

STRATEGIC PLANNING AND ECONOMIC VALUATION FOR SLOPE OPTIMIZATION IN PIT X PT ABC



Dzakkiyyah Nur Khairunissa¹
Institut Teknologi Bandung, Jawa Barat, Indonesia
dzakivah0610@gmail.com

Taufik Faturrohman²
Institut Teknologi Bandung, Jawa Barat, Indonesia
taufik.f@sbm-itb.ac.id

Abstract

This research evaluates two strategic options to extend the life of PT ABC's mature Pit X coal mine beyond its 2027 closure date. The study compares a river relocation plan (Scenario 1) against an integrated approach adding slope depressurization (Scenario 2). The objective is to determine which strategy offers superior economic value under market and regulatory uncertainty. A mixed-methods framework combines PESTEL and VRIO analyses to assess external conditions and internal capabilities, followed by a detailed discounted cash flow (DCF) model using a 13.31% discount rate. Financial results indicate Scenario 2 delivers stronger performance, with an NPV of IDR 2,321.20 billion, an IRR of 60.46%, and a 1.96-year payback period, outperforming Scenario 1 (NPV: IDR 2,283.41 billion, IRR: 40.68%, payback: 7.29 years). The added value stems from improved slope stability, which reduces overburden stripping by 16.4%, increases coal recovery, and lowers land requirements. Sensitivity and Monte Carlo simulations confirm Scenario 2's resilience, identifying production costs and export coal prices as key risk factors. The study provides an integrated strategic financial framework for evaluating mining optimization projects and offers PT ABC a clear recommendation to adopt the slope depressurization strategy. This approach maximizes economic returns while enhancing operational safety and long-term competitiveness.

Keywords: Pit Optimization, Slope Stability, Economic Feasibility, Capital Budgeting, Mining Strategy

INTRODUCTION

Indonesia's economic growth and public welfare depend on dependable and inexpensive power. National electricity generation reached 325,855.69 GWh in 2023, with household consumers accounting for over 40% of total distribution, indicating that residential consumption and economic activity support electricity demand growth (BPS-Statistics Indonesia, 2024). For national energy security and system stability, coal mining is strategic (Ministry of Energy and Mineral Resources, 2024). Coal supplies 67% of power plant fuel in Indonesia, despite energy transition initiatives. In addition, Indonesia's coal industry accounts for 3.6% of GDP and considerable fiscal income. Global coal demand has decreased, but Asia dominates production and consumption, with Indonesia becoming a major thermal coal provider. From 563.73 million tonnes in 2020 to 836.13 million tonnes in 2024, Indonesia became the third-largest coal production after China and India (Ilango & Adhiguna, 2025). An integrated thermal coal mining firm, PT ABC (pseudonym) manages various open pit operations in Southeast Asia's most resource rich coal basin. The business declared 5.77 billion tonnes of geological resources in 2024, including 2.93 billion tonnes of proven reserves for long-term production. In southern Western Indonesia, multi-seam deposits with complicated overburden and difficult hydrological conditions are mined. While PT ABC has grown into downstream infrastructure and energy-related companies, coal still accounts for over 98% of its income in 2024. Portfolio diversity reduces price volatility and demand risk for the firm, which services export and domestic markets.

Pit X, PT ABC's mature operation, was expected to close in 2027. However, recent resource re-evaluations and mine planning updates suggest that an optimized mining strategy that incorporates a 2026 river restoration and relocation program might prolong mine life until 2036. This technique is likely to uncover more mineable deposits, but it requires significant capital investment and execution risks associated to permits, scheduling, and cost escalation. Technical and environmental constraints particularly pit boundary limits, water management, and slope stability become more important in determining economic performance as open-pit mines become older. Pit X groundwater increases pore-water pressure and constrains slope design, possibly raising stripping ratios and decreasing recoverable coal. As an enabling geotechnical investment, a slope depressurization program might improve slope stability, stripping efficiency, and coal recovery. This intervention's economic feasibility is dubious owing to higher capital and operational expenses and technological reliance.

Surface coal mining projects have a long-life cycle and are uncertain, so robust discounted cash flow based valuation frameworks are needed to compare development strategies and identify key value drivers and risks (Hustrulid et al., 2006). For capital budgeting, PT ABC must choose between an optimized mining plan that includes river restoration and an alternate scenario that includes slope depressurization as a geotechnical enabling expenditure. Management needs a consistent and open economic review to evaluate whether slope depressurization's incremental advantages outweigh the costs and dangers under realistic operational and regulatory restrictions. This study compares the economic value of both scenarios using DCF-based capital budgeting, examines the sensitivity of project value to key technical and economic variables, and assesses the probability distribution of project NPV under uncertainty using Monte Carlo simulation to provide an objective basis for investment decision-making in Pit X.

REVIEW OF LITERATURE

Strategic Management

Strategic management provides the conceptual foundation for evaluating long-term investment decisions by linking organizational objectives with internal capabilities and external conditions. It encompasses both external analysis and internal analysis to ensure strategic alignment and competitive positioning. External analysis is commonly conducted using the PESTEL framework, which assesses political, economic, social, technological, environmental, and legal factors that may influence project feasibility and long-term performance (Yüksel, 2012). Internal analysis is grounded in the Resource-Based View, which emphasizes that differences in firm performance arise from variations in resources and capabilities (Barney, 1991). The VRIO framework is used to evaluate whether these resources are valuable, rare, difficult to imitate, and supported by organizational processes, thereby determining their potential contribution to competitive advantage and execution readiness (Barney & Hesterly, 2014).

Slope Stability in Mining

Slope stability is a critical determinant of safety, operational continuity, and economic performance in open-pit mining. Mine planning involves balancing steeper slope designs, which improve resource recovery and reduce stripping ratios, against increased geotechnical risk. Groundwater conditions, particularly pore-water pressure, play a dominant role in slope instability by reducing effective stress and shear strength, especially in high-rainfall environments. As a result, slope depressurization is widely recognized as an enabling measure to improve stability, reduce failure risk, and support economically optimal pit designs in mature mining operations (Reano et al., 2020).

Feasibility Study and Capital Budgeting

Feasibility studies evaluate whether a project is viable from technical, economic, operational, and strategic perspectives before major capital commitments are made. In capital-intensive industries such as mining, feasibility analysis relies heavily on capital budgeting techniques based on projected cash flows rather than accounting profits (Cleland & Ireland, 2007). Discounted Cash Flow (DCF) analysis is the primary valuation method, with Net Present Value (NPV) serving as the main decision criterion, supported by Internal Rate of Return (IRR) and Payback Period (PBP) as complementary indicators (Brigham & Ehrhardt, 2016). Key valuation inputs include cash flow projections, capital expenditure (CAPEX), operating expenditure (OPEX), and an appropriate discount rate that reflects the time value of money and project risk (Brealey et al., 2023).

Risk Management and Uncertainty Analysis

Risk management addresses uncertainty arising from technical, financial, market, and regulatory factors that may cause actual outcomes to differ from expectations. Because deterministic valuation methods assume fixed inputs, modern feasibility studies incorporate quantitative risk analysis to assess robustness under uncertainty (Ward & Chapman, 2003). Sensitivity analysis is used to identify critical value drivers by examining how changes in key assumptions affect valuation results (Pindyck & Rubinfeld, 2018). Scenario-based approaches, particularly Monte Carlo simulation, extend this analysis by generating probability distributions of outcomes such as NPV, thereby supporting more informed decision-making under uncertainty (Avlijaš, 2018).

RESEARCH METHOD

This study adopts a mixed-methods approach using a single-case study design focused on coal reserve optimization at Pit X of PT ABC. The case study approach is appropriate because the research examines an ongoing operational decision within its real organizational context and allows the integration of multiple sources of evidence rather than reliance on a single dataset (Hancock et al., 2021). The unit of analysis is the optimization decision at Pit X, encompassing the evaluation of alternative technical scenarios and their strategic, financial, and risk implications within the firm. The research design integrates qualitative and quantitative analyses in a sequential manner to provide both contextual understanding and measurable evaluation. Qualitative analysis is used to frame the operational setting, validate assumptions, and interpret strategic implications, while quantitative analysis is applied to assess financial feasibility and sensitivity to key value drivers. External conditions are examined using the PESTEL framework to structure macro-environmental influences (Yüksel, 2012), and internal readiness is assessed through VRIO analysis to evaluate whether the firm's resources and capabilities support strategy implementation (Barney & Hesterly, 2019). Alternative technical scenarios are then translated into financial models and evaluated using discounted cash flow techniques, with feasibility assessed through indicators such as Net Present Value and Internal Rate of Return (Damodaran, 2012; Brealey et al., 2020). Finally, sensitivity analysis is conducted to test the robustness of results under changes in key assumptions (Saltelli et al., 2004).

Data Collection Method

This study uses both primary and secondary data to ensure a comprehensive assessment of coal reserve optimization at Pit X. Primary qualitative data were collected through semi structured interviews with internal stakeholders from the Mining, Mine Planning, and Exploration divisions. These interviews were conducted to capture actual operational conditions, geotechnical and hydrogeological constraints, and organizational considerations related to alternatives such as slope depressurization and river restoration. Interview guidelines were used to ensure consistency across respondents, and the full interview protocol is provided. Secondary data were obtained from academic literature, industry reports, and official publications to support external assumptions and financial projections. Macroeconomic inputs, such as inflation rates, are based on official data from Bank Indonesia, while policy and regulatory assumptions are drawn from authoritative sources relevant to coal mining operations. Internal sales and allocation assumptions are applied consistently across scenarios, and key risk variables identified from these sources are later stressed in sensitivity analysis using variation ranges of minus 20 percent to plus 20 percent.

Data Analysis Method

The analysis integrates qualitative interpretation and quantitative evaluation. PESTEL analysis is used to identify external opportunities and risks that may influence project implementation, while VRIO analysis assesses whether internal resources can support value creation and execution capability. Financial feasibility is evaluated through cost-benefit and discounted cash flow analysis to ensure that the proposed optimization strategies are economically viable and aligned with corporate finance principles (Brealey et al., 2019; Koller et al., 2020). Sensitivity analysis is applied to identify the most influential variables affecting project value, thereby supporting informed decision-making under uncertainty.

Capital Budgeting and Cash Flow Analysis

Capital budgeting analysis is conducted using discounted cash flow methods based on incremental project cash flows for each scenario. The financial model incorporates projected revenues, operating costs, capital expenditures, taxes, and depreciation to generate annual free cash flows over the analysis horizon. Project value is assessed using feasibility indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), Modified IRR, payback period, and profitability index, allowing comparison of both value creation and return characteristics across scenarios (Brealey et al., 2019; Koller et al., 2020).

Discount Rate and WACC

The discount rate applied in the discounted cash flow analysis is based on the project’s weighted average cost of capital (WACC), reflecting the blended cost of equity and debt financing. WACC represents the minimum return required to satisfy both investors and creditors and is therefore widely used as a benchmark in capital budgeting decisions (Gitman & Zutter, 2015). Applying WACC ensures that future cash flows are discounted in a manner consistent with the project’s risk profile and financing structure.

Risk and Sensitivity Analysis

Risk analysis in this study is conducted using sensitivity analysis to evaluate how changes in key assumptions affect feasibility outcomes. Sensitivity analysis examines the relationship between uncertainty in model inputs and variation in outputs, thereby identifying the variables that most strongly influence project value (Saltelli et al., 2004). By adjusting major value drivers within a consistent range, the analysis highlights which assumptions require close monitoring, as relatively small deviations in these parameters may materially affect the project’s economic attractiveness.

RESULTS AND DISCUSSION

The exploration of business situational strategies in this chapter are segregated in two folds; external analysis, and internal analysis. For external analysis, the PESTEL tool is to determine the macro-environmental factors that are likely to affect operational performance at Pit X. For internal analysis, the VRIO tool is to assess PT ABC’s resources and competencies and what strategic value they may hold. In consolidation, these two scenarios are sufficient in explaining what the company is presently doing, and aid in the construction of reasonable strategies for advancement.

Table 1.
Business Situation Analysis

External & Internal Factors	Category	Relevance to Pit X	Strategic Impact
Domestic Market Obligation (DMO)	External – Political	Influences production allocation requirements	Requires alignment of production plans to avoid penalties; affects supply flexibility
Global coal demand (China, India)	External – Economic	Determines market absorption of GAR 5000 coal	Supports short-term optimization but introduces long-term demand risk

External & Internal Factors	Category	Relevance to Pit X	Strategic Impact
Environmental and social expectations	External – Environmental/Social	Pressures PT ABC to ensure responsible mining practices	Necessitates environmentally compliant mine designs
Technological advancement (automation, IoT)	External – Technological	Enhances operational control and efficiency	Improves monitoring, productivity, and safety performance
Mining regulations and safety standards	External – Legal	Directly governs mining processes and compliance	Adds operational constraints but stabilizes long-term permit security
High-quality GAR 5000 coal reserves	Internal – VRIO	Core mineral asset of Pit X	Provides long-term economic advantage and supports future expansion
Integrated mine planning & geotechnical capability	Internal – VRIO	Critical for modeling optimization scenarios	Enables accurate decision-making and reduces operational risks
Strong GAR 5000 customer portfolio	Internal – VRIO	Enhances market access and price stability	Sustains revenue certainty and strengthens strategic positioning
Mining infrastructure & equipment readiness	Internal – Competitive Parity	Supports production reliability	Essential operational enabler but not a strategic differentiator
Dewatering & slope depressurization potential	Internal – Competitive Parity	Influences feasibility of future mining phases	Enables deeper optimization scenarios and improves slope stability
Financial discipline and capital budgeting	Internal – Competitive Parity	Ensures funding availability for infrastructure and optimization	Supports long-term investment capacity but is not rare among competitors

Table 1 lists the external and internal elements affecting Pit X's coal reserve optimization business. The study shows that regulatory and commercial issues dominate operational choices from the outside. The Domestic Market Obligation (DMO) and mining regulations limit production flexibility, while global coal demand particularly from China and India supports short-term optimization but introduces longer-term demand uncertainty. Compliance, monitoring, and efficiency are crucial to project profitability due to

environmental, social, and technical constraints that need responsible mining and better operational management.

The internal findings suggest that Pit X has various crucial resources that aid optimisation. High-quality GAR 5000 coal reserves, integrated mine-planning and geotechnical capabilities, and a strong client portfolio provide economic value, decision precision, and revenue stability. PT ABC may pursue optimisation techniques with a solid internal basis thanks to these VRIO-based benefits. Supporting qualities including infrastructural preparedness, dewatering potential, and financial discipline enable rather than differentiate. While these internal circumstances do not provide a competitive advantage, they ensure operational feasibility and reduce execution risk. Internal and external study shows that coal resource optimization at Pit X is strategically possible if regulatory limitations and long-term market uncertainties are controlled.

Capital Expenditures

The financial model's capital expenditure (CAPEX) structure is essential to assessing both optimization scenarios' viability. CAPEX includes all initial investments needed to prepare, develop, and operate the extended pit configuration, including slope depressurization technology and non-depreciable assets like river restoration, dewatering, and land acquisition. CAPEX breakdowns for both scenarios allow cost commitments to be compared and show investment differentials owing to technical differences between the two development methodologies.

Table 2.
Comparison of Capital Expenditures of the Projects

Capital Expenditures (IDR)	Scenario 1	Scenario 2
Non-Depreciable Assets		
River Restoration / Relocation	436,865,492,112.88	436,865,492,112.88
Dewatering & Mud Handling	137,394,669,617.15	137,394,669,617.15
Land Compensation	24,414,603,183.67	15,368,807,265.31
Depreciable Assets		
Slope Depressurization Equipment	–	6,134,651,492.35

The original LOM expansion project involves a three-year river restoration program costing IDR 436,865,492,113. Dewatering and mud-handling must also be done in the first year to prepare the pit for deepening. Project needs IDR 137,394,669,617 in CAPEX to keep the pit's lowest elevation safe for mining. Both possibilities involve land purchase for pit enlargement and river relocation. Scenario 1 requires 80.97 hectares and IDR 24,414,603,184 in CAPEX. Slope-depressurization lets Scenario 2 have a steeper slope and a smaller pitshell. Only 50.97 hectares of land are needed, reducing land acquisition costs to IDR 15,368,807,265. The cost of slope-depressurization equipment, which is only in Scenario 2, is the biggest difference. This cost comprises drilling units, geoelectrical equipment, submersible pumps, piezometer measuring devices, and well monitoring installation components.

Operating Expenditures

PT ABC conducts the mining process by appointing other parties, such as mining contractors, from the mining process in the pit, coal processing, and other indirectly related work activities.

Mining costs consist of the scope of work involved in overburden removal, coal getting, and transportation. The work value per unit of material mined is influenced by the transportation distance from the loading front to the disposal or coal stockpile. Hence more volume of material mined combined with farther hauling distance causing more mining cost.

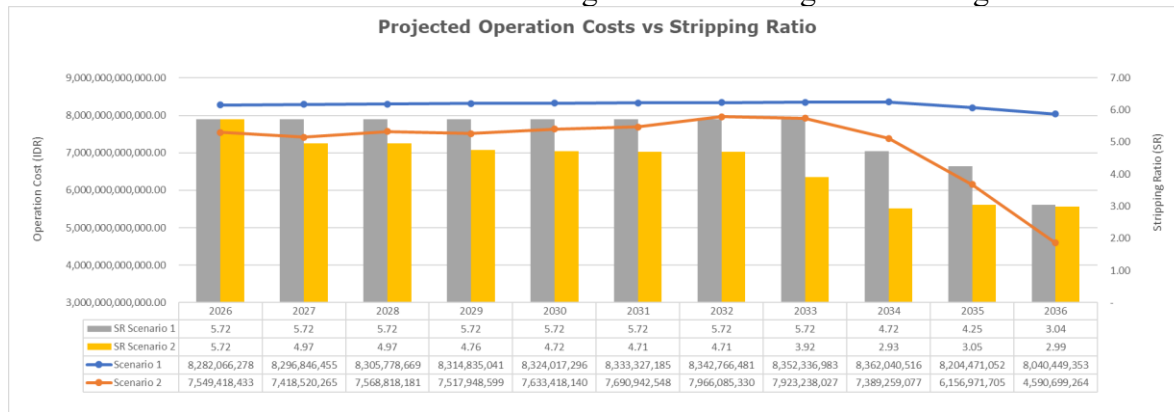


Figure 1
Projected Opex

With the implementation of slope depressurization in Scenario 2, the volume of overburden to be removed is projected to be lower while the coal recovered is projected to be higher compared to Scenario 1. As a result, the stripping ratio (SR) in Scenario 1 is higher than in Scenario 2, which is consistent with the projected operating costs, where Scenario 1 exhibits higher operating expenditures relative to Scenario 2.

Depreciation

Because all used assets will be transferred to the government after mining, straight line depreciation is employed with no salvage value. Only slope depressurisation equipment will be depreciated this way in scenario 2.

Table 3.
Scenario 2 Depreciation Schedule

Year	Depreciation & Amortization (IDR)
2026	0
2027	306,732,575
2028	1,027,595,849
2029	1,037,296,357
2030	1,023,455,050
2031	1,010,305,808
2032	997,814,028
2033	985,946,837

Year	Depreciation & Amortization (IDR)
2034	974,673,005
2035	963,962,866
2036	953,788,233

In this study, the economic evaluation focusses on the incremental cash flows generated by two alternative optimization strategies at Pit X, so existing intangible assets like mining rights, software licenses, and goodwill are identical in both scenarios and largely represent sunk costs that are unaffected by the investment. This research does not simulate amortization since sunk costs and things that do not change between options do not affect the additional net present value of the project, hence they are eliminated from the analysis. The depreciation and amortization schedule above shows asset book value declining throughout the 2026–2036 project timeframe. The expenditure starts in 2027 when depreciable assets become operational and spikes in 2028 when slope depressurization equipment is fully depreciated. Following a straight line technique during the assets' useful life, yearly depreciation decreases steadily. This pattern guarantees that the financial model appropriately incorporates capital investment non cash costs throughout the project lifetime.

Capital Budgeting Analysis

The capital budgeting cash flow analysis used to evaluate the financial feasibility of the two optimization scenarios at Pit X. The analysis consolidates all projected revenues, operating costs, capital expenditures, and non-cash charges into a comprehensive project cash flow framework. It then applies the project's Weighted Average Cost of Capital (WACC) to discount future cash flows, allowing for a time value adjusted assessment of economic performance. Subsequent subsections detail the discounted cash flow (DCF) results and compare the financial outcomes of both scenarios through a structured scenario analysis.

1. Project Cashflow

The cash flow projections show that both optimization scenarios generate positive cumulative net cash flows over the 2026–2036 period, indicating financial viability across the remaining life of Pit X. Scenario 1 produces annual net cash flows that stabilize in the range of approximately IDR 600–800 billion during the later production years, reflecting steady operating performance following the initial investment phase. Scenario 2 exhibits relatively stronger results, with peak annual net cash flows exceeding IDR 1.0 trillion during the mid-to-late mine life, supported by improved stripping efficiency and operational stability. Although Scenario 2 requires higher upfront capital outlays, the higher magnitude and consistency of cash inflows in the production phase suggest superior long-term value generation. These differences in cash flow magnitude and timing provide a clear basis for further comparison using discounted valuation metrics and risk analysis.

2. WACC

a. Cost of Equity

The cost of equity for this project is derived through a series of financial parameters commonly applied in capital budgeting and risk-adjusted valuation. The unlevered

beta is determined at 0.80, representing the underlying business risk of coal mining operations before considering financial leverage. When adjusted for the project's debt-to-equity ratio of 0.62, the resulting levered beta increases to 0.86, reflecting the higher equity risk borne by shareholders under the project's capital structure. The risk-free rate is taken from the 10-year Indonesian government bond yield at 6.31%, while the expected market return is measured at 4.64%. Using these inputs, the baseline cost of equity is estimated at 4.88%. However, when applying the Damodaran equity risk premium of 9.23% which commonly used to reflect broader emerging-market systematic risks, the project's adjusted cost of equity increases to 14.22%.

b. WACC Calculation

In calculating the Cost of Capital for the feasibility of this investment, the Weighted Average Cost of Capital (WACC) is used, or the weighted average cost of capital. The formula used is as follows:

$$WACC = (WD \times CoD \times (1 - T)) + (WE \times CoE)$$

Description:

WD = Debt proportion

WE = Equity proportion

CoD = Cost of debt

CoE = Cost of equity

T = Corporate Tax rate (22%)

therefore:

$$WACC = (8.23\% \times 3.12\% \times (1 - 22\%)) + (91.77\% \times 14.22\%)$$

$$WACC = 13.31\%$$

Discounted Cash Flow of the Project

Discounted Cash Flow is used in this study to evaluate the economic value of each scenario by converting future project cash flows into present value using the project WACC. Given that the two scenarios' cost profiles and timelines are distinct, and because DCF permits a fair comparison regardless of the year in which cash flows, this is important. Annual discounted cash flow and accumulated discounted cash flow are used to display the results. This allows for a clear view of the value movement during the project life. By the conclusion of the analysis period, both scenarios provide positive accumulated discounted cash flow, suggesting that both options are financially viable given the assumptions applied. Scenario 2 is IDR 37,790,584,707 higher than Scenario 1 by 2036, when both scenarios attain a cumulative discounted cash flow of 2,283,411,639,319 and 2,321,202,224,026, respectively. This disparity demonstrates that, after accounting for discounts, the supplementary program in Scenario 2 adds value over Scenario 1.

Capital Budgeting Analysis of the Project

Based on the discounted cash flow, both Scenario 1 and Scenario 2 project positive Net Present Value (NPV), but Scenario 2 yields a positive NPV of 2,321.20 billion IDR, indicating slightly stronger value creation than Scenario 1. The Internal Rate of Return (IRR) reaches 60.46 percent, significantly surpassing the WACC and demonstrating that this scenario delivers a considerably higher return relative to the project's capital cost. The payback period decreases markedly to 1.96 years, with a discounted payback period of only

0.78 years, highlighting the scenario's rapid capital recovery and superior cash-generation profile. The profitability index of 2.76 further reinforces the financial attractiveness of Scenario 2 by indicating that each unit of capital invested generates more than twice its value in present terms. Consequently, Scenario 2 emerges as the more advantageous option when considering both profitability levels and sensitivity to uncertainty.

Table 4.
Comparison of Capital Budgeting Analysis of the Projects

Parameter	Scenario 1	Scenario 2
Payback Period (years)	7.29	1.96
Discounted Payback Period (years)	4.78	0.78
Net Present Value (billion IDR)	2,283.41	2,321.20
Profitability Index	2.69	2.76
Internal Rate of Return (IRR)	40.68%	60.46%

Risk Analysis

1. Sensitivity Analysis

In evaluating investment feasibility under uncertainty, it is necessary to examine how variations in key DCF parameters affect profitability outcomes, particularly the net present value (NPV). Sensitivity analysis helps quantify the extent to which changes in coal price, mining cost, and other operating costs influence overall project viability. By comparing the responsiveness of profitability to these parameters, it becomes clear which variables exert the greatest impact on project value.

To conduct sensitivity analysis and determine how variations affect profitability, several parameters are considered essential, such as:

- Coal Price Realization
- Direct Production Cost Realization
- Quantity Sold Realization
- Inflation Rate
- Exchange Rate

The analysis of the sensitivity of the three factors above to NPV with changes (swing) in parameter values from -20% to +20% can be seen in the Figure below:

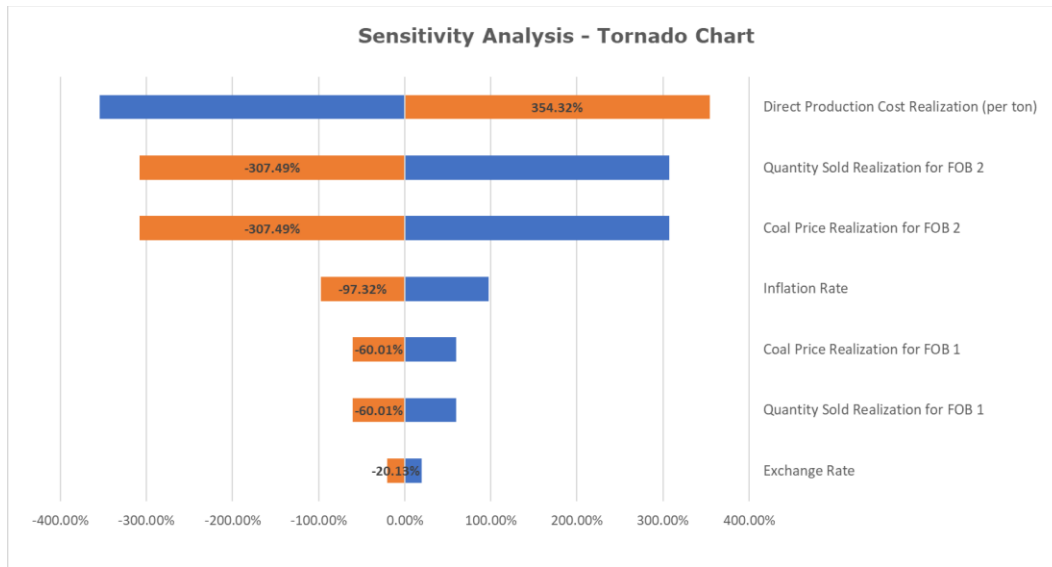


Figure 2
Sensitivity Analysis – Tornado Chart

Figure 2 presents a tornado-style sensitivity chart that ranks the parameters based on their proportional impact on profitability. Direct production cost realization emerges as the most influential variable, followed closely by quantity sold for FOB 2 and coal price realization for FOB 2. These three parameters exhibit the widest ranges, confirming that both production efficiency and FOB 2 market performance represent the critical drivers of financial risk. Variables such as exchange rate, FOB 1 realized price, and quantity sold for FOB 1 appear at the lower end of the chart, indicating comparatively minimal influence on the project’s economic outcome.

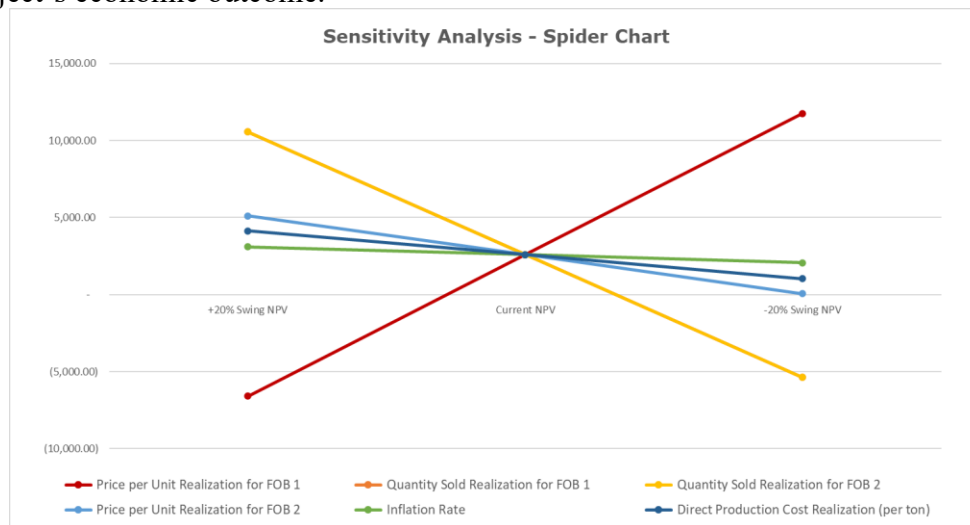


Figure 3
Sensitivity Analysis – Spider Chart

Figure 3 illustrates how the project’s NPV responds to a ±20 percent change in key financial parameters. Among the variables tested, the price realization for FOB 2 shows the largest positive and negative swings, indicating that project profitability is highly sensitive to export coal prices in this market segment. Quantity sold for FOB 2 and direct production costs also produce noticeable NPV movements, although their magnitudes are smaller. In contrast, parameters such as FOB 1 price realization and inflation rate generate more modest variations, suggesting a lower degree of influence on overall project value.

2. Simulation Analysis

The study employs Monte Carlo simulation due to the fact that the assumptions upon which the feasibility conclusions are based are not guaranteed and might undergo changes in actual operations. While sensitivity analysis can reveal the results of a single variable's change, it doesn't account for the reality that multiple variables may change simultaneously and interact. Hence, a probability-based perspective of the project's results is generated by applying Monte Carlo simulation to model several potential combinations of critical drivers. The anticipated outcome, as well as the range of outcomes and the probability of attaining a positive value in the face of uncertainty, can be better understood by management in this way.

Figure 4 shows that Monte Carlo simulation of this financial model produces a wide distribution of possible NPV outcomes for Scenario 2, ranging from approximately – 60,958 to 59,683 in the model’s monetary units. The mean NPV is slightly positive at 1,184, while the median is higher at 2,925, indicating that half of the simulated outcomes lie above this value. The dispersion of results is substantial, as reflected by a standard deviation of about 18,489, which confirms that the project value is highly sensitive to the underlying risk drivers. The distribution is close to symmetric and mesokurtic, with kurtosis around –0.04 and skewness of –0.19, suggesting no extreme fat tails and only a mild tilt towards lower NPV values.

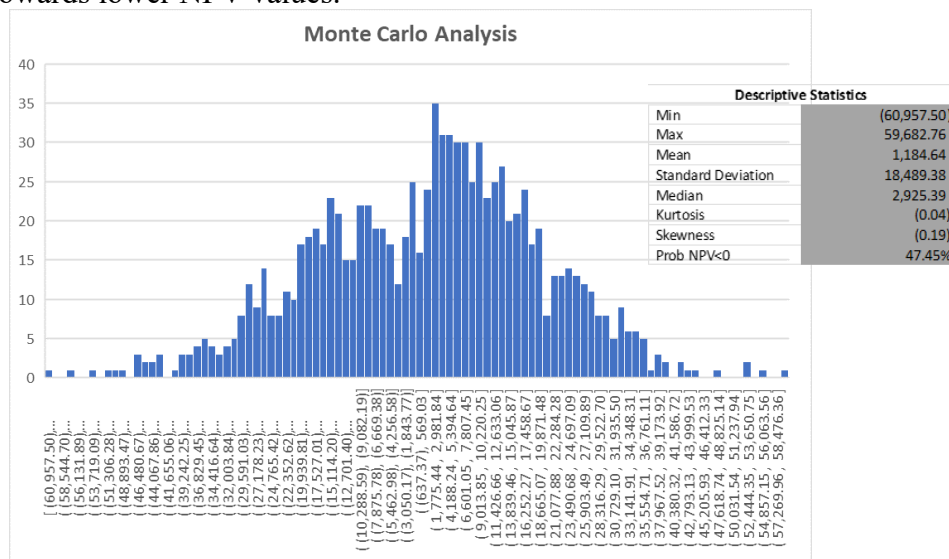


Figure 4
 Sensitivity Analysis – Monte Carlo Simulation

Overall, these sensitivity results indicate that Scenario 2 can deliver attractive value, but its realised outcome will depend heavily on the company's ability to control unit production costs, secure and maintain FOB 2 offtake volumes, and manage exposure to coal-price volatility, especially in the export segment. Targeted risk-management actions such as stringent cost control, robust mine-planning and execution to protect FOB 2 tonnage, prudent pricing and contract strategies, and selective hedging where appropriate are therefore critical to shift the project outcome towards the positive side of the NPV distribution.

Discussion

The financial and technical analyses demonstrate that both Scenario 1 (river relocation only) and Scenario 2 (river relocation plus slope depressurisation) are economically feasible. However, Scenario 2 consistently delivers higher value, such as:

- Higher cumulative discounted cash flow and NPV (IDR 2,321.20 billion vs. IDR 2,283.41 billion).
- A significantly higher IRR (60.46% vs. 40.68%) and a shorter payback, as well as a discounted payback period.
- A better profitability index, indicating more value created per unit of capital invested.

From an operational standpoint, Scenario 2 also improves physical pit performance: the steeper overall slope enabled by depressurisation reduces overburden volume, increases exposed coal tonnage, and shrinks the land-clearing footprint compared with Scenario 1. These effects translate directly into lower unit mining costs and improved stripping ratios over the life of mine. Based on these combined financial and operational advantages, Scenario 2 is selected as the preferred business solution for implementation at Pit X.

The selection of Scenario 2 is supported not only by its superior financial indicators but also by its alignment with the external business environment and the company's internal capabilities. From an external perspective, coal still plays a central role in Indonesia's power system, with the Domestic Market Obligation (DMO) providing a relatively stable demand base while export sales to FOB 1 and FOB 2 allow the company to capture upside from international markets. This demand structure underpins the extension of the life of mine to 2036 and creates a favourable context for long-term optimisation initiatives such as slope depressurisation. At the same time, tightening environmental, legal, and social expectations require mining operations to demonstrate safe pit slopes, robust water management, and compliance with AMDAL and reclamation obligations. Projected increases in rainfall intensity and flood risk in western Indonesia further reinforce the need for proactive groundwater control to maintain slope stability. In parallel, advances in geotechnical investigation, dewatering, and digital mine-planning technologies make large-scale depressurisation a technically feasible and operationally manageable option when properly integrated into existing mine systems.

Internally, the company possesses several strengths that make Scenario 2 particularly implementable. The high-quality GAR 5000 reserves in Pit X, combined with established mine-planning and geotechnical competencies, form a strong foundation for designing and operating a more aggressive yet still safe pit geometry. A solid portfolio of GAR 5000 customers, including FOB 2 export clients, provides a clear commercial outlet for the

additional tonnage unlocked by the optimised pit. Existing mining infrastructure, dewatering installations, and disciplined capital-budgeting practices, while not unique in the industry, offer an enabling platform to absorb and operate the new depressurisation system without requiring a complete redesign of site operations. Taken together, these external pressures and opportunities, along with the company's internal readiness, indicate that PT ABC is well positioned to implement Scenario 2 in a responsible and profitable manner over the 2026–2036 period, making it a strategically robust choice rather than a purely financial one.

However, risk analysis for Scenario 2 shows that project value is highly sensitive to a limited set of financial drivers. Tornado and spider charts indicate that Direct production cost realization (per ton) is the single most influential variable on NPV. Followed by Quantity sold realization for FOB 2 is the second-largest driver, reflecting the importance of sustaining export volumes. And Coal price realization for FOB 2 also exerts a major influence, as most upside and downside in NPV comes from this market-linked segment. Furthermore, Monte Carlo simulation confirms a wide distribution of possible NPV outcomes, with a substantial standard deviation, meaning the realised value of Scenario 2 will depend strongly on the company's ability to control unit costs, secure FOB 2 tonnage realization, and manage exposure to export price volatility.

CONCLUSION

Based on the comprehensive analysis conducted, the following conclusions are drawn in direct response to the research objectives. The analysis concludes that Scenario 2 (river relocation plus slope depressurisation) provides higher economic value for Pit X than Scenario 1 (river relocation only). Both scenarios yield positive NPV and are financially feasible under the common set of assumptions, but Scenario 2 produces a higher NPV (IDR 2,321.20 billion versus IDR 2,283.41 billion), a substantially higher IRR (60.46% versus 40.68%), a much shorter payback and discounted payback period, and a slightly higher profitability index. These financial advantages are reinforced by operational gains: the steeper overall slope in Scenario 2 reduces overburden volume, improves stripping ratio, increases recoverable coal tonnage, and decreases the land-clearing footprint, thereby lowering unit operating costs over the extended life of mine to 2036.

The sensitivity analysis identifies seven variables as the most critical drivers of the project's feasibility under Scenario 2, namely direct production cost realization (per tonne), quantity sold realization for FOB 2, quantity sold realization for FOB 1, coal price realization for FOB 1, coal price realization for FOB 2, inflation rate, and exchange rate. Direct production cost realization emerges as the most influential parameter in the tornado chart, highlighting the importance of maintaining planned stripping ratios and hauling distances to protect project margins. Quantity sold to FOB 2 and coal price realization for FOB 2 also show large swings in both the tornado and spider charts, confirming that the economic success of the optimisation strategy depends strongly on sustaining export volumes and managing exposure to international coal-price volatility. Other factors such as exchange rate, FOB 1 price, and inflation rate exhibit comparatively smaller effects on NPV and are therefore considered secondary risk drivers.

The Monte Carlo simulation of Scenario 2 demonstrates that the NPV of the project follows a wide, approximately bell-shaped probability distribution, centered around a

modestly positive mean but with substantial dispersion. Simulated NPV outcomes range from around 60,958 to 59,683 in the model's monetary units, with a slightly positive mean of 1,184, a higher median of 2,925, and a standard deviation of about 18,489. The distribution is close to symmetric and mesokurtic, with only mild negative skewness, indicating that there is meaningful probability mass on both the upside and downside of the base-case NPV. This pattern implies that, while Scenario 2 is value-creating on average, the realised outcome will depend heavily on how effectively PT ABC controls unit production costs, secures FOB 2 sales volumes, and mitigates coal price risk issues that are explicitly addressed in the KPI-based risk management framework and implementation plan developed in the business solution.

REFERENCES

- Avlijaš, G. (2019). Examining the value of Monte Carlo simulation for project time management. *Management: Journal of Sustainable Business and Management Solutions in Emerging Economies*, 24(1), 11–23.
- Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99–120.
- BPS-Statistik Indonesia. (2024). *Statistik Listrik 2019–2023* (Vol. 13).
- Brealey, R. A., Myers, S. C., & Allen, F. (2020). 4.3. Economic and legal governance. *Curriculum & Syllabi Handbook MBA International Management Full-Time*.
- Brealey, R. A., Myers, S. C., Allen, F., & Edmans, A. (2023). *Principles of corporate finance* (14th ed.). McGraw-Hill.
- Cleland, D. L., & Ireland, L. R. (2006). *Project management*. McGraw-Hill Professional.
- Damodaran, A. (2002). *Valuation: Tools and techniques for determining the value of any asset*. John Wiley & Sons.
- Gitman, L. J., Juchau, R., & Flanagan, J. (2015). *Principles of managerial finance*. Pearson Higher Education AU.
- Hancock, D. R., Algozzine, B., & Lim, J. H. (2021). *Doing case study research: A practical guide for beginning researchers*.
- Hesterly, W., & Barney, J. (2014). *Strategic management and competitive advantage* (Vol. 28). Pearson Education.
- Hustrulid, W., Kuchta, M., & Martin, R. (2006). *Open pit mine planning & design* (3rd ed.). CRC Press.
- Isbahi, M. B., Zuana, M. M. M., & Toha, M. (2024). The Multi-Social Relation of the Cattle Industry in the Plaosan Subdistrict Animal Market of Magetan Regency. *Malacca: Journal of Management and Business Development*, 1(1), 31–46. <https://doi.org/10.69965/malacca.v1i1.51>
- Koller, T., Goedhart, M., & Wessels, D. (2020). *Valuation: Measuring and managing the value of companies*.
- minerba.esdm.go.id. (2024, October 3). *Batubara Indonesia: Pilar utama energi di era transisi energi dan hilirisasi menuju kemandirian bangsa*.
- Pindyck, R. S., & Rubinfeld, D. L. (2018). *Microeconomics* (9th global ed.). Pearson.
- Read, J., & Beale, G. (2013). *Guidelines for evaluating water in pit slope stability*. CSIRO Publishing.

- Saltelli, A., Tarantola, S., Campolongo, F., & Ratto, M. (2004). *Sensitivity analysis in practice: A guide to assessing scientific models*.
- Terzaghi, K. (1943). Liner-plate tunnels on the Chicago (IL) subway. *Transactions of the American Society of Civil Engineers*, 108(1), 970–1007.
- Ward, S., & Chapman, C. (2003). Transforming project risk management into project uncertainty management. *International Journal of Project Management*, 21(2), 97–105.
- Yüksel, I. (2012). Developing a multi-criteria decision-making model for PESTEL analysis. *International Journal of Business and Management*, 7(24), 52.