of concern to stakeholders, namely Pit Readiness, Disposal Readiness, Water Management System, Infrastructure Readiness, and Government Compliance. Then, each concern was analyzed using the Kepner-Tregoe method, and the following results were obtained (Table 1).

Table 1. Situation Appraisal Analysis

No	Concern	Sub-Concern	Action Statement	Timing	Trend	Impact	Process Needed	Priority
1	Pit Readiness	1.1 Former Taiwasi river area	Pumping the former river area and constructing perimeter drainage or embankments to reduce the catchment area outside the 2024 mining plan boundary.	H	H	H	DA	1
		1.2 Sand Material or Soft Material	Mapping areas with good material content and applying blending methods to sand or soft materials according to the composition.	H	H	H	DA	2
2	Water Management System	2.1 Catchment Area	Construct a drainage line to reduce the catchment area entering the Pit.	H	H	H	DA	3
		2.2 Submerged Working Area	Set up additional pumps to reduce the rise of water elevation to the work area	H	H	H	DA	4
		2.3 Contamination from water runoff disposal	Construct the Settling Pond facility and submit the operational feasibility document to the Environmental Agency.	H	H	H	DA	5
3	Disposal Readiness	3.2 IPPKH permit for disposal extension	Hold a meeting and follow-up with the KLHK regarding the new IPPKH submission.	H	H	H	DA	6
		3.1 Disposal Capacity	Creating alternative disposal or mining sequences that accommodate disposal availability to support operational sustainability in Pit KGB.	H	H	H	PA	7
4	Government Compliance	4.2 Mine Accident	Conducting a technical study to improve control and monitoring of high-risk activity	M	H	H	PPA	8
		4.1 Reclamation Compliance	Implementing soil-less planting methods in the final disposal area that lacks topsoil sources	M	M	H	PPA	9
5	Infrastructure Readiness	5.1 Availability of infrastructure areas	Propose and increase the number of vendors to accelerate the construction of the workshop facility in the CIA area.	M	M	H	PPA	10

The table above shows that the problem that requires a Problem Analysis (PA) process is the limited disposal capacity in Pit KGB, which can significantly impact production continuity.

Identify Root Cause

The limited capacity of KGB Disposal requires a root cause analysis process to prevent it from impacting production continuity at PT BIB. To determine the root cause of the problem, the author conducted an analysis using the Fishbone or Ishikawa method, which provides a systematic and in-depth examination covering various factors from all internal departments of the company involved. Each summarized aspect was obtained from FGDs with stakeholders and field observations. Then the processes carried out are explained in a Fishbone or Ishikawa diagram to obtain an easier visualization (Figure 5).

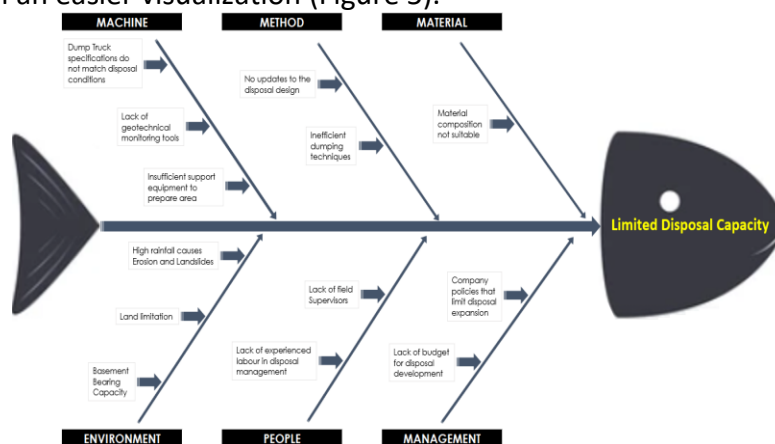


Figure 5. Fish Bone Diagram of Root Causes Limited Disposal Capacity

Machine factors reflect the equipment condition that can hinder Disposal's availability, including the Dump Truck specification gap, a lack of Geotech monitoring tools, and insufficient support equipment. The method factor reflects the way of working to support the availability of

disposal areas, which includes outdated disposal design and inefficient dumping techniques. The Material Factor reflects the material condition that needs to be considered in the Disposal area, with the cause of poor material condition being predominant. Environmental factors reflect the environmental conditions in the surrounding area that affect drainage availability and stability, including erosion and landslides, land limitation, and basement bearing capacity. The People Factor reflects human conditions that can hinder the availability of Disposal, including the lack of experienced labor in disposal management and the lack of field supervisors. The Management Factor reflects stakeholders' policies and decisions that can hinder Disposal capacity's availability, including company policies and lack of budget.

The results of the FGD conducted agreed that the main factors limiting disposal capacity are the dominance of poor material (mud, soft, watery) in the Pit, the limited area of alternative disposal if the active disposal has issues, landslide incidents that reduce disposal capacity, and the unsupportive condition of the planned disposal basement.

Identify the Decision Maker

Based on the issues outlined in the previous section, the appropriate decision-maker is the Mine Operation Production Division Head, the main executor of the short-term mining operational strategy in the company's mining work areas. This person is responsible for controlling the implementation of mining operational activities by considering health, occupational safety, and environmental aspects effectively and efficiently to achieve production targets. A cross-divisional team will support the Mine Operation Production Division Head in addressing the company's operational sustainability challenges.

Identify the Alternatives

Three alternatives have been developed to address the ongoing issues. Based on the focus group discussion results with stakeholders, they have been summarized and processed: Maintain Fleet, Relocate Fleet, and Improvement Sequence.

Maintain Fleet (option 1) is an alternative designed to maintain the existing fleet in the KGB Pit and utilize the disposal that is still available in the area around KGB. It is known that the landslide that occurred at the KGB disposal resulted in the planned capacity in 2024 being reduced so that this could disrupt the continuity of PT BIB's production until the end of the year. To increase the disposal capacity, option 1 utilizes the KA void, which is an old pit that has been mined. The void has not been included in the disposal plan in the near future so based on the results of coordination with the MTP and LTP departments, the area can be used more quickly if there are no other disposal areas.

Relocate Fleet (option 2) is an alternative design that only utilizes the existing disposal capacity in the KGB area after the landslide impact to reduce the storage capacity. Thus, the remaining capacity of the overburden fleet that does not get a storage area in the disposal in the KGB Pit is transferred to the KGU Pit, another work site owned by PT BIB. Pit KGU is a new work area with an IPPKH area and a disposal location included in the long-term planning.

Improvement Sequence option is an alternative created by combining several actions, namely recovering disposal affected by landslides, engineering the Pit design to increase the coal reserves to be mined, and utilizing the overburden transport distance by adjusting the work area towards additional disposal locations in the KA void (Frejowski et al., 2021; Tanujaya, 2023).

Identify Relevant Attributes

After a number of alternatives are determined based on the results of discussions with the parties and Minescape software simulations, the next stage is to identify and determine the relevant attributes or criteria to be used to determine the level of importance of each attribute to each alternative. The various attributes used by the author were obtained from the literature study results and discussed during the interview. The attributes are then divided into 3 criteria, namely Cost criteria, Technical criteria and Compliance's criteria. Cost criteria are divided into 3 sub-criteria, namely operation cost, overhauling cost, and reclamation cost. Technical criteria are divided into 4 sub-criteria: production volume, hauling distance, stripping ratio, and time preparation. Meanwhile, the Compliances criteria are divided into 2 sub-criteria: safety and environment (Figure 6).

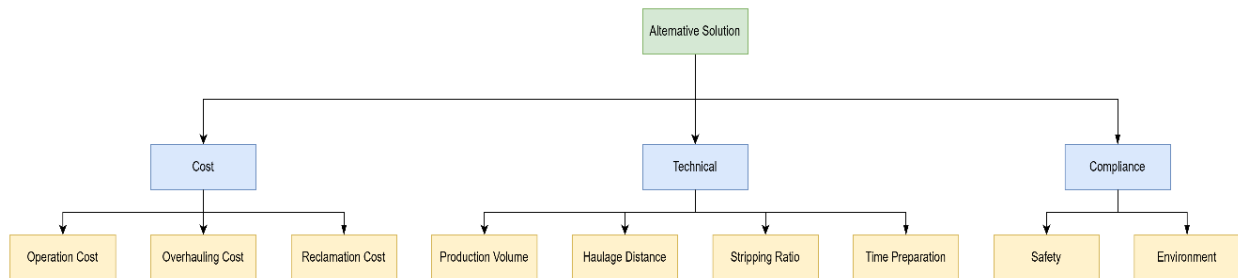


Figure 6. Value Tree Diagram of Decision Making

Determine the Weights of Each Attribute

To determine the scale value of each attribute, the author uses the direct rating method to determine the score value of the existing criteria; the author created a ratings matrix for each attribute. For the benefit criteria, the assessment of each alternative obtained from the questionnaire responses is then converted using direct rating, where each sub-criterion is given a score from 0 to 100, ranging from the lowest to the highest assessment (Table 2).

Table 2. Score Rating for each Criterion

No	Criteria	Requirement	Category	Score
1	Production Volume	The larger volume of coal production has higher value	Low	0
			Medium Low	40
			Medium High	70
			High	100
2	Haulage Distance	Shorter overburden hauling distance has a higher value	Long	0
			Fairly Long	40
			Fairly Short	70
			Short	100
3	Stripping Ratio	Smaller stripping ratio has a higher value	High	0
			Medium High	40
			Medium Low	70
4	Time Preparation	Drier basement disposal has higher value	Low	100
			Long	0
			Fairly Long	40
			Fairly Short	70
5	Safety		Short	100
			High Risk	0

No	Criteria	Requirement	Category	Score
6	Environment	Lower safety risk has a higher value	Medium High	40
			Medium Low	70
			Low Risk	100
		Larger final disposal area for the reclamation plan has a higher value	Not Comply	0
			Less Comply	40
			Fairly Comply	70
Comply	100			

After the scores for each criterion were determined, the author created a questionnaire and distributed it to each respondent involved to understand the benefits of each alternative against those criteria, including the Short-Term Planning Department, Medium-Term Planning, Long-Term Planning, Geotechnics, Operations, Safety, and Environment (Table 3).

Table 3. Assessment Result for each Criterion

No	Criteria	OPTION 1	OPTION 2	OPTION 3
1	Production Volume	Medium High	Low	High
2	Haulage Distance	Long	Short	Fairly Short
3	Stripping Ratio	Low	High	Medium Low
4	Time Preparation	Short	Short	Long
5	Safety	High Risk	Low Risk	High Risk
6	Environment	Not Comply	Not Comply	Comply

The assessment results for the sub-criteria of production volume show that Option 3 received the highest score, 100, Option 1 received a value of 70, and Option 2 received the lowest score (Table 4).

Table 4. Direct Rating of Production Volume

No	Attributes	Criteria	Value
1	Option 1	Medium High	70
2	Option 2	Low	0
3	Option 3	High	100

For the sub-criteria of haulage distance, the assessment results show that Option 2 received the highest score, 100, Option 3 received a value of 70, and Option 1 received the lowest score (Table 5).

Table 5. Direct Rating of Haulage Distance

No	Attributes	Criteria	Value
1	Option 1	Long	0
2	Option 2	Short	100
3	Option 3	Fairly Short	70

The assessment results for the stripping ratio sub-criteria show that Option 2 received the highest score, 100, Option 3 received a value of 70, and Option 1 received the lowest score (Table 6).

Table 6. Direct Rating of Stripping Ratio

No	Attributes	Criteria	Value
1	Option 1	Low	100
2	Option 2	High	0

3	Option 3	Medium Low	70
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The assessment results for the time preparation sub-criteria show that Option 1 and Option 2 received the highest score of 100, while Option 3 received the lowest score (Table 7).

Table 7. Direct Rating of Time Preparation

No	Attributes	Criteria	Value
1	Option 1	Short	100
2	Option 2	Short	100
3	Option 3	Long	0

The assessment results for the safety sub-criteria show that Option 2 received the highest score, 100, while Option 1 and Option 3 received the lowest scores (Table 8).

Table 8. Direct Rating of Safety

No	Attributes	Criteria	Value
1	Option 1	High Risk	0
2	Option 2	Low Risk	100
3	Option 3	High Risk	0

The assessment results for the environment sub-criteria show that Option 3 received the highest score, 100, while Option 1 and Option 2 received the lowest scores (Table 9).

Table 9. Direct Rating of Environment

No	Attributes	Criteria	Value
1	Option 1	Not Comply	0
2	Option 2	Not Comply	0
3	Option 3	Comply	100

Assigning Value of Each Alternative on Each Attribute

After the value of each criterion is obtained, the next step is to determine the original weight of the criteria against the alternatives. This enables us to see the level of importance of each criterion in the selection of an alternative. The original weight assessment was conducted through interview with experts, and it was found that the production volume criterion has the highest priority with the highest value, the safety criterion with a value of 90, the environment criterion with a value of 80, the haulage distance criterion with a value of 70, the time preparation criterion with a value of 60, and the lowest priority was given to the stripping ratio with a value of 50 (Figure 7).

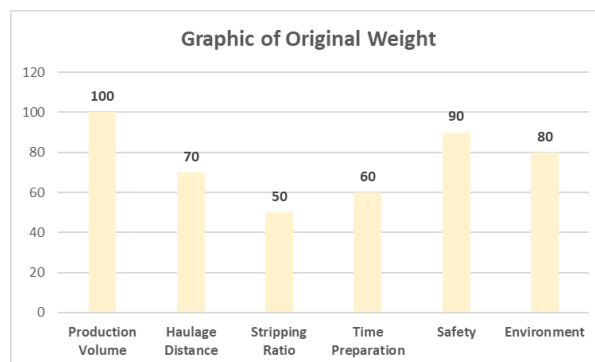


Figure 7. Graphic of Original Weight of Each Alternative on Each Attribute

From the original weight, the normalized weight is then calculated (Table 10).

Table 10. Normalized Weight of Criteria

No	Attributes	Value	Normalized Weight
1	Production Volume	100	0.22
2	Haulage Distance	70	0.16
3	Stripping Ratio	50	0.11
4	Time Preparation	60	0.13
5	Safety	90	0.20
6	Environment	80	0.18

Calculate the Aggregate of Weighted Value

After the normalized weight is obtained, the aggregate weight value is calculated by multiplying the normalized weight of each attribute by the Original Weight of Each Alternative (Table 11).

Table 11. Aggregate of Weighted Value Calculation

No	Attributes	Production	Haulage	Stripping	Time	Safety	Environment	Aggregate Value
		Volume	Distance	Ratio	Preparation			
		0.22	0.16	0.11	0.13	0.20	0.18	
1	Option 1	70	0	100	100	0	0	40.00
2	Option 2	0	100	0	100	100	0	48.89
3	Option 3	100	70	70	0	0	100	58.67

Make Provisional Decision

The next step is to make a provisional decision by comparing each alternative's costs and benefits (in this case, technical and compliance criteria). This serves to assist the author in choosing the most preferred efficient frontier point (Table 12).

Table 12. Cost vs Benefit of each Alternative

Alternatives	Total Cost	Aggregated Benefit
Option 1	109.26	40.00
Option 2	105.03	48.89
Option 3	111.53	58.67

The graph below shows two alternatives, Option 2 and Option 3, positioned on the efficient frontier. This option allows decision-makers to determine the best alternative by considering the relative costs and benefits (Figure 8).

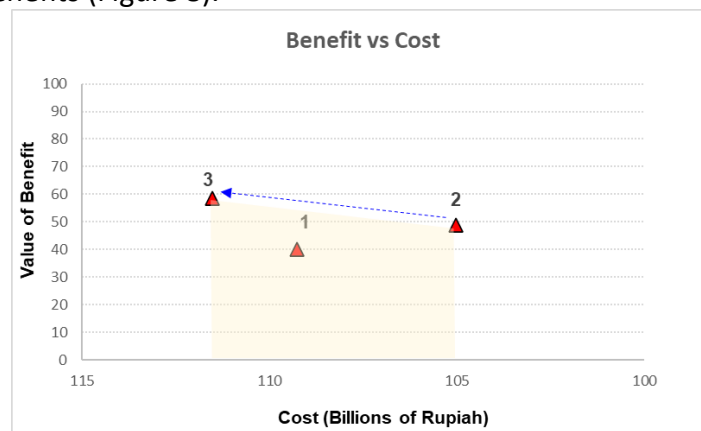


Figure 8. Graphic Plot of Trading Cost vs Benefits

To facilitate the decision-making process between Option 2 and Option 3, the author created a cost vs. benefit ratio to determine the extent of the movement in benefit points obtained relative to the cost effort required (Table 13).

Table 13. Trading Cost vs Benefits Ratio

Alternative	Option 3		
	111.53	58.67	
Option 2	105.03	6.50	9.78
	48.89	0.66	Billion Rupiah / point

The table above shows that the company can increase the benefit by 9.78 points by moving from Option 2 to Option 3 at an additional cost of Rp 6.50 billion. In other words, an extra cost of Rp 0.66 billion is needed for each point's additional value benefit.

Perform Sensitivity Analysis

After the utility value of each alternative and the preliminary decision are determined, the next step is to calculate the robustness level of each existing alternative if the importance level of each existing attribute changes. This stage is performed by repeatedly changing the utility value of each criterion to be considered unimportant (valued at 0) and comparing each change made (Table 14).

Table 14. Trading Cost vs Benefits Ratio

No	Attributes	Aggregate of Weighted Value (Technical = 0)	Aggregate of Weighted Value (Original)	Aggregate of Weighted Value (Compliance = 0)
1	Option 1	0.00	40.00	42.86
2	Option 2	52.94	48.89	25.00
3	Option 3	47.06	58.67	65.71

The change in the value of benefits for each alternative due to sensitivity analysis is then plotted as shown in the graph below (Figure 9).

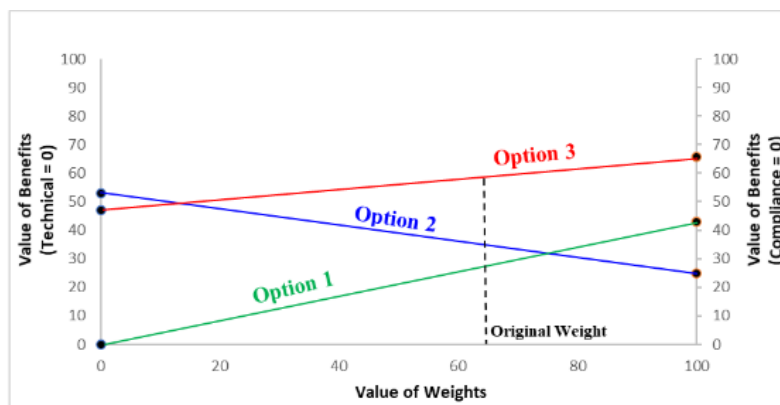


Figure 9. Graphic Plot of Sensitivity Analysis

The graph above shows that if the importance of the technical criteria (Technical Value = 0) changes, the best alternative that provides the highest benefit value is Option 2. However, if

the importance of the compliance criteria changes (Compliance Value = 0), the best alternative that provides the highest benefit value is Option 3.

Potential Problem Analysis

After the decision-making analysis and alternative solutions were obtained, the author then performed a potential problem analysis to identify any obstacles and issues that may arise during the implementation of the chosen alternative program. This is done as a mitigation step in the initial phase of the implementation plan so that if obstacles or problems do occur, anticipatory actions can be taken to maintain the implementation of the alternative program and achieve the company's goals (Table 15).

Table 15. Potential Problem Analysis Operational Activity

No	Potential Problem	Consequence	Possible Cause	Preventive Action	Contingent Action
1	Mine accident	Worker injury or fatality, and property damage	Unsafe conditions and unsafe actions occur in the work operational area	Conduct periodic inspection and observation	Conducting training to improve employee competencies. In addition, the installation of monitoring equipment is carried out in operational work areas that are prone to accidents
2	The reclamation activities did not meet the target	Non-compliance with government regulations results in the non-refund of reclamation guarantee costs that the company has already invested in the government	The limited availability of topsoil material to be spread in the final disposal area	Identifying areas with topsoil material outside the work area and allocating additional equipment to carry out soil spreading activities	Conducting a benchmark or research related to reclamation methods without using topsoil material
3	The delay in stripping the overburden and coal getting	The production target according to the RKAB was not achieved.	The mining equipment is in inadequate and outdated condition.	Adding vendors to accelerate infrastructure development and replace equipment that is already outdated.	Conducting periodic maintenance of mining equipment to identify potential damage to the equipment.

The first potential issue is mining accidents during operational activities. These accidents can result in injuries or even fatalities among workers and property damage. The main causes are unsafe working conditions and unsafe actions in the operational area. To prevent this, regular inspections and observations are conducted to identify potential hazards early on. If a potential hazard is found, it must be immediately reported to the authorized supervisor for follow-up. As

a contingency measure, the company needs to conduct training to enhance employees' competence in safely performing operational tasks and install monitoring equipment in accident-prone work areas.

The second issue is related to post-mining land reclamation not meeting targets. This can lead to non-compliance with government regulations, resulting in the reclamation guarantee funds that have been deposited being non-refundable. The cause is the limited availability of topsoil material needed for reclamation in the final disposal area. To prevent this, the company must identify areas outside the worksite that have potential topsoil and allocate additional tools to expedite the spreading of the soil. If this solution is insufficient, research or benchmarking of alternative reclamation methods that do not require topsoil can be conducted.

The third issue is the delay in overburden stripping and coal extraction activities, which affects the achievement of production targets according to the Work Plan and Budget (RKAB). The main causes are inadequate mining equipment repair infrastructure and the outdated condition of the equipment. To prevent this, the company can increase the number of vendors to expedite infrastructure development and replace equipment that is no longer usable. As a contingency measure, regular maintenance of mining equipment must be carried out to detect damage early before heavy equipment failure occurs.

Implementation Plan

The first stage conducted is to identify and explore the aspects needed in the implementation plan using 5W + 1H (What, Why, When, Where, Who, and How) with results as shown in the table below (Table 16).

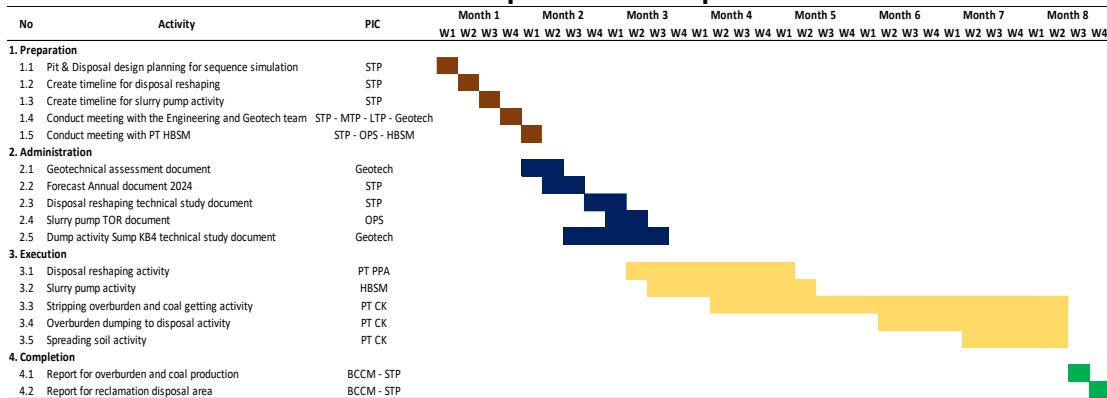
Table 16. Aspect 5W+1H for Implementation Plan

Question	Description
What	Program Improvement Sequence Pit KGB
Why	<ol style="list-style-type: none"> 1. To make improvements regarding the production shortfall that occurred during the period from January to July 20204 in Pit KGB. 2. To manage the limited disposal land due to landslides occurring at the KGB disposal site, which impacts the current reduction in disposal capacity. 3. To maintain the continuity of mining equipment operating in the KGB pit area. 4. To maintain compliance with government regulations regarding safety and environmental aspects.
When	The Programme is expected to be implemented in Quarter 2 of 2025.
Where	The work program will be carried out in the PT BIB concession area, specifically at Pit KGB.
Who	<ol style="list-style-type: none"> 1. STP Department as Programme planner and controller 2. Section Geotech in SGE Department as controller of disposal assessment 3. Operations department as a monitor and supervisor of fieldwork activities 4. Safety Department as the monitor and supervisor of the safety program conducted in the work area

Question	Description
	5. Enviro Department as the monitor and supervisor of reclamation activities conducted in the final disposal area
	6. PT CK as the operational activity implementation partner in the KGB and KGU Pit areas
How	Program improvement sequence involves creating a sequence plan design for Pit and Disposal, reshaping landslides in the KGB disposal area, pumping sludge in the former sump area as an additional disposal plan, and shifting the fleet to the area of the planned sequence change.

The second stage is to create a sequence of implementation for the improvement program in Pit KGB, including the details of the tasks that need to be considered to ensure that the activities run smoothly and efficiently. Then, the work details are given a timeline so that control and monitoring can be carried out (Table 17).

Table 17. Timeline Improvement Sequence Pit KGB



CONCLUSION

This research successfully identified the key factors contributing to operational delays at PT BIB’s KGB Pit, including machine, method, material, environmental, human, and management factors. The root causes, such as the dominance of poor materials, landslide incidents, and limited disposal capacity, were effectively analyzed using the Kepner-Tregoe, Fishbone Diagram, and SMART methods. After evaluating three potential solutions—Maintain Fleet, Relocate Fleet, and Improvement Sequence—based on criteria like production volume, haulage distance, stripping ratio, preparation time, safety, and environmental impact, the Improvement Sequence option emerged as the most viable solution. This alternative was selected after conducting a cost-benefit comparison and sensitivity analysis. To ensure successful implementation, potential risks and issues should be addressed with mitigation strategies, while an implementation plan with clear work stages and timelines should be established for smooth execution.

Future research could explore the long-term impacts of the Improvement Sequence option on operational efficiency and overall cost savings in similar mining operations. Additionally, studies could investigate the integration of advanced technologies, such as automation and real-time monitoring systems, to further optimize production and disposal processes. Further

research may also examine the role of stakeholder engagement in ensuring the successful implementation of operational strategies in large-scale mining projects.

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