OPTIMIZING COAL RESERVES AT PIT MUARA TIGA BESAR UTARA (MTBU) PT BUKIT ASAM TO INCREASE PRODUCTION IN 2025

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Abstract

The mining sector plays a vital role in meeting energy needs and contributing to national export revenues. PT Bukit Asam is a key player in the coal supply chain. One of the primary challenges the company faces is the discrepancy between its internal work plan and budget and the government-approved annual work plan and budget for 2025. This research focuses on determining the most effective strategy to boost coal production in one of its major sites, the Muara Tiga Besar Utara (MTBU) pit. The strategic analysis began with the use of PESTEL and VRIO frameworks to evaluate external and internal conditions. Two strategic options were generated based on this analysis. A cost-benefit analysis was employed for determine the most suitable option. The findings suggest that optimizing the central bottom pit area using alternative 2 is more financially advantageous, surpassing the alternative in financial metrics such as Net Operating Profit Margin (NOPM), Return on Investment (ROI), and Break-Even Point (BEP). Moreover, the sensitivity analysis found that the coal price and the change in operating costs have a large impact on NOCF. There are various phases of implementation of the selected strategy including initial preparation, production optimization, and monitoring, and evaluation. Risk management strategies involve optimizing equipment utilization, using cost tracking on a real-time basis and minimizing the exposure to price fluctuations.

Keywords: Coal Production, Reserve Optimization, Cost-Benefit Analysis, Sensitivity Analysis, Risk Management

INTRODUCTION

The mining industry is critically important to the economy, as it supplies essential raw materials. Coal is particularly necessary as cheap and reliable energy source. In Indonesia, coal plays a double role as source for domestic consumption and export earnings. Being a finite commodity, the coal mining industry does not constitute an attractive investment opportunity and it is extremely sensitive to pricing fluctuations. Despite these challenges, Indonesia successfully boosted its coal production to over 800 million tons in 2024 [1]. It has also managed to meet its export targets and fulfil Domestic Market Obligation (DMO) requirements.

As one of the leading global coal producers alongside China, India, and Australia Indonesia significantly contributes to the world-wide coal supply [2]. Globally and domestically, coal power still remains a primary power, thus making it strategic [3]. Given the elevated coal prices toward the end of 2024, companies such as PT Bukit Asam are in a good position to enhance profitability through production efficiency and maximizing the reserve (pit optimization).

The Annual Work Plan and Budget (RKAB) is a fundamental component in coal mining operations, serving as a blueprint for business, technical, and environmental planning and monitoring. In 2025, PT Bukit Asam has received permit from the government to produce 50 million tons, as mentioned in the RKAB. However, the company internal Annual Work Plan and Budget (RKAP) only targets 48.6 million tons, indicating a production shortfall requiring a strategic solution. With market prices still favorable, the company have the opportunity to maximize its coal reserves. Conducting a cost-benefit analysis is crucial to evaluate the feasibility and economic viability of increasing output to match the approved RKAB target thereby enhancing both production volume and revenue.

This disparity between the RKAB and RKAP highlights a strategic measure that should be made by PT Bukit Asam, especially in the Muara Tiga Besar Utara (MTBU) pit. The purpose of this study is to identify potential strategies that can be executed in the MTBU pit under current operational conditions, evaluate and compare these strategies to select the most effective one, and formulate an implementation plan to support increased coal production.

REVIEW OF LITERATURE

Chapter Review: Strategies for Optimizing Coal Reserves and Enhancing Production

This chapter examines various studies that concern to the optimization of coal reserves and strategies to increase coal production. It highlights important aspect essential for creating effective optimization methods.

2.1 Coal Mining Operations

Coal mining activities in Indonesia are governed by Ministerial Decree No. 1827 K/30/MEM/2018 which provides guidance on processes for land clearance, handling topsoil, remove overburden, extracting coal, stock piling and transporting [4]. Each of these phases demands careful planning and engineering achievement in support of environmentally responsible mining. Each of these phases must align with Good Mining Practices (GMP) taking into account regulatory requirement, environmental sustainability, occupational health and resource efficiency.

Strategic mine planning and pit optimization are the key factors for the maximization of the coal reserve. Hustrulid et al. [5] (2013 define mine planning as the designing of layouts, schedules and pits that maximise the economic reward and minimise the environmental and social consequences. The process involves the geological modelling, resource estimation and production scheduling which are responsible for determining the most economical methods of extraction. Pit optimization is in particular the process of establishing pit shells and depths which allows the greatest exploitation of reserves, with the end goal invariably seeing reserve extracted to a practical base level. These co-ordinated actions ensure that technical working is in line with business goals and sustainability goals.

2.2 Cost-Benefit Analysis

The cost-benefit analysis (CBA) is an important financial method in short-term coal production planning. It is short-term outcome-oriented as it foregoes long-term alternatives and evaluates the value of the strategy of reserve maximization. Net operating profit margin (NOPM), return on investment (ROI) and break-even point (BEP) are the financial performance measures generally used to assess the capability of a proposed strategy to generate the acceptable level of profits [6]. These types of measures help policy makers direct the market to the financial impacts of engineering and production decisions in an uncertain coal market. CBA is also a useful tool for making rational choices about scarce resources, by comparing anticipated benefits and costs. As demonstrated in studies by Locurcio et al. [7] (2022) and Thrikawala et al. [8] (2021), combined with considering of financial risk, so that this method not only can improve the accuracy of strategic planning, but also can reduce the financial risk, which can be well used to judge investment feasibility, especially in large investments areas, such as mining.

2.3 Sensitivity Analysis

Sensitivity is a useful tool for understanding how moves in key inputs affect financial and operational results. This is particularly valuable in high uncertainty sectors like mining. Damodaran [9] (2012) noted that valuation always involves uncertainty due to assumptions about future cash flows, risk, and growth. Sensitivity analysis helps validate these assumptions using scenario-based simulations. Research supports the method effectiveness. Chen [10] (2012) used sensitivity analysis to evaluate investment risks in power plant projects, while Rocco et al. [11] (2021) applied global sensitivity analysis in manufacturing to identify uncertainty drivers and optimize system performance. These cases illustrate how the technique not only enhances project reliability but also enables data-driven, risk-informed decision-making.

2.4 Risk Management Analysis

Risk management involves systematically identifying, evaluating, and mitigating potential threats and opportunities that could impact organizational goals [12]. Effective risk management supports not just loss prevention but also better decision-making and enhanced operational performance [13]. It is applicable across sectors. For example, Silk and Dash [14] (2008) pointed out that it was essential to enhancing the reliability and quality of decision in aerospace sector. Risk in the mining sector is high, and the unforeseen quickly becomes the expected, so risk management is important. Darmansyah et al. [15] (2025) showed that robust risk management approaches significantly improve financial performance by addressing solvency-related risks. These examples highlight how risk management supports both operational resilience and strategic alignment key considerations for sustainability in high-risk industries like mining.

2.5 Conceptual Framework

Companies need to develop holistic strategies, which focus on the technical, operational and financial dimensions, in order to close the gaps between regulatory requirements and operational capabilities. Coal reserve optimisation is a fundamental solution that makes it possible to balance production capacity, regulatory needs, and market conditions. Maximize recovery with targeted pit optimization, smart mine planning and selective scheduling, you can maximize resource recovery. But these efforts must be complemented by economic analyses to enable technical strategies to be financially sustainable. Adding risk management framework makes decision making even better by predicting uncertainty and allowing for proactive mitigation. By doing this, companies can find the right balance between compliance, operational efficiency, and profitability, which will help companies stay competitive in a volatile coal market.

RESEARCH METHOD

This study seeks for a strategy to maximize the coal reserve at the Muara Tiga Besar Utara (MTBU) Pit of PT Bukit Asam. The company is trying to increase coal production for an RKAP-RKAB gap closer in 2025. The study begins by identification of business issue and gathering data through interviews with internal stakeholders and reviews of corporate document. PESTEL analysis is used for evaluation of the external factors and VRIO model is employed to determine company resources and competences for competitive advantage. This intelligence provides a unified model of the competitive business environment and two different strategies. For each of the considered strategies, a cost-benefit analysis is used to assess economic viability. These findings are additionally questioned in a sensitivity analysis for the robustness. Finally, the conclusion encompasses action plan and risk management required for successful realization of strategy.

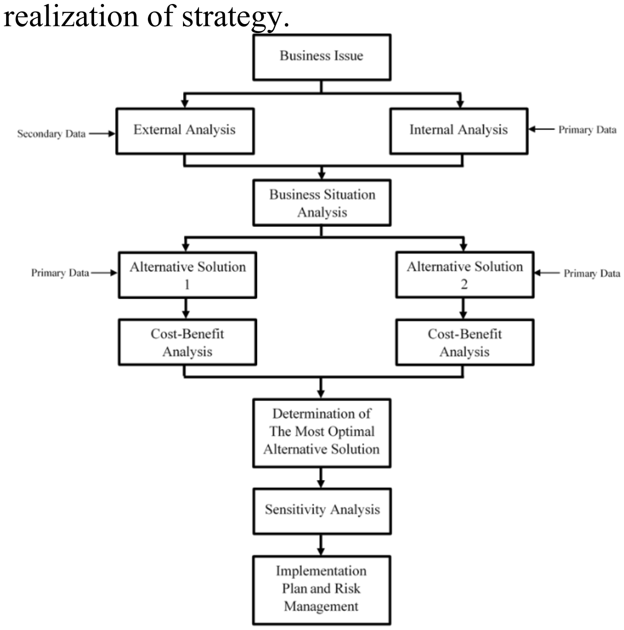


Figure 1.
Research Design

The study results are from internal and external sources. The research considers PESTEL and VRIO as the frameworks to analyze external conditions and internal resources, and examine implementation of optimization coal reserves. Additionally, cost-benefit analysis, sensitivity analysis and risk management: the fore mentioned methodologies are employed to ensure that the proposed methods are potentially feasible and best practice. The following sections describe in detail each analytical approach applied in the study.

1. PESTEL Analysis

PESTEL analysis is a strategic tool to analyze the macro environment of the organization. As Johnson et al. (2008), based on this model tries to identify external threats and opportunities and for those focuses on six factors: Political, Economic, Social, Technological, Environmental and Legal. Political factors comprise of government regulations, trade policies, tax laws and the stability of the political climate that give to determine the legal and operation environment. Economic elements cover inflation, GDP trends, interest rates, currency fluctuations, and employment levels that impact business operations and consumer behavior. Social dimensions relate to cultural shifts, demographic patterns, education, and evolving lifestyles that influence labor markets and customer preferences. Technological: Relate to levels of automation and digitization and attitudes to innovation that may or may not challenge existing business models for efficiency. Concerns about the environment, climate change, resource depletion and sustainable regulations drive businesses to implement green strategies. Last, a legal perspective considers the formal framework and regulations that firms should also consider in their strategic and operational decision-making.

2. VRIO Analysis

The VRIO (Value, Rarity, Imitability, and Organization) framework is a set of questions that can be asked about a resource or capability to determine whether it can be the basis of a long-term advantage. A resource provides value when it allows the company to capture opportunities, or lower costs, so becoming a stronger market player (Rothaermel, 2015). The rarity of the resource This means the resource isn't commonly available to the competitors. But if an asset can be easily duplicated, its lead time is likely to be fleeting. The Imitability factor is concerned with the ease at which competitors can imitate the resource as the result of unique processes of development or complex social networks. The Organization point of view closes examining, whether the organization has in place right systems, leadership and structures to exploit the resource to the full extent. It is the intersection of these 4 elements that will determine if a company is on its way to a competitive disadvantage, parity or advantage in the long-run. Thus, VRIO can be a valuable model for capturing internal resources and for generating sustainable advantage in the long run.

3. Cost-Benefit Analysis

A definite financial study is essential to short-term coal reserve optimization plans (pit deepening) to prove profit and workability. Cost-Benefit Analysis (CBA) is used to assess whether the proposed strategies are economic feasible. This research focuses on short-term performance indicator such as Net Operating Profit Margin (NOPM), Return on Investment (ROI) and Break-Even Point (BEP). These measures provide us with direct and compelling evidence of where the money will come out on the proposed activities. Each of these metrics is discussed in greater detail in the next section, offering a framework for determining whether coal reserve optimization could be possible over the short term.

A. Net Operating Profit Margin (NOPM)

Net Operating Profit Margin (NOPM) measures a company's ability to realize profit from its operations, along with effects ranged from operating expenses. It is interest, taxes, and other non-operating items (nonrecurring charges) from the business value, which presents a picture of operating efficiency. The calculation is as follows:

(1)

$$Operating\ Proft\ Margin\ (NOPM) = \frac{Operating\ Profits}{Sales}$$

B. Return on Investment (ROI)

ROI measures how effectively a business uses its investment to generate income, by comparing the net income earned with the total amount invested. This is just a part of the reason why "simple ROI" has proven to be one of the most popular tools used in early-stage financial analysis (Brealey, Myers, & Allen [18], 2020). In industries with extensive capital requirements, such as mining, the terms ROI and Return on Assets are often synonymous. The formula is as follows:

(2)

$$ROI(ROA) = \frac{Earning\ available\ for\ common\ stakeholders}{Total\ Assets}$$

C. Break-Even Point (BEP)

The Break-Even Point (BEP) represents the amount of output or sales for which a firm generates just enough revenue to cover its total costs without making any profit. This becomes crucial for capital-intensive industries such as mining; not achieving a break-even point may lead to significant financial risk. The BEP can be calculated using the following formula:

(3)

$$BEP\ (Units) = \frac{Fixed\ Costs}{Price\ per\ Unit - Variable\ Cost\ per\ Unit}$$

4. Sensitivity Analysis

This research employs sensitivity analysis to investigate the impact of changes such as fluctuations in coal prices, operating costs and labor strength on financial feasibility of the project. The process is necessary to find the variables with the greatest effect on profit and to predict the amount of potential financial risk in the event of bad conditions (Damodaran 2012). Sensitivity analysis is important for the coal mining industry which is prone to price volatility that helps to predict the risk and management to create robust plans against letting the organisation standing still in the face of industries uncertainties.

5. Risk Management Analysis

Risk management is a logical, systematic process of identifying, analyzing, evaluating, and responding to risks that threaten the ability of the organization to achieve its objectives. These risks may be associated with either favorable or adverse effects, depending on whether the uncertainty affects firm behavior. It usually involves four key stages: identification of risk, risk analysis, risk evaluation, and risk mitigation. An industry that finds itself particularly susceptible is mining, due to exposure to uncontrollable factors such as weather changes, changing input prices and fluctuating market prices, an established risk management model is required. Using guidance such as ISO 31000:2018, businesses can develop effective strategies to prevent the threat of catastrophic risk, maintain operational stability, and remain disciplined in the pursuit of immediate and enduring success.

RESULTS AND DISCUSSION

The results of coal reserve optimization in Pit Muara Tiga Besar Utara (MTBU) are reported in this chapter which is based on primary data and secondary obtained as described in the methodology section. The objective is to find strategic alternatives to optimize coal production, fill the gap between RKAP and RKAB, and to assess the feasibility of such alternatives in order to form the best business strategies and its implementation.

4.1. Business Situation Analysis

4.1.1. External Analysis: PESTEL

The external analysis is concerned with factors that affect the market, regulations and economy that might affect the company and constrain in its success. PESTEL analysis highlights the most significant external factors impacting on PIT MTBU and includes political, economic, social, technological, environmental and legal references. Politically, government regulations such as Ministerial Decree No. 139.K/HK.02/MEM.B/2021 require a minimum of 25% domestic coal allocation, with penalties for non-compliance. The demand from China is expected to keep running till 2026, offering short-term prospect of exports even if they did crash after 2027. Economically, world coal price fluctuation directly affects revenue and cost structure of PT Bukit Asam. Firm demand from top importers China and India and domestic infrastructure development provides good grounds for production gains and maximizing coal reserves.

In terms of social aspect, the increasing public and driving companies to adopt more transparent and responsible processes that extend into CSR programs and relations with local communities as a means to reduce risks in relation to the activities of the company. Technologically, such as automation and IoT-based field monitoring technology, improves efficiency and safety. Environmentally, PT Bukit Asam also faces growing pressure regarding its emissions and the responsible treatment of mining waste (such as acid mine drainage). Strictly speaking, the company is subject to multiple national regulations including government regulations No55, 22, 96 of 2021 as well as requirements of a rigorous nature included in ministerial decree No1827. K/30/MEM/2018, both of which posted the operational and environmental obligations.

4.1.2. Internal Analysis: VRIO Framework

The internal analysis evaluated PT Bukit Asam key resources and capabilities related to coal reserve optimization at Pit MTBU. Data from interviews with mining unit managers, mine planners, and geologists revealed both tangible and intangible assets that enhance operational effectiveness. Tangible assets include the Coal Reserve Optimization Area, characterized by calorific value that has low sulphur content; a well-managed fleet supported by advanced equipment management systems; efficient stockpile infrastructure; and a cost structure designed to maximize profitability through operational efficiency. Intangible assets encompass skilled mine engineers, internationally recognized coal brands known for consistent quality, and dependable mining contractors engaged through performance-based contracts. These resources are vital for ensuring production stability, improving reserve recovery, and sustaining long-term operational success.

Table 1.
VRIO Analysis (Author, 2025)

Resource	Valuable	Rare	Costly to Imitate	Organized to Capture Value	Competitive Sequence
Tangible Assets					
Coal Reserve Optimization Area	✓	✓	✓	✓	Sustained Competitive Advantage
Equipment Population	✓	✗	✓	✓	Competitive Parity
Mining Infrastructure	✓	✗	✓	✓	Competitive Parity
Financial Performance	✓	✗	✗	✓	Competitive Parity
Intangible Assets					
Mine Engineers	✓	✓	✓	✓	Sustained Competitive Advantage
Coal Brands	✓	✓	✓	✓	Sustained Competitive Advantage
Mining Contractors	✓	✗	✓	✓	Competitive Parity

Based on the VRIO analysis, certain resources were identified as sources of sustained competitive advantage. The Coal Reserve Optimization Area, skilled Mine Engineers, and reputable Coal Brands satisfy all VRIO criteria being valuable, rare, difficult to imitate, and well-organized, enabling PTBA to maintain a strong long-term market position and operational excellence. Other assets, including Equipment Population, Mining Infrastructure, Financial Performance, and Mining Contractors, fall under competitive parity. Although they contribute value and support operations, these resources are more easily replicated by competitors. By capitalizing on its strategic assets and improving operational efficiency, PT Bukit Asam is well equipped to enhance coal production and narrow the gap between RKAP and RKAB in 2025.

A summary of the external and internal analyses for the coal reserve optimization project at Pit Muara Tiga Besar Utara (MTBU) by PT Bukit Asam is provided in the tables below.

Table 2.
Summary of External Analysis (Author, 2025)

Factor	Analysis	Impact
Political	The Indonesian government has implemented Domestic Market Obligation (DMO) and increasingly strict environmental policies, affecting PTBA production strategy and export market.	High
Economical	The fluctuating global coal prices create opportunities to increase production when prices are high, but also require cost efficiency to remain competitive.	High
Social	Public awareness of the environmental impact of mining operations requires PTBA to adopt sustainable strategies and enhance Corporate Social Responsibility (CSR).	Moderate
Technological	The implementation of digital technology in operational monitoring and production optimization can improve efficiency and operational effectiveness.	Moderate
Environmental	PTBA must manage the environmental impact of mining operations, including waste management and energy conservation, to comply with regulations and maintain its corporate image.	High
Legal	Changes in regulations and permit requirements can affect PTBA production planning and long-term investments.	High

Table 3.
Summary of Internal Analysis (Author, 2025)

Factor	Analysis	Impact
PTBA Competitive Advantage	PTBA has large coal reserves with competitive quality.	High
Resource Optimization	The evaluation of coal reserves and the implementation of pit optimization strategies allow for increased production without significant new exploration.	High
Infrastructure and Equipment Readiness	An efficient heavy equipment management system and infrastructure support productivity, but further optimization in equipment usage is needed to reduce operational costs.	Moderate

Factor	Analysis	Impact
Human Resources and Technology Capabilities	The competency of PTBA mining planning and geotechnical engineering teams plays a key role in resource optimization, but further efficiency improvements are needed.	Moderate
Financial Performance	PTBA has a competitive cost structure, but challenges in maintaining profit margins amid coal price volatility need to be addressed through cost efficiency.	High

4.2. Business Solution

4.2.1. Alternative Solution

The first alternative involves optimizing coal reserves by focusing on maximizing the extraction of reserves situated in the western bottom section of Pit Muara Tiga Besar Utara (MTBU), specifically within the elevation levels ranging from RL -64 to RL -72.

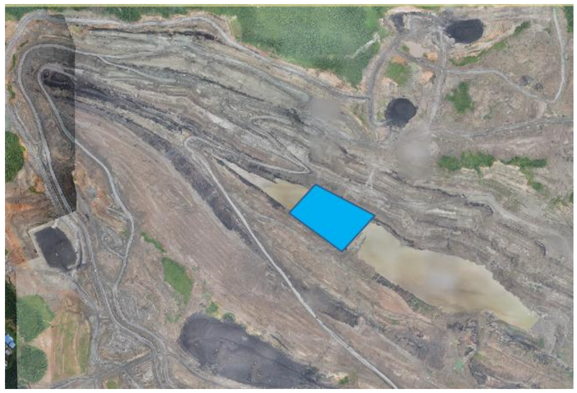
Figure 2.
Coal Reserve Optimization Area – Alternative Solution 1

This option is projected to increase coal production by an additional 823,724.53 tons and will require moving an extra 626,953.13 BCM of overburden. Overall, the optimized production is estimated to reach 5,582,724.53 tons of coal, with a total overburden removal of 40,776,953.13 BCM, resulting in a stripping ratio of 7.30.

Table 4.
Alternative Solution 1 Summary

Alternative Solution 1	RKAP	Optimization	Post-Optimization
Coal (Ton)	4,750,000.00	832,724.53	5,582,724.53
Overburden (BCM)	40,150,000.00	626,953.13	40,776,953.13
Stripping Ratio	8.45	0.75	7.30

Alternative solution 2 involves optimizing coal reserves by focusing on the central bottom pit area of Pit Muara Tiga Besar Utara (MTBU), specifically within the elevation range of RL -88 to RL -96.



This alternative solution is projected to add 563,908.50 tons to coal production, necessitating an extra 269,274.10 BCM of overburden removal. Overall, the optimized production is estimated at 5,313,908.50 tons of coal, with a total overburden removal of 40,419,274.10 BCM, resulting in a stripping ratio of 7.61.

Table 5.
Alternative Solution 2 Summary

Alternative Solution 2	RKAP	Optimization	Post-Optimization
Coal (Ton)	4,750,000.00	563,908.50	5,313,908.50
Overburden (BCM)	40,150,000.00	269,274.10	40,419,274.10
Stripping Ratio	8.45	0.48	7.61

4.2.2. Cost-Benefit Analysis

After developing two alternative strategies for optimizing coal reserves, a cost-benefit analysis is performed to evaluate the economic feasibility of each option by comparing the benefits against the associated costs. To ensure fairness and consistency in comparison, several assumptions are applied equally to both alternatives: projected revenues including coal prices, taxes, and royalties are considered the same; the project implementation is scheduled for the dry season of 2025 (June to October) to minimize weather-related disruptions and improve efficiency; financing is assumed to come entirely from internal funds; 25% of total coal production is allocated to the domestic market at a fixed price as per the Domestic Market Obligation (DMO) policy outlined in Ministerial Decree No. 399.K/MB.01/MEM.B/2023, with the remaining 75% expected to be sold at the projected Coal Benchmark Price (HBA); and it is assumed that all necessary supporting infrastructure such as haul roads and stockpile facilities is fully available and in good condition. Given these assumptions, the Net Operating Profit Margin (NOPM) will be used to evaluate the operational profitability contributed by each alternative.

4.2.2.1. Net Operating Profit Margin (NOPM)

Using the formulas presented in Chapter 3, the calculation results are as follows:
a. Alternative Solution 1

Table 6.
Alternative Solution 1 Operating Cashflow

Description	Amount
Revenue	IDR 5,195,237,677,886.10
Operating Costs	IDR 3,740,529,567,129.19
Gross Profits	IDR 1,454,708,110,756.90
Tax & Royalty	IDR 598,830,283,417.90
Net Operating Cashflow	IDR 855,877,827,339.01
Net Operating Profit Margin	16.47%

The total revenue from coal production at Pit MTBU amounts to IDR 5.19 trillion, with operating expenses totaling IDR 3.74 trillion. After accounting for taxes and royalties of IDR 598.83 billion, the net operating cash flow stands at IDR 855.88 billion. This results in a Net Operating Profit Margin (NOPM) of 16.47%, indicating that 16.47% of the revenue is retained as operational profit. This margin demonstrates the favorable financial outcome of the reserve optimization strategy, although there remains potential to further enhance profitability.

b. Alternative Solution 2

Description	Amount (IDR)
Revenue	4,946,556,595,387.82
Operating Costs	3,451,537,685,257.00
Gross Profits	1,495,018,910,130.82
Tax & Royalty	570,172,993,221.20
Net Operating Cash Flow	**924,845,916,909.62**
Net Operating Profit Margin	**18.70%**

The total revenue amounts to IDR 4.95 trillion, accompanied by lower operating expenses of IDR 3.45 trillion. With taxes and royalties estimated at IDR 570.17 billion, the resulting net operating cash flow stands at IDR 924.85 billion. This leads to a higher Net Operating Profit Margin (NOPM) of 18.70%, indicating that a larger share of the revenue is retained as profit compared to the first alternative. The increased profit margin reflects greater operational efficiency and highlights the financial strength of Alternative 2, making it the more advantageous option for optimizing coal reserves.

4.2.2.2. Return on Investment (ROI)

Based on the formulas presented in Chapter 3, the calculation results are as follows:

Indicators	Alternative 1	Alternative 2
Return on Investment	38.89%	43.31%

As illustrated in Table 8, the Return on Investment (ROI) for Alternative 1 is 38.89%, while Alternative 2 achieves a higher ROI of 43.31%. This implies that for every IDR 1 invested, Alternative 1 returns a profit of IDR 0.3889, whereas Alternative 2 generates IDR 0.4331. Alternative 2 has a better ROI, so it is more likely to be cost-effective. These observations provide additional support for the economic justification of choosing

Alternative 2 and show that it is a project that can provide large returns in a one-year time frame.

4.2.2.3. Break-Even Point (BEP)

Based on the formulas presented in Chapter 3, the results are as follows:

Indicators	Alternative 1	Alternative 2
Break-Even Point (Ton)	745,691.42	740,036.57

As presented in Table 9, the Break-Even Point (BEP) for Alternative 1 is 745,691.42 tons, while Alternative 2 demonstrates a lower BEP of 740,036.57 tons. This suggests that Alternative 2 can reach profitability with a smaller production volume, highlighting its superior cost efficiency. A lower BEP minimizes financial risk, particularly in situations where actual output may fall short of expectations. Therefore, Alternative 2 is deemed more advantageous, as it offers a higher safety margin and a greater likelihood of achieving profitability within the project timeframe.

4.2.2.4. Summary of Alternative Solutions

Comparative analysis was performed based on the three performance measures namely Net Operating Profit Margin (NOPM), Return on investment (ROI) and Break-Even Point (BEP) to select an appropriate strategy. An elevated NOPM and ROI indicate enhanced profit-making and investment-efficiency contribution and, on the contrary, a lower BEP indicates superior cost efficiency and lesser financial exposure.

Indicators	Alternative 1	Alternative 2	Decision
NOPM	16.47%	18.70%	Alternative 2
ROI	38.89%	43.31%	Alternative 2
BEP (Ton)	745,691.42	740,036.57	Alternative 2
Final Decision			**Alternative 2**

As outlined in Table 10, Alternative 2 consistently outperforms Alternative 1 across all key indicators: it achieves a higher Net Operating Profit Margin (NOPM) of 18.70% compared to 16.47%, a greater Return on Investment (ROI) of 43.31% versus 38.89%, and a lower Break-Even Point (BEP) of 740,036.57 tons compared to 745,691.42 tons. These results clearly demonstrate that Alternative 2 delivers stronger financial and operational outcomes. It not only yields higher profitability and investment returns but also minimizes the production threshold required to reach break-even, thereby reducing vulnerability to production shortfalls. Consequently, Alternative 2 is identified as the most effective strategy for coal reserve optimization at the Muara Tiga Besar Utara (MTBU) Pit to support the targeted production increase in 2025.

4.2.2.5. Sensitivity Analysis

After selecting Alternative 2 as the most optimal approach, a sensitivity analysis was performed to assess how resilient this strategy is to changes in key variables, including coal selling price, operating costs, and production volume. As shown in Figure 4, fluctuations in coal prices have the most pronounced effect on Net Operating Cash Flow (NOCF). A 10% decline in price significantly reduces NOCF to IDR 487.21 billion, while a 10% increase boosts it to IDR 1,362.48 billion emphasizing coal price volatility as the most critical financial risk factor.

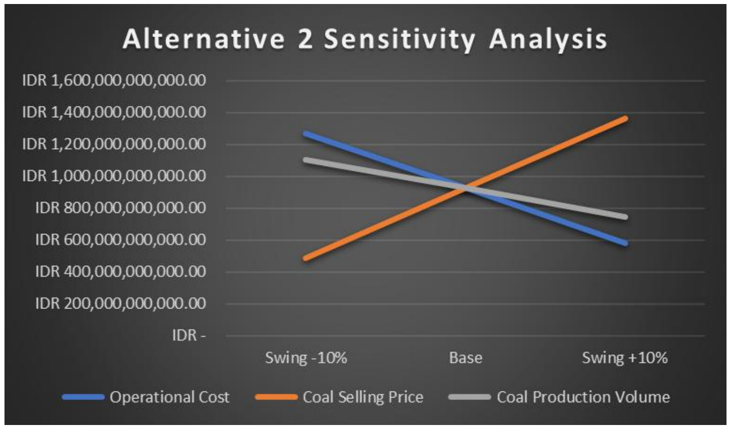


Figure 4.
Spider Chart – Sensitivity Analysis of Alternative 2

Operating costs also have a significant impact. A 10% decrease in operating costs boosts Net Operating Cash Flow (NOCF) to IDR 1,269.99 billion, while a 10% increase lowers it to IDR 579.69 billion, underscoring the critical importance of maintaining cost efficiency. In comparison, changes in production volume have a more moderate influence: a 10% drop results in an NOCF of IDR 743.79 billion, while a 10% increase raises it to IDR 1,195.90 billion. With a baseline NOCF of IDR 924.85 billion, the analysis confirms that Alternative 2 ensures financial stability under standard conditions. However, effective risk management, particularly in response to coal price fluctuations remains essential for sustaining profitability.

4.2.3. Implementation Plan and Risk Management

4.2.3.1. Implementation Plan

The optimization of the coal reserve of Pit Muara Tiga Besar Utara (MTBU) would proceed through the three main stages namely the initial preparation, production optimization, and monitoring. Pre-stripping the pit, preparing the ramps and dewatering would take place from January to May. This step is accomplished with the cooperation of mine planning engineer, geotechnical engineer, dewatering section and mining operation people. The production optimization phase is planned to occur during the period of June until October so that minimum weather impact can be expected. During this time, mining and safety teams will be watching coal production closely and ensuring it complies with HSE regulations.

From November through December, the focus will shift to evaluating the actual NOCF against projected targets and conducting performance reviews to inform planning for the following year. This phase will involve cooperation between the mine planning, operations, and finance teams. A comprehensive schedule and role distribution for each phase are detailed in Appendix 1 Implementation Plan for Coal Reserve Optimization.

4.2.3.2. Risk Management

It is critical to identify and manage threats, which might influence the project outcome, in order to successfully implement the coal reserve optimization strategy at Pit Muara Tiga Besar Utara (MTBU). The next section shows the major risks to be addressed in the course of Implementation and includes the counter-narcotics capacity development strategies aimed at mitigating these risks and ensuring increased overall impact of the plan.

Risk Category	Risk Description	Risk Analysis		Mitigation Strategies
		Causes	**Impacts**	
Operational Risk & Production Disruption	Equipment readiness and weather disturbances during production optimization (June–October)	• Limited coal fleet availability • High rainfall • Decreased slope stability	• Delay in stripping and coal extraction • Production targets not achieved	• Ensure availability of heavy equipment (Excavators, Haulers) • Optimize geotechnical measures and dewatering
Cost Overrun Risk	Increase in operational costs	• Hauling inefficiencies during optimization period	• Profit margins and Net Operating Cash Flow (NOCF) decline	• Monitor costs in real-time• • Implement continuous improvement to reduce operational costs
Market Price Risk	Decline in coal selling price despite increased production volume	• Global price volatility	• Revenue decreases despite higher production	• Conduct hedging • Prioritize long-term contracts

Discussions

The production plan of coal at Pit Muara Tiga Besar Utara (MTBU) was determined based on the PESTEL and VRIO both analysis for the identification of external and internal conditions. Two alternative solutions were generated from this study, one being optimizing reserves in the west bottom pit (RL-64 to RL-72) (alternative 1), and the other central bottom pit (RL-88 to RL -96) (Alternative 2). The optimum alternative was identified using the Cost-Benefit Analysis using Net Operating Profit Margin (NOPM), Return on Investment (ROI) and Break-Even Point (BEP) as the performance metrics. The results showed that the Alternative 2 was better than the Alternative 1 in which it obtained the NOPM of 18.70%, the ROI of 43.31%, and the BEP of 740.036.57 tons. These findings indicated that Alternative 2 is the most preferable alternative for enhancing the production at MTBU.

A sensitivity analysis was also performed to observe the impact of changes in the price of coal, operating costs, and production volume on NOCF. It founds that coal price and operating costs had the most significant influence, while changes in production volume had a moderate impact. The stable NOCF of IDR 924.85 billion assuming the base case scenario. However, coal price volatility remains the primary risk, emphasizing the need for strict cost control and efficient operational planning. There are 3 phases to the implementation plan: planning from January to May, production optimisation from June to October, and monitoring from November to December. Risk management identified critical risks such as limitation of availability of equipment, weather-related disruptions, hauling inefficiencies, and market price fluctuations. These risks can be mitigated by ensuring sufficient equipment allocation, improving dewatering and geotechnical measures, conducting real-time cost monitoring, and adopting financial strategies like hedging and negotiating long-term contracts to support project success.

CONCLUSION

The strategy formulated to improve coal production at Pit MTBU in concordance with the present situation was formulated through process intensive internal and external assessments employing PESTEL and VRIO framework. Based on these evaluations, two options resulted: To maximize the coal reserve plan in the western bottom pit (RL -64 to -72) Alternative 1, and the central bottom pit (RL -88 to -96) Alternative 2. A Cost-Benefit Analysis demonstrated that Alternative 2 has a better performance than Alternative 1 on all key indicators, reflecting superior profitability and cost efficiency. A sensitivity analysis validated this finding, which found that coal price and operational costs had the biggest effect. The baseline scenario indicates that the project will make a Net Operating Cash Flow (NOCF) of IDR 924.85 billion, which means that it is financially viable.

The implementation plan is consisting of three stages: an initial preparation phase from January to May, a production optimization phase from June to October, and a monitoring phase from November to December. A risk management assessment was conducted in order to ensure success of the plan, identifying potential risks such as limitation of equipment availability, weather-related disruptions, hauling inefficiencies, and coal price volatility. Common methods to manage such risks include focusing on readying equipment, tightening geotechnical and dewatering controls, tracking costs in real time, driving ongoing operational efficiencies and using financial approaches such as hedging as well as securing long-term contracts.

Recommendations

Based on the analysis, Alternative 2 was chosen due to its superior cost-benefit performance. Given that coal prices, operating costs, and production levels may fluctuate over time, successful implementation requires continuous project monitoring, strong interdepartmental collaboration, and rigorous cost control to prevent budget overruns and delays. The implementation phases include preparing a detailed proposal with pit design specifications (RL -88 to RL -96), obtaining management approval, coordinating activities among mine planning, operations, and finance teams, followed by operational preparations, pit development, and coal extraction. Real-time performance tracking and weekly coordination meetings will facilitate ongoing evaluation and timely adjustments, with a comprehensive review scheduled for Q4 2025 to assess outcomes and inform future planning. It is also recommended that future studies explore the integration of real-time data to support dynamic pit design modifications and examine the environmental and social impacts of short-term production increases to ensure alignment with ESG and sustainability objectives.

Acknowledgments

The completion of this study, titled "Optimizing Coal Reserves at Pit Muara Tiga Besar Utara (MTBU) PT Bukit Asam to Increase Production in 2025," would not have been possible without the invaluable support and guidance of many individuals and organizations. First and foremost, I express my deepest gratitude to Allah SWT, the Almighty, for His continuous blessings and guidance throughout this journey. I also sincerely thank my wife and daughter, Riska Cahya Maulidina and Aluna Nadezhda Sophia Mecca Ahmad, for their unwavering motivation and steadfast support. I am grateful to my parents, in-laws, and family members for their prayers, love, and encouragement, as well as to my sister, brothers-in-law, and sisters-in-law for their support. I extend heartfelt appreciation to PT Bukit Asam for providing the necessary data for this research. My profound thanks go to Mr. Dr. Ir. Asep Darmansyah, M.Si., my academic supervisor, for his ongoing guidance, invaluable advice, and encouragement throughout this project. I also acknowledge the support and camaraderie of my classmates in PTBA Batch 2. Finally, I thank everyone else who has supported me in various ways, though not mentioned individually. I sincerely hope this study contributes meaningfully to both academic knowledge and industry practice. Any constructive feedback and suggestions for improvement are most welcome.

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