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DECISION-ANALYSIS FOR THE BEST OPTION TO OPTIMIZE MINE PLANNING AT PIT KUSAN FOR 2025-2029 PERIOD, PT BORNEO INDOBARA

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ABSTRACT:
Revisions to the Feasibility Study (FS) have increased the annual coal production target from 46 million tons to 54 million tons, necessitating adjustments to the strategic mining plan in the PKP2B area of PT Borneo Indobara. The Kusan Pit is one of the pits that must adjust its mining planning strategy during the 2025-2029 period. Currently, the Kusan Pit has a coal production target of 9 million tons per year, and to support this revised target, coal production capacity will be increased gradually from 9 million tons in 2025 to 22 million tons in 2029. This increase in coal production capacity presents several challenges, including limitations in overburden disposal capacity, increasing transport distances, additional infrastructure requirements, and interdependencies with the forest area lease approval process (PPKH). These challenges necessitate a systematic and data-driven strategic decision-making approach. This study aims to develop an evaluative approach for selecting the optimal mining strategy. Several alternative mining plan options for the Kusan Pit for the 2025–2029 period was developed using simulation with SPRY Scheduling software. To evaluate these options, the Simple Multi-Attribute Rating Technique (SMART) was used, considering various criteria, including overburden transport distance, disposal capacity, additional operational costs, opportunity benefits, and PPKH permit readiness. This study establishes a conceptual framework that integrates technical, regulatory, and cost-benefit aspects into the strategic decision-making process. By employing qualitative-quantitative modeling, cost analysis, and sensitivity analysis, it is expected to assist the company in determining a mining planning strategy that is not only cost-efficient but also sustainable and aligned with government policies.

Keywords: Strategic Mining Planning, Pit Kusan, Overburden Disposal, PPKH, SPRY Scheduling, SMART Analysis, Decision Making.

INTRODUCTION

Pit Kusan is one of the operational sites of PT Borneo Indobara. The recent increase in coal prices has prompted management to optimize Pit Kusan from a price of $36 to $44 per ton, which will result in an increase in both coal reserves and overburden material. This optimization change has been formalized in the revised Feasibility Study and Environmental Impact Analysis (FS AMDAL) document, which raises the coal production target from 46 million tons per year to 54 million tons per year. The FS AMDAL for the 54-million-ton target is currently in process and is expected to be completed by April 2025, enabling the 54-million-ton target to be achieved by 2025.

Currently, Pit Kusan has a coal production capacity of 9 million tons. To support the achievement of the overall target of 54 million tons per year, the production capacity of Pit Kusan will be increased to 22 million tons. However, several challenges have been identified that could impact mining costs, necessitating the prompt development of appropriate strategies. These challenges include:

- Pit Expansion: The expansion of the pit has resulted in areas previously designated for overburden disposal being repurposed as pit areas, requiring the identification of new disposal areas.
- Large-Scale Landslides and Geotechnical Constraints: Large-scale landslides at the East Pit Kusan outpit disposal site have resulted in the loss of near-pit disposal volumes, Based on back analysis slope stability so now, the target overall slope stability from 8 degree to 4-6 degree and from elevation 140 to elevation 90.
- Forest Area Borrow-Use Permit Quotas: Delays in obtaining the necessary quotas for the Forest Area Borrow-Use Permit have disrupted the mining sequence from the original plan, which will impact the hauling distance for overburden material.

Due to these changes, the long-term mine planning department has prepared several options and mining strategies for the 2025-2029 period. These options will be evaluated, analyzed, and compared to provide PT BIB management with a solid foundation for making the best decisions and strategies for business development at Pit Kusan during the 2025-2029 period.

RESEARCH METHODS

The research design for this study addresses key challenges in Pit Kusan’s mine planning for the 2025–2029 period through a comprehensive methodology that integrates both qualitative and quantitative approaches. It begins by establishing clear research questions and objectives, focusing on resolving these challenges via data collection from primary and secondary sources. In-depth interviews with key stakeholders provide insights into operational and strategic issues, while a literature review offers contextual background and best practices. Following data collection, the information is analyzed to identify main challenges related to technical, operational, and regulatory factors, particularly concerning Forest Area Utilization Permits (PPKH). Multiple mine planning options are developed, optimized for production and sustainability, and simulated using mine planning software (SPRY). These alternatives are evaluated through the SMART method to determine the most optimal strategy, ensuring long-term sustainability for Pit Kusan. This structured approach aligns with the conceptual framework, contributing to the study's overall objectives and resulting in a robust strategy for mine planning in the specified period.

RESULTS AND DISCUSSION

Analysis

Effective mine planning is not just about meeting production targets. It also involves ensuring operational sustainability, cost efficiency, and regulatory compliance. This chapter provides a detailed analysis to support strategic decision-making for Pit Kusan's mining plan from 2025 to 2029. The main goal is to achieve the 22-million-ton production target by 2029, while keeping costs low and ensuring long-term stability.

The analysis begins by identifying key challenges and evaluation criteria that must be addressed for a successful mine plan. Then, various planning options are developed using SPRY Scheduling software, which simulates mining sequences and overburden haul distances to assess their impact on operational costs.

To evaluate and rank these options, the Simple Multi-Attribute Rating Technique (SMART) is applied based on predefined criteria. This chapter includes the following sections:

1. Identification of key challenges and criteria.
2. Development of alternative strategies using SPRY for haul distance simulation.
3. Business solution formulation based on SMART analysis.
4. Implementation strategy covering operations and permits.

1) Identification of Key Challenges and Criteria

From the data collected through in-depth interviews with management and secondary data sources, several key challenges in planning the Pit Kusan mine for the 2025–2029 period were identified. Some of these main challenges include:

a. Change in Feasibility Study from FS 46 to FS 54

The shift from a 46-million-ton target to a 54-million-ton target significantly affects Pit Kusan. This change is reflected in the Pit Design simulation, which previously used a pit based on a $36 price per ton, now modified to a pit based on a $44 price per ton, leading to an expanded pit area. Consequently, for the 2025–2029 planning period, Pit Kusan must adopt the $44 Pit Simulation.

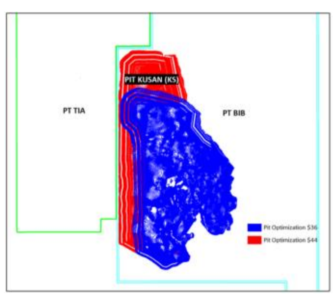

Figure 1. Comparison Pit Price $36 with Pit Price $44 (FS Revision 54 Mio Tonnes)

b. Production Target from Management

To achieve the peak coal production target of 54 million tons per year as specified in FS Techno 54 million tons, the peak coal production target for Pit Kusan during the 2025–2029 period, as determined by management, is set at 22 million tons by 2029, as shown in Table 1.

Table 1. Production Target for Pit Kusan Period 2025-2029

Material	Unit	2025	2026	2027	2028	2029	Total
Overburden	Kbcm	42,049	64,179	84,489	99,064	99,372	389,153
Coal	Kton	9,250	12,455	15,333	21,500	22,000	80,538
SR	bcm/ton	4.55	5.15	5.51	4.61	4.52	4.83

c. Geotechnical Limitation Recommendations

The disposal capacity is limited by geotechnical safety analysis, which restricts the disposal height to an elevation of 90–100 meters with an overall slope of 5–6 degrees. This limitation results in an increased overburden hauling distance to the disposal area, necessitating an optimal hauling distance strategy for mining operations in Pit Kusan. Initially, the mining planning team proposed a disposal target with an overall slope of 14 degrees. However, the final disposal design must adhere to geotechnical recommendations to mitigate landslide risks and maintain safety in the operational area.

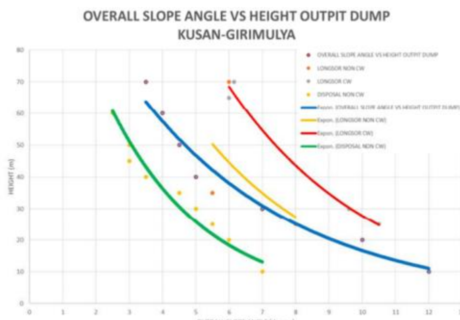

Figure 2. Results of Back Analysis on Slope Stability of Disposal under Various Condition

d. Operational Feasibility with Disposal Area Availability

The availability of overburden disposal areas to achieve optimal haul distances is one of the primary concerns for management. Disposal area availability is the most critical factor to ensure that the 54-million-ton coal reserves at Pit FS can be mined efficiently. Various disposal options significantly impact the overburden hauling distances, which in turn affects the operational cost calculations resulting from mining activities.

e. Collaboration Between BIB and TIA for Overburden Disposal Placement (Disposal in BIB's Area)

Pit Kusan is adjacent to the IUP of PT TIA, located in the HW Pit Kusan area. According to mining rule-of-thumb practices, one of the best ways to minimize overburden hauling distance is to establish disposal sites within the HW Pit area.

Currently, TIA has expressed openness to a cooperation agreement, supported by government regulations on operational collaboration. Furthermore, TIA's mining operations are expected to conclude by the end of 2024, leaving a large mining void as a result of their excavation activities.

One practical solution to reclaim and close TIA's mining void is through cooperation with PT BIB, allowing BIB to deposit its overburden material into TIA's void. This initiative presents an opportunity for mutual benefits, addressing both mine closure obligations and cost optimization for BIB's overburden disposal. Management is currently evaluating several cooperation scenarios with TIA, assessing the benefits and trade-offs between partnering with TIA versus alternative disposal strategies.

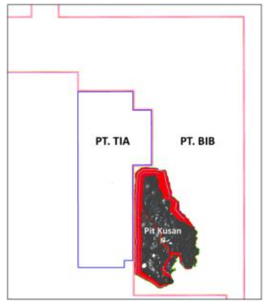

Figure 3. Location PT BIB and PT TIA

f. Bridge Construction Across the Taiwasi River

The Taiwasi River separates Pit Kusan from the TIA disposal area, creating a logistical challenge for overburden transportation. To address this, PT BIB must construct a connecting bridge to facilitate the movement of materials. The number of bridges built will directly impact the hauling distance of overburden throughout the 2025-2029 period.

g. Borrow-to-Use Forest Area (PPKH) Approval

Both PT BIB and PT TIA’s mining concessions are located within a designated forest area, requiring PPKH approval from the forestry department before expanding operations.

For the 2025-2029 period, PT BIB has already secured PPKH approval for its concession. However, PT TIA has only obtained partial PPKH approval, and additional permits will be required if the company seeks to increase its disposal capacity. Figure 4.2 illustrates the locations of PT BIB and PT TIA within the forest area.

Based on the key challenges identified as primary concerns for management, several evaluation criteria have been established to assess the feasibility of each alternative option. These criteria include:

a. Availability and location of disposal areas to ensure sufficient space for overburden storage.
b. Total operational costs incurred from potential collaboration with PT TIA.
c. Optimization of disposal capacity within PT TIA’s concession to improve efficiency.
d. Opportunity benefits of working with PT TIA, compared to operating independently.
e. Compliance with PPKH regulations, ensuring all necessary permits are secured.

From this analysis, three key focus areas have been identified as critical for achieving the 2025-2029 production targets at Pit Kusan:

1. Ensuring adequate overburden disposal capacity to prevent bottlenecks in mining operations.
2. Securing PPKH approvals to expand disposal areas and maintain regulatory compliance.
3. Assessing additional costs associated with collaboration to determine whether a partnership with PT TIA is financially viable.

To evaluate these options, various disposal strategies will be simulated using SPRY Scheduler, a long-term mine planning tool that generates annual projections. These simulations will provide overburden haul distance estimates, serving as the foundation for total operational cost calculations.

2) Development of Alternative Options

Based on the key challenges identified, four alternative options have been developed and simulated using SPRY Scheduler software. From these options, the most viable strategy will be selected for implementation. The alternative options are as follows:

1. Option 1: Disposal Within PT BIB Only

This option proposes using disposal areas exclusively within PT BIB's concession, without any collaboration with PT TIA. As a result, no additional PPKH approval would be required for disposal expansion in PT TIA's concession.

The disposal design in this option follows geotechnical recommendations, ensuring stability and safety. The overburden material from Pit Kusan would be placed solely within PT BIB's concession, without utilizing any external disposal sites.

Table 2, presents the target production and the corresponding haul distances for this option. However, since all overburden must be transported to disposal areas within PT BIB, this option results in longer haul distances throughout the 2025-2029 period. Consequently, operational costs will be significantly higher due to increased transportation requirements.
To assess the feasibility of this option, a comparison will be made with other alternatives, particularly those involving disposal collaboration with PT TIA, where 284 million BCM or 201 million BCM of overburden capacity could potentially be allocated within PT TIA's concession.

Table 2. Option 1: Report Production Target and Overburden Haul Distance

Material	Unit	2025	2026	2027	2028	2029	Total
Overburden	Kbcm	42,049	64,179	84,489	99,064	99,372	389,153
Coal	Kton	9,250	12,455	15,333	21,500	22,000	80,538
SR	bcm/ton	4.55	5.15	5.51	4.61	4.52	4.83
OHDA Opt. 1	meter	4,777	5,233	6,182	3,550	3,754	4,584

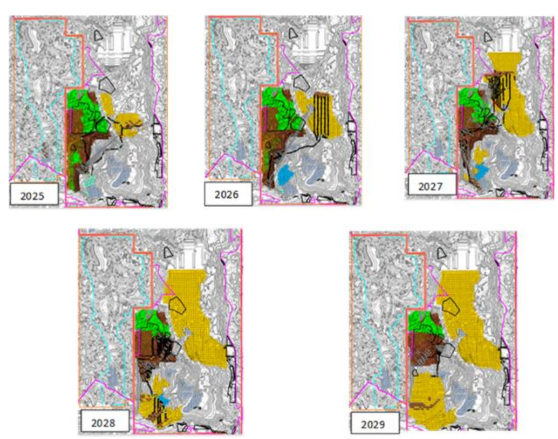

Figure 4. Option 1 Mine Plan Simulation by SPRY Scheduler

2. Option 2: Combined Disposal Between PT BIB and PT TIA (Using Existing PPKH)

This option involves a collaboration between PT BIB and PT TIA, utilizing a combined disposal strategy within both PT BIB's concession and PT TIA's concession. However, this alternative only maximizes the disposal capacity within PT TIA's existing PPKH and does not require additional PPKH approvals for expansion.

Under this plan, overburden from Pit Kusan will be allocated between disposal areas in PT BIB and PT TIA. The maximum disposal capacity available within PT TIA's existing PPKH is 201 million BCM.

To support this disposal arrangement, the project will require the construction of a single bridge over the Taiwasi River. This bridge will act as a critical connection between Pit Kusan and the designated disposal sites, enabling efficient overburden transportation.

Table 3. Production Target dan Overburden Haul Distance Option 2 for Mine Planning Pit Kusan Period 2025-2029

Material	Unit	2025	2026	2027	2028	2029	Total
Overburden	Kbcm	42,049	64,179	84,489	99,064	99,372	389,153
Coal	Kton	9,250	12,455	15,333	21,500	22,000	80,538
SR	bcm/ton	4.55	5.15	5.51	4.61	4.52	4.83
OHDA Opt. 2	meter	4,132	3,930	4,750	3,504	3,690	3,960

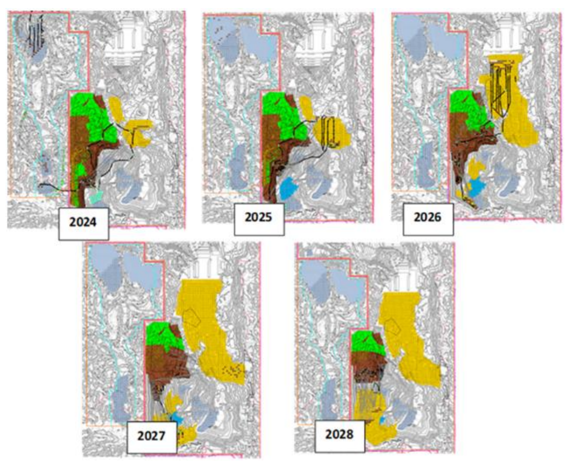

Figure 5. Option 2 Mine Plan Simulation by SPRY Scheduler

3. Option 3: Combined Disposal Between PT BIB and PT TIA (With Additional PPKH Approval)

This option proposes a collaboration between PT BIB and PT TIA, utilizing a combined disposal strategy within both PT BIB's and PT TIA's concessions. Unlike Option 2, this alternative maximizes PT TIA's existing PPKH capacity while also requesting additional PPKH approvals to accommodate a total disposal capacity of 284 million BCM. In this scenario, overburden from Pit Kusan will be dumped in both PT BIB and PT TIA's disposal areas, fully utilizing PT TIA's expanded disposal capacity of 284 million BCM.

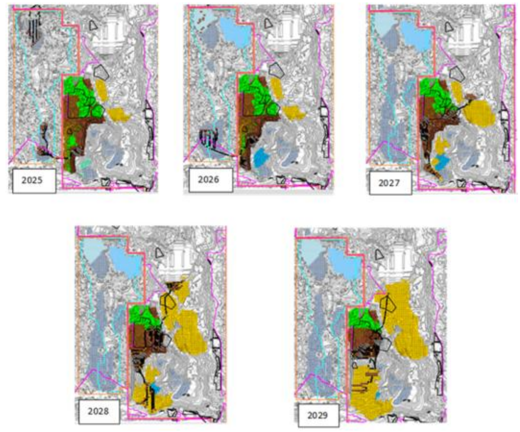

Figure 6. Option 3 Mine Plan Simulation by SPRY Scheduler

To facilitate this operation, a single bridge will be constructed over the Taiwasi River, serving as a transportation link between PT BIB and PT TIA. The SPRY Scheduler simulation has provided haul distance estimates for this option, which are detailed in the following table:

Table 4. Production Target and Overburden Haul Distance Option 3 for Mine Planning Pit Kusan Period 2025-2029

Material	Unit	2025	2026	2027	2028	2029	Total
Overburden	Kbcm	42,049	64,179	84,489	99,064	99,372	389,153
Coal	Kton	9,250	12,455	15,333	21,500	22,000	80,538
SR	bcm/ton	4.55	5.15	5.51	4.61	4.52	4.83
OHDA Opt. 3	meter	4,132	3,830	4,157	3,433	3,590	3,771

4. Option 4: Combined Disposal Between PT BIB and PT TIA (With Additional PPKH Approval and Two Bridges)

This option involves a collaboration between PT BIB and PT TIA, using a combined disposal strategy within both PT BIB's and PT TIA's concessions. Similar to Option 3, this alternative maximizes PT TIA's existing PPKH capacity while also securing additional PPKH approvals for expanded disposal operations. Under this plan, overburden from Pit Kusan will be dumped in both PT BIB and PT TIA's disposal areas, utilizing the full disposal capacity of 284 million BCM at PT TIA.

However, unlike Option 3, this alternative requires the construction of two bridges over the Taiwasi River, as the transportation route crosses multiple points between PT BIB and PT TIA's concessions. The first bridge will be built in 2025, followed by the second bridge in 2026, ensuring smooth overburden transportation and minimizing haul distances.The SPRY Scheduler simulation has provided haul distance estimates, which are detailed in the following table:

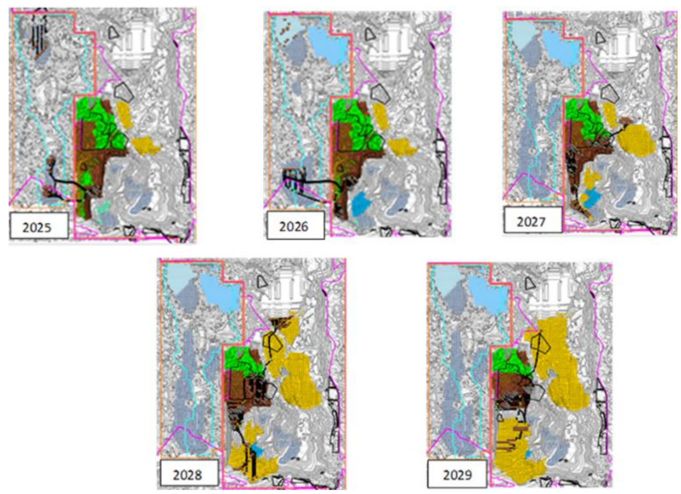

Figure 7. Option 4 Mine Plan Simulation by SPRY Scheduler

Table 5. Production Target and Overburden Haul Distance Option 4 for Mine Planning Pit Kusan Period 2025-2029

Material	Unit	2025	2026	2027	2028	2029	Total
Overburden	Kbcm	42,049	64,179	84,489	99,064	99,372	389,153
Coal	Kton	9,250	12,455	15,333	21,500	22,000	80,538
SR	bcm/ton	4.55	5.15	5.51	4.61	4.52	4.83
OHDA Opt. 4	meter	4,132	3,133	3,364	3,380	3,590	3,471

Business Solution

Based on the 2025-2029 Pit Kusan Mine Planning Simulation using SPRY Scheduler, four alternative options have been identified that align with management's key concerns. To determine the best mining strategy, the SMART (Simple Multi-Attribute Rating Technique) method is applied. This method ranks the available options based on predefined criteria, with the highest-ranking option selected for implementation. Several steps are involved in determining the best option, which will be discussed in this section.

1) Defining Evaluation Criteria and Assigning Scores

To begin the SMART evaluation, six key criteria have been established based on the four alternative options simulated in SPRY Scheduler. These criteria represent the primary concerns of management and will be used to rank each alternative strategy.

1) Overburden Haul Distance to TIA Cost

This criterion represents the total overburden haul distance, calculated as an average value for the 2025-2029 period across all options. The results are as follows:

a. Option 1: 4,584 meters
b. Option 2: 3,960 meters
c. Option 3: 3,771 meters
d. Option 4: 3,471 meters

2) Additional Operational Costs (other cost)

This criterion evaluates the extra operational costs associated with activities within PT TIA's concession. These costs arise due to the collaboration between PT BIB and PT TIA and include:

a. Transport and hauling costs for overburden disposal at PT TIA.
b. Infrastructure development expenses, such as road maintenance and bridge construction.
c. Regulatory and administrative costs related to compliance with government permits and approvals.

All cost calculations are based on internal assessments and potential agreements that PT TIA may propose as part of a collaboration with PT BIB. These costs represent PT BIB's financial responsibility throughout the partnership period. The Other Costs category consists of the following components:

1. License Cost

This includes expenses related to permits and documentation required for the joint operation between PT BIB and PT TIA. It covers:

a. Feasibility Study (FS) adjustments,
b. Environmental Impact Assessment (AMDAL) revisions,
c. Redistribution permits,
d. PPKH approvals, and
e. All necessary government authorizations.

2. Infrastructure Cost

This refers to the costs incurred by PT BIB to relocate or rebuild structures impacted by the mining disposal sequence. Expenses include:

a. Relocation of office buildings, workshops, and mess areas belonging to PT TIA,
b. Construction and modification of supporting infrastructure.

3. Environmental Cost

This includes expenses for constructing and maintaining sedimentation ponds to manage runoff water from mining operations, ensuring compliance with environmental regulations.

4. Reclamation and Mine Closure Cost

This represents the cost of reclamation and land restoration that PT BIB must cover to ensure that post-mining areas in PT TIA's concession are rehabilitated and returned to the government following regulatory standards.

5. Fee Cost

This is the financial compensation that PT BIB must pay PT TIA, based on the volume of overburden disposed within PT TIA's concession. The greater the volume of overburden placed in PT TIA's area, the higher the fees that PT BIB must pay (calculated in x$ per BCM).

Total Other Costs Per Alternative Option

Based on calculations, the total Other Costs for each alternative option are as follows:

a. Option 1: $0 (since disposal is entirely within PT BIB's area).

b. Option 2: $86,648,000
c. Option 3: $97,965,000
d. Option 4: $98,631,000

Since Options 2, 3, and 4 involve collaboration with PT TIA, they incur additional operational costs, while Option 1 has no extra cost as it does not require external disposal agreements.

3) Overburden Haul Distance Cost

The Overburden Haul Distance Cost (OHDA) represents the cost incurred per BCM per meter for transporting overburden to disposal areas in PT TIA's concession. This cost is calculated based on:

a) The total disposal capacity allocated in PT TIA.
b) The average haul distance for overburden transportation to PT TIA.

For Option 4, this cost is also evaluated under a scenario where the full disposal capacity of 284 million BCM at PT TIA is redirected to PT BIB's area instead.

Based on these calculations, the OHDA cost for each option is as follows:

a) Option 1: $1,391,880,000 (highest cost due to long haul distances within PT BIB).
b) Option 2: $288,896,000
c) Option 3: $445,622,000
d) Option 4: $441,525,000

From these results, Option 1 has the highest cost since all overburden disposal is handled within PT BIB, resulting in longer transport distances and higher expenses. Meanwhile, Options 2, 3, and 4 reduce costs by utilizing disposal areas within PT TIA

4) Disposal Capacity in PT TIA

This criterion evaluates the total available disposal capacity within PT TIA's concession.

a) Option 1 does not allocate any disposal capacity to PT TIA, as all overburden disposal remains within PT BIB's concession.
b) Options 2, 3, and 4 involve collaboration with PT TIA, allowing a portion of overburden to be placed within PT TIA's disposal areas.
c) The capacity breakdown for each option is as follows:
d) Option 2: Utilizes only PT TIA's existing PPKH and provides a disposal capacity of 201 million BCM.
e) Option 3: Expands disposal capacity by securing additional PPKH, increasing the total disposal capacity to 284 million BCM.
f) Option 4: Similar to Option 3, this option maximizes disposal capacity at PT TIA to 284 million BCM, using both existing and newly acquired PPKH permits.

Figure 8. illustrates the 201 million BCM disposal allocation for Option 2, while Figure 9. shows the expanded 284 million BCM disposal scenario for Options 3 and 4.

Figure 8. Disposal Design for Alternative Option 2 (201 m-BCM)

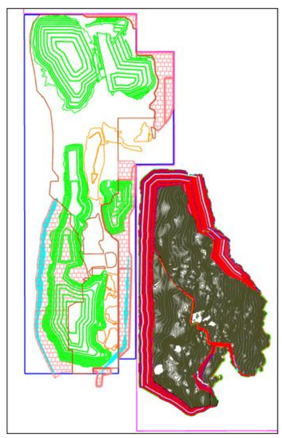

Figure 9. Disposal Design for Alternative Option 3 and 4 (284 m-BCM)

5) Opportunity Benefits of Collaboration with PT TIA

The benefit of collaborating with PT TIA is calculated based on the difference in Overburden Haul Distance Cost (OHDA) between disposing overburden within PT BIB's concession versus disposing it in PT TIA's area, considering both disposal capacity and additional operational costs.

The formula used for this calculation is:

$$\text{Benefit} = \text{OHDA Cost for Disposal in BIB} - (\text{OHDA Cost for Disposal in TIA} + \text{Other Costs})$$

Based on this formula, the calculated benefits for each option are as follows:

a) Option 1: No benefit, as all disposal occurs within PT BIB's concession.
b) Option 2: $4,011,000
c) Option 3: $21,150,000
d) Option 4: $54,582,000

These results indicate that Option 4 provides the highest financial benefit, as it optimizes disposal capacity at PT TIA, leading to significant cost savings in overburden haul distance and operational expenses.

6) Readiness for Additional PPKH in PT TIA

This criterion evaluates the feasibility of obtaining additional PPKH (Forest Area Utilization Permit) for disposal expansion in PT TIA's concession. The assessment is based on document readiness and efforts required by the licensing team. The feasibility is categorized into four levels:

- Feasible (Score: 4) → The process is straightforward with minimal obstacles.
- Moderately Feasible (Score: 3) → Some challenges exist, but approval is likely.
- Difficult (Score: 2) → The process requires significant effort, time, and regulatory compliance.
- Not Feasible (Score: 1) → Approval is highly unlikely or impossible.

From assessment based on Deep Interviews with the Licensing Team, the licensing team provided the following evaluation scores for each option:

- Option 1: Score: 4 (Feasible) – No additional PPKH is needed, as disposal remains entirely within PT BIB's concession.
- Option 2: Score: 4 (Feasible) – Uses PT TIA's existing PPKH, which has already been approved.
- Option 3: Score: 2 (Difficult) – Requires additional PPKH outside PT TIA's existing permit, needing significant government approval efforts.
- Option 4: Score: 2 (Difficult) – Similar to Option 3, requiring new PPKH approvals beyond PT TIA's existing permit, making the process challenging and time-consuming.

Based on these six evaluation criteria, the following summary scores have been compiled for all options:

Table 6. Criteria Values

Alternative Option	OB Cost (k$)	Other Cost (k$)	Cost OHDA (k$)	Disposal Capacity to TIA (m-BCM)	Opportunity Benefit (k$)	Readiness for PPKH
Option 1	-	-	1,391,880	-	-	4
Option 2	590,958	86,648	291,585	201	1,318	4
Option 3	827,143	97,965	445,622	284	21,150	2
Option 4	827,143	98,631	411,525	284	54,582	2

From this, the Value Tree for the criteria is established as follows:

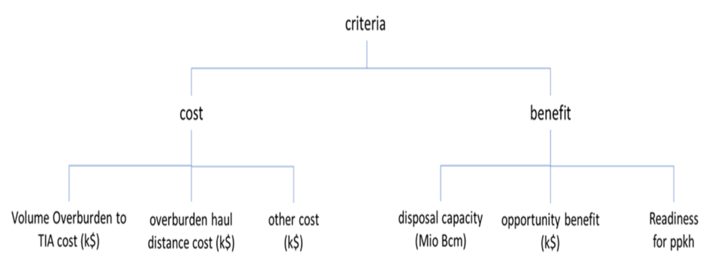

Figure 10. Value Tree

2) Determining Criteria Weights and Normalization

The next step is to determine the weighting of each evaluation criterion based on the benefit criteria previously established. The weights are assigned based on management's priorities, which were gathered through interviews with key decision-makers.

Management agreed to assign a ranking value between 1 and 100 for each criterion. These weights reflect the priority level of each factor in the decision-making process.

a. Disposal Capacity to PT TIA is assigned a weight of 95, as ensuring sufficient disposal space is a critical requirement for the operation.
b. Opportunity Benefit of Collaboration with PT TIA is given the highest weight of 100, as management wants to assess the financial advantage of collaborating with PT TIA versus relying solely on PT BIB's disposal areas.
c. Readiness for Additional PPKH is assigned a weight of 80, as obtaining additional PPKH approvals is challenging but still achievable, making it a significant factor in the evaluation process.

Each evaluation criterion has now been assigned a corresponding attribute value, which will be used for SMART analysis and ranking of the alternative options.

Figure 11. Original Weight of Each Attributes

After determining the weight values for each criterion, normalization is performed to ensure that the weight distribution is proportional and comparable across all evaluation criteria. The normalized weight for each criterion is calculated using the formula:

$$W_n = \frac{W_i}{\sum W}$$

Where:

- W_n = Normalized weight
- W_i = Assigned weight for each criterion
- $\sum W$ = Total sum of all assigned weights

Using the weights determined from management's prioritization, the normalization process is applied to each criterion to establish fair and balanced comparisons between the different options in the decision-making process.

Here are the results of the normalized weight calculations:

Table 7. Normalized Weighted for Each Attribute

Attributes	Original Weight	Normalized Weight
Disposal Capacity to PT TIA	95	0.345
Opportunity Benefit of Collaboration with PT TIA	100	0.364

Attributes	Original Weight	Normalized Weight
Readiness for Additional PPKH	80	0.291

3) Calculate Aggregate of Weighted Value

Based on the Benefit and Cost formulas:

- **Benefit Formula:**

$$u_i(a_i) = \left(\frac{c_{out} - c_{min}}{c_{max} - c_{min}}\right) \times 100\%$$

- **Cost Formula:**

$$u_i(a_i) = \left(\frac{c_{max} - c_{out}}{c_{max} - c_{min}}\right) \times 100\%$$

To determine the best option, the selection process is based on benefit criteria. Using these formulas, the values for each benefit criterion are calculated as follows:

Table 8. Total Weight Value

Alternative Option	Disposal Capacity to TIA	Opportunity Benefit	Readiness for PPKH
Option 1	0	0	100
Option 2	70.77	2.41	100
Option 3	100	38.75	100
Option 4	100	100	0

This table summarizes the weighted values for each alternative option based on the Disposal Capacity to TIA, Opportunity Benefit, and Readiness for PPKH criteria.

4) Calculate Aggregate of Weighted Value

The final value for each benefit criterion is determined by multiplying the normalized criterion values with their respective normalized weight values. The results are then summed up to obtain the aggregate weighted value.

The formula used for this calculation is:

$$u(a_i) = \sum_{j=1}^{m} w_j * u_j(a_i)$$

Where:

- $u(a_i)$ → The final **aggregate weighted value** for an alternative option a_i.
- w_j → The **normalized weight** of criterion j, which represents the importance of each evaluation criterion.
- $u_j(a_i)$ → The **normalized performance score** of option a_i under criterion j.
- m → The total number of evaluation criteria.

Based on this formula, the final calculated values are as follows:

Table 9. Final Value

Alternative Option	Disposal Capacity to TIA	Opportunity Benefit	Readiness For PPKH	Aggregate of Weighted Value
Option 1	0.00	0.00	29.09	**29.09**
Option 2	24.45	0.88	29.09	**54.42**
Option 3	34.55	14.09	0.00	**48.64**
Option 4	34.55	36.36	0.00	**70.91**

This table presents the final weighted values for each alternative option, allowing for the selection of the most optimal choice.

5) Ranking

The weighted values for each option are aggregated to determine the best alternative for the Pit Kusan mine planning, with rankings displayed in Table 11. The next step involves an accuracy analysis using the SMART method, where the sum of all values is calculated, resulting in an accuracy level of 99.95%. This confirms the high precision of the criteria in selecting the optimal option for the 2025-2029 planning period. Based on the rankings, Option 4 emerges as the best choice, featuring collaboration between BIB and TIA, with a combined disposal capacity of 284 million BCM in TIA, necessitating the construction of two bridges and additional PPKH approval. The second-best option also involves collaboration with TIA but has a lower disposal capacity of 201 million BCM and requires only one bridge, without the need for extra PPKH approval.

Table 10. Ranking

Alternative Option	Disposal Capacity to TIA	Opportunity Benefit	Readiness For PPKH	Aggregate of Weighted Value	Ranking
Option 1	0.00	0.00	29.09	29.09	**4**
Option 2	24.45	0.88	29.09	54.42	**2**
Option 3	34.55	14.09	0.00	48.64	**3**
Option 4	34.55	36.36	0.00	70.91	**1**

6) Provisional Decision: Trading Benefit vs Cost

In making a provisional decision, a cost-benefit comparison is used by employing visual tools such as graphs and tables to identify the most favorable alternative option.

As shown in Table 12, the total cost in k$ for each alternative is as follows:

- Alternative 1: k$ 1,391,880
- Alternative 2: k$ 966,498
- Alternative 3: k$ 445,622
- Alternative 4: k$ 411,522

Additionally, Table 12. presents the comparison between Total Cost (k$) and Aggregate Benefit, serving as the basis to guide final decision-making in the SMART analysis framework. This visual and quantitative comparison ensures a more transparent and justifiable selection process aligned with the organization's strategic objectives.

Table 11. Total Cost (K$)

Alternative Option	Cost OB (K$)	Other Cost (K$)	Cost OHDA (K$)	Total Cost (K$)
Option 1	-	-	1,391,880	1,391,880
Option 2	590,958	86,648	291,585	969,191
Option 3	827,143	97,965	445,622	1,370,730
Option 4	827,143	98,631	411,525	1,337,299

Table 12. Total Cost (K$) vs Aggregate Benefit

Alternative Option	Total Cost (K$)	Aggregate Benefit
Option 1	1,391,880	29.09
Option 2	969,191	**54.42**
Option 3	1,370,730	48.64
Option 4	1,337,299	**70.91**

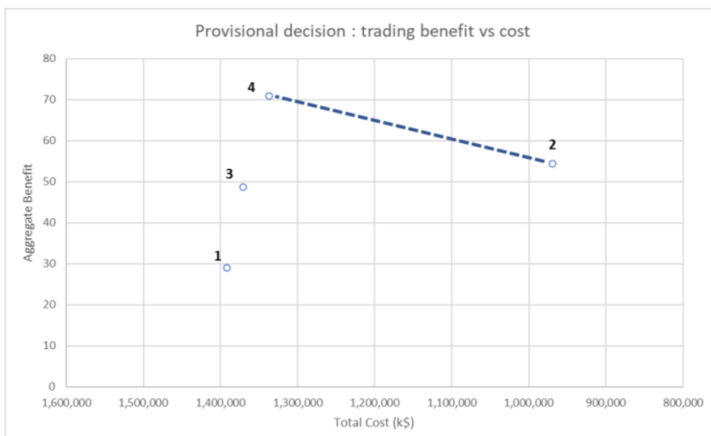

Figure 12. Provisional Decision: Trading Benefit vs Cost

Based on the graph, it can be seen that the alternative option with the highest aggregate benefit is Option 4, followed by Option 2.

To determine whether the increase in benefit is significant enough compared to the rise in cost, a quantitative approach is applied using the concepts of Extra Value per Cost and Cost per Benefit Point

Formula for Cost per Benefit Point:

$$\text{Cost per Benefit Point} = \frac{\text{Total Cost}}{\text{Aggregated Benefit}}$$

Formula for Extra Value Point:

$$\text{Extra Value Point} = \frac{\text{Extra Cost}}{\text{Extra Benefit}}$$

Using these formulas, Table 13. is generated to calculate the Cost per Benefit Point for each alternative.

Table 13. Cost per Benefit point

Alternative Option	Total Cost (K$)	Aggregate Benefit	Cost per Benefit Point (K$/Point)
Option 1	1,391,880	29.0909	47,841
Option 2	969,191	54.4181	17,804
Option 3	1,370,730	48.6360	28,188
Option 4	1,337,299	70.9091	18,857

To calculate the Extra Value Point, the two options with the highest aggregate benefits are selected: Alternative Option 2 and Alternative Option 4.

Calculation of Extra Cost:

Extra Cost = Total Cost of Option 4 – Total Cost of Option 2

Extra Cost = K$ 1,330,348 – K$ 969,191

Extra Cost = K$ 361,157

Calculation of Extra Benefit:

Extra Benefit = Aggregate Benefit of Option 4 – Aggregate Benefit of Option 2

Extra Benefit = 70.9091 – 54.3190

Extra Benefit = 16.5901

Thus, Extra Value Point is calculated as:

Extra Value Point = K$ 361,157 / 16.5901

Extra Value Point = K$ 21,769 per Point

From this calculation, it is concluded that Alternative Option 4 provides an Extra Value Point greater than the Cost per Benefit Point, indicating that Option 4 is the most beneficial when evaluating both cost efficiency and benefit maximization.

Table 14. Extra Value Point between Option 2 with Option 4

Alternative Option		Option 4	
		K$ 1,330,348	70.9091
Option 2	K$ 969,191	**K$ 361,157**	16.5901
Option 4	54.32	**K$ 21,769 /point**	

7) Perform Sensitivity Analysis

Sensitivity analysis is a method used to evaluate the impact of changes in input variables on the outcome of a decision or calculation. In the context of decision-making using the SMART method (Goodwin & Wright), sensitivity analysis is used to observe how changes in factors such as cost, benefit, criterion weights, or other parameters can influence the final decision outcome.

Based on the available data, the analysis was conducted by modifying the benefit value of disposal capacity to zero, and comparing it with the scenario where the PPKH readiness value is set to zero. Table 15. shows the results of these comparative changes, and Figure 13. illustrates the graphical representation of those changes.

Table 15. Aggregate of Weighted Value After Sensitivity Analysis

Alternative Option	Aggregate of weighted value (if Capacity Disposal = 0)	Aggregate of weighted value (Normal)	Aggregate of weighted value (If Readiness for PPKH = 0)
Option 1	44.4444	29.0909	0.0000
Option 2	45.6340	54.3190	35.5780
Option 3	19.0957	47.0444	66.3447
Option 4	55.5556	70.9091	100.0000

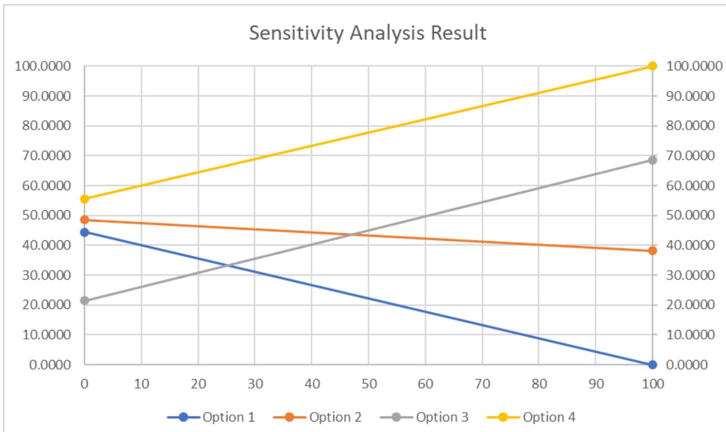

Figure 13. Sensitivity Analysis Result

From the Sensitivity Analysis Result, it can be concluded that if PPKH readiness is not an issue or if disposal capacity becomes zero, then Alternative Option 4 remains the best choice. However, if obtaining PPKH becomes increasingly difficult, then Alternative Option 2 can be considered as an alternative strategy.

CONCLUSION

The answer to research question number 1, this analysis aims to determine the most optimal mining plan for Pit Kusan during the 2025–2029 period, ensuring operational efficiency, cost-effectiveness, and compliance with regulations (PPKH). Based on an in-depth technical, financial, and regulatory analysis, several key challenges were identified in the mine planning process. One major challenge was the revision of the Feasibility Study (FS), where a shift from FS 46 to FS 54 expanded the pit boundaries due to an assumed coal price increase from $36 to $44 per ton, requiring adjustments to the mine planning strategy. Additionally, slope stability limitations restricted disposal heights to 90–100 meters at an overall angle of 5–6 degrees, affecting overburden hauling distance and increasing operational costs. Another major challenge was the limited disposal capacity, requiring assurance of sufficient space to accommodate overburden to achieve the 22 million tons production target by 2029. From a regulatory standpoint, securing the PPKH (Forest Area Utilization Permit) is essential to expand disposal capacity within PT TIA's concession. Infrastructure development is also a key factor in this strategy, particularly the need to build one or more bridges across the Taiwasi River to support overburden transportation. Collaboration with PT TIA in overburden placement is another critical consideration, as such partnerships may offer cost optimization opportunities but require thorough financial and operational assessment.

To address these challenges, six key criteria were defined to evaluate alternative solutions: disposal capacity, overburden hauling distance, total operational costs, regulatory readiness, economic benefits of collaboration, and compliance with environmental and safety aspects. The answer to research question number 2, four disposal strategy alternatives were evaluated using SPRY Scheduling simulation and the SMART (Simple Multi-Attribute Rating Technique) method:

1. Option 1: Disposal only within PT BIB, offering strong regulatory compliance but high operational costs due to long hauling distances and limited disposal capacity.
2. Option 2: Combined disposal in PT BIB and PT TIA with existing PPKH, easing capacity limitations with 201 million BCM at PT TIA and improving haul distance, but limited to one bridge and higher infrastructure cost.
3. Option 3: Combined disposal in PT BIB and PT TIA with PPKH expansion, enabling up to 284 million BCM of disposal while balancing cost and operational feasibility with one bridge. However, it involves complex regulatory challenges due to additional permit requirements.
4. Option 4: Full collaboration with PT TIA with maximum disposal and infrastructure investment, considered the most optimal solution. It combines maximum disposal capacity (284 million BCM), cost optimization, long-term sustainability, and two bridges to reduce haul distance and enhance operational efficiency, though it requires higher initial investment and more complex permitting.

The answer to research question number 3, The Evaluation using SMART, Cost-Benefit Analysis (CBA), and sensitivity testing indicates that Option 4 is the best solution to be proposed by the SPO Department to management and implemented, based on the following considerations:

1. Optimization of 284 million BCM disposal capacity at PT TIA, ensuring long-term operational continuity for the 2025–2029 period.
2. Use of two bridges crossing the Taiwasi River improves haulage efficiency and reduces overburden transport costs.
3. Operational cost optimization: An initial investment of $1,330,348,000 yields an opportunity benefit of $54,582,000, compared to Option 1 (BIB-only dumping) requiring $1,391,880,000 without opportunity benefit.
4. Sensitivity analysis shows Option 4 remains the best under various scenarios, including cost changes, permit delays, and other operational shifts.
5. Option 4 aligns with PT BIB's production targets as mandated by management for long-term financial sustainability.

Taking all of these aspects into account, this study concludes that the collaboration strategy between PT BIB and PT TIA is the best decision to support the sustainable operations of Pit Kusan for the 2025–2029 period, improving cost efficiency and ensuring compliance with PPKH regulatory requirements.

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