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The Feasibility Study of A8 Pit Project in PT XYZ

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ABSTRACT

PT XYZ, a coal mining company in East Kalimantan, faces a strategic decision regarding the development of Pit A8, a boundary area adjacent to PT MAG's concession. This study aimed to evaluate the financial feasibility of three operational alternatives: full joint operation, self-managed mining, and joint operation with independent coal marketing. The analysis employed Discounted Cash Flow (DCF) methods, including Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP), complemented by sensitivity analysis and Monte Carlo simulation to assess project uncertainty. The results indicated that all alternatives were financially feasible, as reflected by positive NPV values and IRRs exceeding the required rate of return. Among the alternatives, the joint operation with independent marketing demonstrated the highest financial performance, achieving an NPV of USD 209.52 million, an IRR of 438%, and a payback period of 0.59 years. Sensitivity analysis identified coal price and gross calorific value (GCV) as the most significant value drivers, while Monte Carlo simulation with 10,000 iterations produced an expected NPV of USD 248.62 million with a positively skewed distribution, indicating greater upside potential despite existing downside risks. The findings suggested that a hybrid joint operation model provided the optimal balance between operational efficiency and value creation. To ensure project sustainability, risk mitigation strategies, including price hedging, cost control, and integrated mine planning, are essential.

INTRODUCTION

Indonesia remains a major coal producer, and mining companies are required to improve operational efficiency while responding to commodity price volatility and increasing energy demand. PT XYZ is pursuing production growth through the development of Pit A8, one of its strategic mining areas in East Kalimantan. Pit A8 contains approximately 35.5 million tonnes of coal reserves and is located directly adjacent to PT MAG's concession, creating both operational synergies and coordination challenges (Ncube, 2022; Peta, 2022).

The boundary position of Pit A8 requires an integrated decision regarding mine planning, infrastructure utilization, regulatory compliance, and revenue-sharing arrangements. Joint Operation (JO) models can support resource optimization and risk sharing; however, they may also introduce governance and control issues (Chatterjee, 2026; Hussain et al., 2026; Liu et al., 2025; Moon et al., 2026; Pathirana et al., 2025; Xu et al., 2024). In contrast, self-managed mining provides stronger operational control but requires higher capital commitments. Therefore, a structured financial evaluation is needed to determine the alternative that generates

the highest economic value for PT XYZ under uncertain conditions (Nainggolan et al., 2023; Sudarsono & Harahap, 2023; Tsabita & Kitri, 2024; Ziyad & Sudrajad, 2025).

This study contributes to mining investment analysis by combining deterministic capital budgeting with sensitivity analysis and Monte Carlo simulation. The objective is to compare the financial feasibility of three operational alternatives and identify the key variables influencing project value.

PT XYZ is a coal mining company operating in East Kalimantan and seeking to increase its production capacity to meet growing domestic and global energy demand (Budi, 2025; Lopez, 2024; Pratama et al., 2022). Coal mining in Indonesia continues to play a significant role in energy supply despite facing challenges from commodity price volatility and the global transition toward cleaner energy sources. Pit A8 is one of the potential development areas, with approximately 35.5 million tonnes of reserves and relatively stable coal quality characteristics.

Operational efficiency and resource optimization are critical for maintaining competitiveness, particularly amid coal price volatility and the transition toward cleaner energy sources.

Because Pit A8 is adjacent to PT MAG's concession, its development requires careful assessment of collaboration potential, infrastructure utilization, boundary mine planning, and regulatory compliance requirements. This condition makes the selection of the operational model a strategic business decision.

The development of Pit A8 presents a critical strategic decision for PT XYZ regarding the selection of the most economically viable operational scheme through a joint operation with PT MAG, self-managed mining, or a hybrid scheme that combines joint operation with independent coal marketing.

A joint operation can improve efficiency and facilitate operational risk sharing; however, it may reduce control over revenue management, governance, and marketing decisions. In contrast, self-managed mining provides greater operational control but requires the company to assume full operational responsibilities and risks.

Since each alternative differs in capital expenditure (CAPEX), operating expenditure (OPEX), production responsibility, and revenue structure, direct comparison requires a consistent financial model rather than experience-based judgment.

Several previous studies have discussed mining investment evaluation using capital budgeting approaches. Damodaran (2012) emphasized the importance of discounted cash flow (DCF) analysis in assessing the feasibility of capital-intensive projects, while Gitman and Zutter (2015) highlighted the use of NPV, IRR, and payback period as key indicators in investment decision-making. In the mining context, Pannell (1997) developed a sensitivity analysis framework to measure the impact of uncertainty on project feasibility, while Haq (2018) introduced probabilistic-based decision risk modeling for large-scale mining projects. Meanwhile, Prakoso and Faturohman (2024) applied a stochastic approach to forecast coal price uncertainty in investment evaluation, suggesting that price volatility is a dominant factor affecting project value.

However, most previous research remains limited to deterministic analysis or focuses on only one operational model. Studies that comparatively evaluate multiple operational schemes—particularly in frontier mining areas with potential collaboration between concessions—remain limited. In practice, joint operating models can provide cost efficiency

and risk sharing but may also create governance and revenue control challenges. Conversely, self-managed mining provides full operational control but requires greater capital commitment and exposes companies to full operational risks. Therefore, a more comprehensive analytical approach is needed to measure financial feasibility, incorporate uncertainty, and compare multiple operational scenarios simultaneously.

Accordingly, this study aimed to determine which operational alternative provides the highest economic value while considering profitability, risk exposure, and long-term sustainability. Thus, this study not only provides strategic recommendations for PT XYZ but also contributes an analytical framework applicable to other frontier mining projects, particularly in Indonesia, which shares similar geographical and regulatory characteristics.

The evaluation of mining investment alternatives in this study was grounded in capital budgeting theory, which evaluates long-term investments by estimating future cash flows, incorporating the time value of money, and measuring feasibility through NPV, IRR, and Payback Period (Gitman & Zutter, 2015).

Mining projects require rigorous financial evaluation because they involve substantial upfront investments and cash flows that are highly sensitive to commodity prices, operating costs, and production assumptions. To incorporate uncertainty, this study applied sensitivity analysis and Monte Carlo simulation. Sensitivity analysis identified the variables with the greatest impact on NPV, while Monte Carlo simulation estimated the probability distribution of project outcomes based on variability in key drivers. Project cash flows were discounted using the weighted average cost of capital (WACC) to determine whether the project created value above its cost of capital (Damodaran, 2010). This framework enabled a comprehensive comparison of Pit A8 alternatives in terms of profitability, capital efficiency, and risk exposure.

METHOD

The research employed a business feasibility study approach to evaluate alternative operational schemes for the development of Pit A8 at PT XYZ. The analysis integrated financial and operational assessments using primary and secondary data, including mine planning data, production forecasts, CAPEX and OPEX estimates, coal price assumptions based on the Indonesian Coal Index (ICI), fuel price data, and financial parameters for estimating the cost of capital. Financial analysis was conducted using the Discounted Cash Flow (DCF) method to generate key feasibility indicators, including Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP). Sensitivity analysis was performed to evaluate the impact of key variables, such as coal price, gross calorific value (GCV), fuel price, and operating costs, on project performance. Furthermore, Monte Carlo simulation with 10,000 iterations was conducted to assess uncertainty and estimate the probability distribution of project outcomes. This integrated approach enabled a comprehensive evaluation of project feasibility, risk exposure, and value creation across alternative scenarios.

RESULTS AND DISCUSSION

Technical Analysis

The Pit A8 production plan is design to maintain stable coal supply while keeping the stripping ratio economically acceptable. Production begins in 2027 and reaches a steady-state level of 5 million tons peryear from 2029 onward. Over 2027-2034, total coal production is

estimated at 35.5 million tons, with 218.1 million bcm of overburden and an average stripping ratio of 6.14 bcm/ton. Coal quality parameters are assumed to remain stable throughout the mine life.

Tabel 1. Summary of Production Plan Pit A8

Year Range	Total Coal (Mt)	OB (Mbcm)	Avg SR
2027 - 2034	35.5	218.1	6.14

Source: Author's compilation from PT XYZ mine planning data (2026)

Coal Price Assumption

Project revenue is mainly generated from coal sales, with price assumptions based on coal quality and benchmarked against the Indonesia Coal Index (ICI). Historical ICI4 price movements from 2021 – 2025 are used to reflect market conditions and maintain consistency with Pit A8 coal specifications.

Tabel 2. Projection Coal Price (USD/t)

	Alternative 1	Alternative 2	Alternative 3
Coal Price	47.14	52.74	52.74

Source: Author's calculation based on ICI4 historical movement (2021–2025) and PT XYZ marketing assumptions

Fuel Price Assumption

Fuel price is used in estimating mining operating costs because it is embedded in contractor-based unit rates. Based on historical monthly fuel price data from 2020-2025, the median value of USD 1.34 per liter is adopted as the base-case assumption.

Capital Expenditure (CAPEX) Assumptions

Capital expenditure (CAPEX) represents the initial investment required before production starts in 2027, including mine infrastructure, exploration, and mining equipment.

Infrastructure covers haul roads and settling ponds, exploration covers additional drilling, technical studies, and permitting, while mining equipment includes primary excavators, haul trucks, and supporting units.

The CAPEX allocation differs across alternatives, especially between contractor-based and owner-operated schemes, leading to different investment requirements and financial implications.

Operating Expenditure (OPEX) Assumptions

Operating costs is mainly driven by mining activities, including overburden removal, coal getting, coal hauling, road maintenance, exploration, and mining equipment.

Infrastructure covers haul roads and settling ponds, exploration covers additional drilling, technical studies, and permitting, while mining equipment includes primary excavators, haul trucks, and supporting units.

The CAPEX allocation differs across alternatives, especially between contractor-based and owner-operated schemes, leading to different investment requirements and financial implications.

Tabel 3. Summary of Mining Cost by Alternative

Cost Component	Alternative 1	Alternative 2	Alternative 3
Mining Cost (USD/t)	28.80	30.45	33.04

Source: Author's estimation based on PT XYZ operational cost structures and contractor rate benchmarks

Depreciation Assumptions

Depreciation is applied to infrastructure, exploration, and mining equipment using the straight-line method with no residual value assumed. Infrastructure and exploration costs are depreciated over the project life, while mining equipment under the owner-operated scheme is depreciated over a shorter useful life due to higher utilization and replacement needs.

Depreciation is treated as a non-cash expense that reduces taxable income and creates a tax shield, while being added back in Free Cash Flow calculations

Tabel 4. Depreciation Pit A8 Project

Alternative 1	**Unit**	**Total**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
Capital Expenditure	**USD Million**	**6.84**	**6.00**	**0.84**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	USD Million	2.64	1.80	0.84	-	-	-	-	-	-	-
Exploration	USD Million	4.20	4.20	-	-	-	-	-	-	-	-
Equipment	USD Million	-	-	-	-	-	-	-	-	-	-
Depreciation and Depliation	**USD Million**	**6.84**	**-**	**0.86**	**0.86**	**0.86**	**0.86**	**0.86**	**0.86**	**0.86**	**0.86**
Depreciation	USD Million	2.64	-	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Depliation	USD Million	3.20	-	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53

Alternative 2	**Unit**	**Total**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
Capital Expenditure	**USD Million**	**116.24**	**85.40**	**30.84**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	USD Million	2.64	1.80	0.84	-	-	-	-	-	-	-
Exploration	USD Million	4.20	4.20	-	-	-	-	-	-	-	-
Equipment	USD Million	109.40	79.40	30.00	-	-	-	-	-	-	-
Depreciation and Depliation	**USD Million**	**116.24**	**-**	**16.48**	**16.48**	**16.48**	**16.48**	**16.48**	**16.48**	**16.48**	**16.48**
Depreciation Infra	USD Million	2.64	-	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Depreciation equipment	USD Million	109.40	-	15.36	15.36	15.36	15.36	15.36	15.36	15.36	-
Depliation	USD Million	4.20	-	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53

Alternative 3	**Unit**	**Total**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
Capital Expenditure	**USD Million**	**6.64**	**6.00**	**0.64**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	USD Million	2.24	1.80	0.64	-	-	-	-	-	-	-
Exploration	USD Million	4.20	4.20	-	-	-	-	-	-	-	-
Equipment	USD Million	-	-	-	-	-	-	-	-	-	-
Depreciation and Depliation	**USD Million**	**6.64**	**-**	**0.83**	**0.83**	**0.83**	**0.83**	**0.83**	**0.83**	**0.83**	**0.83**

Depreciation	USD Million	2.24	-	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Depliation	USD Million	4.20	-	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53

Source: Author's calculation based on PT XYZ financial policy, asset useful life assumptions from industry benchmarks, and internal technical estimates (2026).

Cost of equity (Ke)

The components used for calculating the cost of equity are as follows:

Tabel 5. Assumption for Cost of Equity Calculation

Cost of Equity calculation		
Risk free Rate	6.35%	IBPA 10 years government bond yield
Beta	1.37	using relative company (ADRO)
Equity Risk Premium	6.87%	Damodaran (Coal Indonesia)

Source: Risk-free rate: IBPA 10-year government bond yield (2026); Beta: relative company (ADRO) from Bloomberg; Equity Risk Premium: Damodaran (2024) – Indonesia Coal

Calculates Cost of Equity

$Ke = Rf + \beta (Rm - Rf)$

$Ke = 6.35\% + (1.37*6.87)$

$Ke = 15.76\%$

According to the above data, the cost of equity of the project is 15.76%

Cost of Debt (Kd)

The components used for calculating the cost of debt are as follows:

Tabel 6. Assumption for Cost of Debt

Cost of debt calculation	
Cost of debt	10.00%
Corporate Tax	22%

Source: Cost of debt: PT XYZ corporate bond benchmark; Corporate tax: Indonesian tax regulation (22%)

Calculates Cost of debt after tax

Kd(after tax) = Kd x (1- corporate tax)

Kd(after tax) = 10% x (1-22%)

Kd(after tax) = 7.8%

Weighted Average Cost of Capital (WACC)

The WACC represents the average rate of return required by both debt and equity holders, weighted according to their respective proportion in the company's capital structure. Using the capital structure of 40% equity and 60% debt, the WACC for this project is:

$WACC = (W_e \times K_e) + (W_d \times K_d(1-T)$

$WACC = (40\% \times 15.7\%) + (60\% \times 7.8\%)$

$WACC = 10.98\%$

Analysis Alternative using Discounted Cash Flow

The Discounted Cash Flow (DCF) method is applied to evaluate and compare the financial feasibility of the three operational alternatives for Pit A8 development. The analysis

assesses each alternative based on its ability to generate economic value, considering profitability, capital efficiency, and risk exposure.

Table 7. Free Cash Flow with DCF Method (Alternative 1)

Alternative 1

Description	Unit	Total	2026	2027	2028	2029	2030	2031	2032	2033	2034
Sales	USD Million	1,673	-	117.85	141.42	235.70	235.70	235.70	235.70	235.70	235.70
Royalty (PNPB)	USD Million	226	-	15.91	19.09	31.82	31.82	31.82	31.82	31.82	31.82
Net Sales	**USD Million**	**1,448**	**-**	**101.94**	**122.33**	**203.88**	**203.88**	**203.88**	**203.88**	**203.88**	**203.88**
Capital Expenditure	USD Million	6.84	6.00	0.84	-	-	-	-	-	-	-
Operational Expense	USD Million	1,022	-	72.00	86.40	144.00	144.00	144.00	144.00	144.00	144.00
EBITDA	**USD Million**	**425**	**-**	**29.94**	**35.93**	**59.88**	**59.88**	**59.88**	**59.88**	**59.88**	**59.88**
Amortisation	USD Million	-	-	-	-	-	-	-	-	-	-
Depreciation	USD Million	6.84	-	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
EBT	**USD Million**	**418**	**-**	**29.09**	**35.07**	**59.03**	**59.03**	**59.03**	**59.03**	**59.03**	**59.03**
Corporate Tax	USD Million	92.03	-	6.40	7.72	12.99	12.99	12.99	12.99	12.99	12.99
EAT	**USD Million**	**326**	**-**	**22.69**	**27.36**	**46.04**	**46.04**	**46.04**	**46.04**	**46.04**	**46.04**
Add back Depreciation	USD Million	6.84	-	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Cashflow	**USD Million**	**333**	**(6.00)**	**23.54**	**28.21**	**46.89**	**46.89**	**46.89**	**46.89**	**46.89**	**46.89**
Accumulated Cashflow	USD Million		(6.00)	17.54	45.75	92.65	139.54	186.44	233.33	280.23	327.12

Source: Author's calculation based on integrated DCF model

Table 8. Free Cash Flow with DCF Method (Alternative 2)

Alternative 2

Description	Unit	Total	2026	2027	2028	2029	2030	2031	2032	2033	2034
Sales	USD Million	1,872	-	131.85	158.22	263.70	263.70	263.70	263.70	263.70	263.70
Royalty (PNPB)	USD Million	253		17.80	21.36	35.60	35.60	35.60	35.60	35.60	35.60
Net Sales	**USD Million**	**1,620**		**114.05**	**136.86**	**228.10**	**228.10**	**228.10**	**228.10**	**228.10**	**228.10**
Capital Expenditure	USD Million	116.24	85.40	30.84	-	-	-	-	-	-	-
Operational Expense	USD Million	1,081	-	76.13	91.35	152.25	152.25	152.25	152.25	152.25	152.25
EBITDA	**USD Million**	**539**	**-**	**37.93**	**45.51**	**75.85**	**75.85**	**75.85**	**75.85**	**75.85**	**75.85**
Amortisation	USD Million	-	-	-	-	-	-	-	-	-	-
Depreciation	USD Million	116.24	-	16.48	16.48	16.48	16.48	16.48	16.48	16.48	0.86
EBT	**USD Million**	**422**	**-**	**21.44**	**29.03**	**59.37**	**59.37**	**59.37**	**59.37**	**59.37**	**75.00**
Corporate Tax	USD Million	92.91	-	4.72	6.39	13.06	13.06	13.06	13.06	13.06	16.50

EAT	**USD Million**	**329**	**-**	**16.72**	**22.64**	**46.31**	**46.31**	**46.31**	**46.31**	**46.31**	**58.50**
Add back Depreciation	USD Million	116.24		16.48	16.48	16.48	16.48	16.48	16.48	16.48	0.86
Cashflow	**USD Million**	**446**	**(85.40)**	**33.21**	**39.12**	**62.79**	**62.79**	**62.79**	**62.79**	**62.79**	**59.35**
Accumulated Cashflow	USD Million		(85.40)	(52.19)	(13.07)	49.72	112.51	175.30	238.09	300.88	360.23

Source: Author's calculation based on integrated DCF model

Table 9. Free Cash Flow with DCF Method (Alternative 3)

Alternative 3

Description	Unit	Total	2026	2027	2028	2029	2030	2031	2032	2033	2034
Revenue	USD Million	1,872	-	131.85	158.22	263.70	263.70	263.70	263.70	263.70	263.70
Royalty (PNPB)	USD Million	253		17.80	21.36	35.60	35.60	35.60	35.60	35.60	35.60
Net Sales	**USD Million**	**1,620**		**114.05**	**136.86**	**228.10**	**228.10**	**228.10**	**228.10**	**228.10**	**228.10**
Capital Expenditure	USD Million	6.64	6.00	0.64	-	-	-	-	-	-	-
Operational Expense	USD Million	1,173	-	82.60	99.12	165.20	165.20	165.20	165.20	165.20	165.20
EBITDA	**USD Million**	**447**	**-**	**31.45**	**37.74**	**62.90**	**62.90**	**62.90**	**62.90**	**62.90**	**62.90**
Amortisation	USD Million	-	-	-	-	-	-	-	-	-	-
Depreciation	USD Million	6.64	-	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
EBT	**USD Million**	**440**	**-**	**30.62**	**36.91**	**62.07**	**62.07**	**62.07**	**62.07**	**62.07**	**62.07**
Corporate Tax	USD Million	96.79	-	6.74	8.12	13.66	13.66	13.66	13.66	13.66	13.66
EAT	**USD Million**	**343**	**-**	**23.88**	**28.79**	**48.42**	**48.42**	**48.42**	**48.42**	**48.42**	**48.42**
Add back Depreciation	USD Million	6.64	-	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Cashflow	**USD Million**	**350**	**(6.00)**	**24.71**	**29.62**	**49.24**	**49.24**	**49.24**	**49.24**	**49.24**	**49.24**
Accumulated Cashflow	USD Million		(6.00)	18.71	48.33	97.58	146.82	196.07	245.31	294.56	343.80

Source: Author's calculation based on integrated DCF model

Tabel 10. Summary of Financial Feasibility

Discounted Cash Flow	Unit	Alternative 1	Alternative 2	Alternative 3
NPV	USD Million	199.25	190.54	209.52
IRR	%	419%	53%	438%
PBP	year	1.34	3.57	0.59

The results indicate that Alternative 3 offers the strongest financial performance because it allows PT XYZ to retain independent coal marketing and pricing control, resulting in higher revenue despite higher operating cost.

Alternative 1 provides the lowest operating cost but is constrained by lower selling price under the pit to market arrangement with PT MAG. Alternative 2 requires higher capital investment, reducing capital efficiency and extending the payback period.

The findings suggest that, for boundary mining projects, revenue control and strategic flexibility may create greater value than cost minimization alone.

Sensitivity Analysis

Sensitivity analysis is conducted to assess the impact of changes in key input variables on the project's Net Present Value (NPV). The analysis evaluates the effect of a ±5% variation in selected variables from the base case scenario, while holding other assumptions constants. The key variables tested include coal selling price, calorific value (GCV), royalty rate (PNBP), fuel price, and overburden hauling distances.

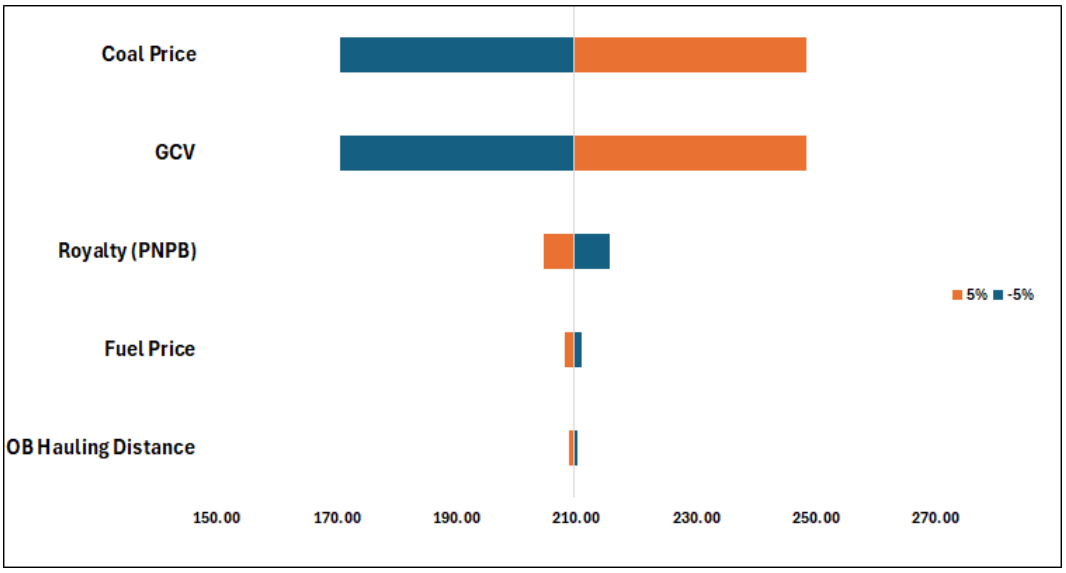


Figure 1. Tornado Diagram Sensitivity

Source: Author's calculation using @RISK 8.2, based on PT XYZ data, ICI4, ESDM, and PP No. 15/2022.

The tornado diagram shows that coal price and GCV are the most influential variables, producing the widest NPV variation under a ±5% change. The indicates that relatively small movements in revenue side drivers can significantly affect project profitability.

Fuel price, royalty rate, and hauling distance have smaller effects on NPV, suggesting that cost-related variables remain important but are secondary to revenue-related factors.

Overall, the result highlights the need to manage coal price exposure and maintain consistent product quality to sustain project value.

Monte Carlo Simulation

Monte Carlo simulation is applied to extend the deterministic DCF analysis by capturing uncertainty in key project variables. While DCF provides a single-point estimate, mining projects are exposed to variability in both market and operational assumptions.

The simulation uses 10,000 iterations and models key variables identified in the sensitivity analysis, including coal price, GVC, fuel price, and operating cost. Each variable is assigned a profitability distribution based on historical data and realistic operational assumptions.

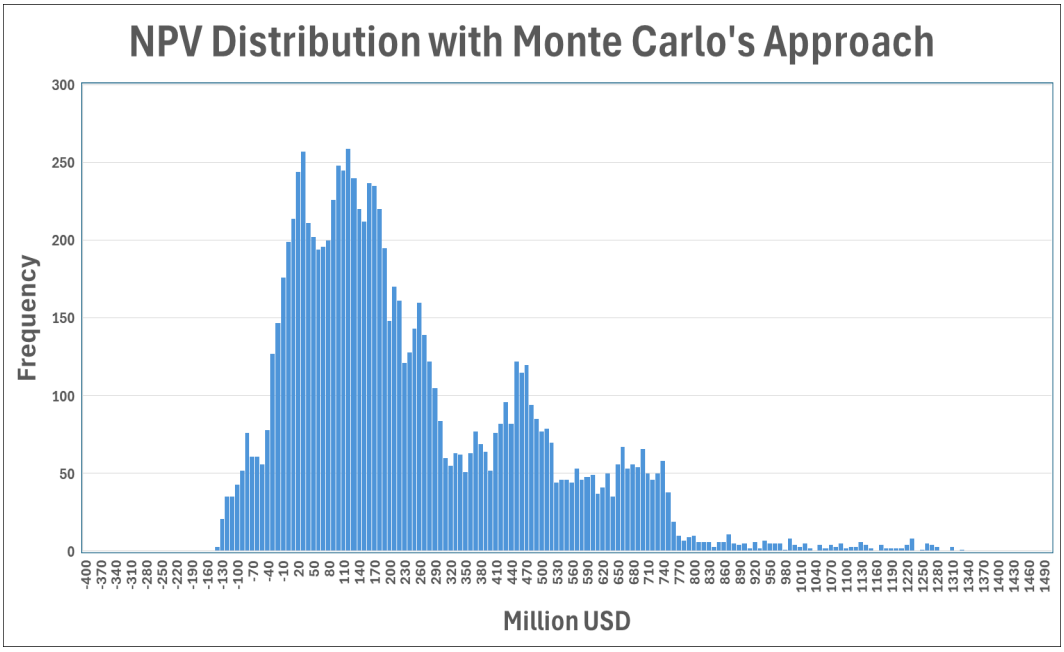


Figure 2. NPV Distribution with Monte Carlo's Approach
Source: Author's calculation using @RISK 8.2, based on PT XYZ data and historical market references (ICI4, ESDM)

The simulation results show a positive expected NPV of approximately USD 248.62 million, indicating strong overall project viability. The NPV distribution is positively skewed, suggesting higher upside potential than downside risk.

Nevertheless, the lower tail includes negative outcomes, indicating that unfavorable scenarios remain possible, mainly due to coal price declines and coal quality variation.

The Monte Carlo result confirm the financial robustness of the project while providing a clearer view of downside risk and the probability of value creation under uncertainty.

CONCLUSION

This study evaluated the financial feasibility of three operational alternatives for the development of Pit A8 at PT XYZ using a capital budgeting framework supported by sensitivity analysis and Monte Carlo simulation. The results indicated that all alternatives were financially feasible, as reflected by positive Net Present Value (NPV) values and Internal Rate of Return (IRR) values exceeding the required rate of return. Among the alternatives, the joint operation with independent coal marketing (Alternative 3) demonstrated the highest financial performance, with an NPV of USD 209.52 million, an IRR of 438%, and the shortest payback period of 0.59 years. In contrast, Alternative 1 offered the lowest operating costs but was constrained by a lower selling price, while Alternative 2 required significantly higher capital investment, resulting in lower capital efficiency and a longer payback period.

The findings highlighted that project value was not solely determined by cost efficiency but was also strongly influenced by revenue structure and capital intensity. In the case of Pit A8, operational flexibility in marketing and pricing played a key role in maximizing project value. Furthermore, sensitivity and Monte Carlo analyses confirmed that coal price and gross calorific value (GCV) were the dominant drivers of project risk, indicating that revenue-side variables had a greater impact on project feasibility than cost-related factors. Overall, this study

provided a structured and quantitative framework for evaluating mining investment decisions under uncertainty, particularly in boundary mining conditions. However, the analysis was subject to limitations, particularly regarding the use of historical price assumptions, which may not fully represent future market conditions.

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