# Financial Feasibility Study for A River Diversion Project to Optimize the Pit P Marginal Reserve as Part of PT PQR's Implementing the Coal Conservation Aspect

Seno Alfi Syahrin[1], Ahmad Danu Prasetyo[2]
{seno_alfi@sbm-itb.ac.id[1], ahmad.danu@sbm-itb.ac.id[2]}

Bandung Insitute Technology, Bandung[1,2]

**Abstract.** One part of the Good Mining Practices (GMP) application is related to the coal conservation aspect, in which mining companies are expected to promote optimal reserve conservation to ensure the mine's sustainability. It is estimated that the Pit P area contains 16.6 million tons of marginal reserve. The unmet modifying factor is the reserve beneath a major river. The river must be diverted in order to mine coal and maintain the environment. A capital budget analysis and a risk analysis technique were developed to determine the project's feasibility. The analysis shows that scenario 1 is financially viable, as demonstrated by its net present value of US$35.6 million and internal rate of return of 34.94 percent. It has a 61% chance of success, according to Monte Carlo simulations. More output results in the creation of companies' profits, which eventually results in increased income for the state.

**Keywords:** Coal Conservation; Marginal Reserve; Modifying Factor; Monte Carlo

## 1 Introduction

Good Mining Practice (GMP) is a standard of practice for mining activity that follows the rules, is well planned, implements appropriate technology, conserves coal, maintains environmental functions, ensures worker safety, accommodates community desires and participation, generates added value, improves the capabilities and welfare of the surrounding community, and fosters sustainable development. Indonesia's Ministry of Energy and Mineral Resources issued Ministerial Decree No.1827 K/30/MEM/2018 in 2018 outlining guidelines for implementing good mining practices. In Annex VII, guidelines for implementing aspects of mineral and coal conservation are provided, as well as activities for collecting data on marginal reserves and determining how marginal reserves should be optimized. The companies are expected to maximize reserve conservation in order to ensure the mine's long-term viability while also earning revenue for the state. PT. PQR is one of Indonesia's largest coal mining companies. PT PQR is one of Indonesia's largest open-pit mining operators. Since 1991, PT PQR has operated an open-pit mining operation in East Kalimantan. In 2019, PT PQR produced 60.7 million tons. The company's output will decline in the coming years as

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reserves are depleted and no additional mineable reserves are discovered (see in Figure 1). This decline in reserves was caused by mining activities. Additionally, some companies' marginal reserve areas remain unoptimized.

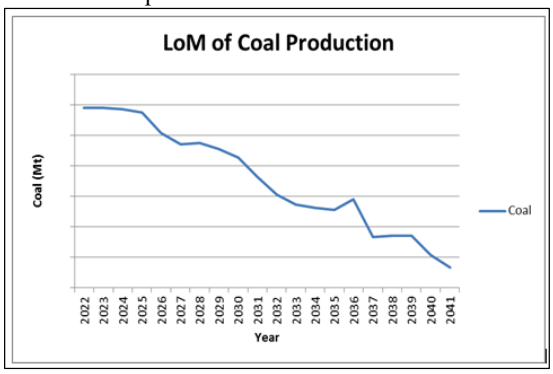


**Fig. 1.** PT PQR's Long term Plan When Coal Price Low (Source: Company's Internal Document)

Near the Pit P area is one of the company's marginal areas of PT PQR. The Pit P is estimated to have a 16.6 million ton marginal reserve (see in Table 1). Certain areas of marginal reserve are located beneath the river, which is classified as a major river. The river must be diverted in order to mine coal and address environmental concerns.

**Table 1.** Pit P Marginal Reserve End of 2020 (Source: Company's Internal Document)

| Pit | Marginal Reserve (Million ton) | Ash (ar) (%) | Calorific Value (ar) (kkal/kg) | Sulfur (ar) (%) | Total Moisture (ar) (%) |
|---|---|---|---|---|---|
| Pit P | 16.6 | 5.34 | 4,373 | 0.20 | 31.05 |

*The five whys* approach reveals that the Pit P's marginal reserve is under-optimized. The marginal Pit, located beneath the river, is the primary reason for the reserve's decline. It will result in a decrease in production levels and a negative impact on cash flow. It will also have an impact on the government's revenue. The purpose of this study is to determine the feasibility of a river diversion project in terms of increasing the status of the Pit P's marginal reserve. When the marginal status of a mine can be raised to reserve, the mine's life can be extended or the company's production level maintained. Additionally, it resulted in the creation of company profit and increased government revenue. The pit and dump design for Pit P, the conceptual design of the river diversion, the initial investment estimation, the physical production of the Pit P marginal reserve, mining cost parameters, the company's historical financial ratios from 2016 to 2019, the company's historical cost escalation rate from 2015 to 2020, the company's historical sustainability capex from 2015 to 2019, and the company's historical coal recovery from 2011 to 2020 are all gathered qualitatively via semi-structured direct interviews with. This project analysis proposes two alternative solutions (see in Figure 2 and Table 2):

a) Scenario1: River diversion in the northern area. It will be built on a hill area.
b) Scenario2: River diversion in the middle area, where more than half of the construction area is swamp.

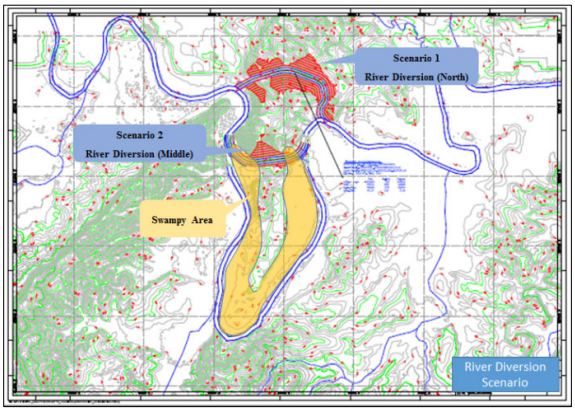


**Fig. 2.** Scenarios of River Diversion

**Table 2.** Scenarios of Physical Quantity for River Diversion

| No | Item | Unit | Scenario 1 | Scenario 2 |
|---|---|---|---|---|
| 1. | Clearing and grubbing | Ha | 29.1 | 13.1 |
| 2. | Removal of topsoil and unsuitable material within a hauling radius of 500m. | Bcm | 3,053,855 | 1,535,164 |
| 3. | Land Compensation | Ha | 522 | 522 |

## 2 Literature Review

Prior to beginning a business, it is necessary to conduct a feasibility study. Additionally, this analysis serves as the basis for corporate decision-making, ensuring that no party is negatively affected. Additionally, the feasibility analysis takes a variety of factors into account, including market, technological, financial, legal, and risk identification [21]. A Feasibility study is the stage of mining activities intended to obtain detailed information on all aspects related to determining the financial and technical feasibility of the business, including an analysis of environmental impacts and post-mining planning [23]. An 'Ore Reserve' is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined or extracted and is defined by studies at Pre-Feasibility or Feasibility level as appropriate that include application of Modifying Factors. Such studies demonstrate that, at the time of reporting, extraction could be reasonably justified [15]. A Probable Mineral Reserve is the economically mineable part of an indicated and, in some circumstances, a measured mineral resource. A Proved Mineral Reserve is the economically mineable part of a Measured Mineral Resource. A Proved Mineral Reserve implies a high degree of confidence in the Modifying Factors. These include: mining practicality, processing, metallurgical, economic, infrastructure, marketing, legal, environmental, social, and governmental factors. Mineral Reserves, which are a modified sub-set of the Indicated and Measured Mineral Resources (shown within the dashed outline in Figure 3), require consideration of the modifying factors affecting extraction, and should, in most instances, be estimated with input from a range of disciplines [16].

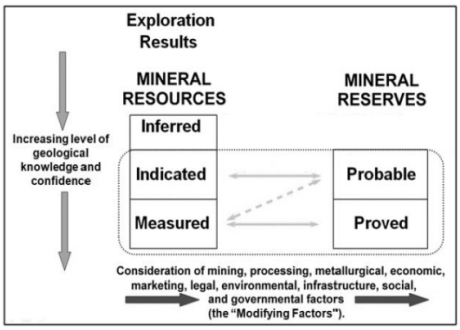


**Fig. 3.** Exploration Results, Mineral Resources, and Reserves in General (Source: KCMI Code, 2017)

According to SNI 5015; 2019, a marginal reserve is a portion of a coal reserve (probable reserve) that was at the economic boundary at the time of feasibility study preparation but still has to consider changes in technical and economic mining factors so that the reserves status can return to being a resource [3]. There are one or two modifying factors that have not been fulfilled that have to be in reserve. According to the regulation contained in the Decree of the Director General of the Ministry of Energy and Mineral Resources, Annex 6 of No. 182.K/30/DJB/2020, marginal reserves become probable reserves as a result of regulatory factors, specifically those that remain subject to government policy considerations before being designated as proven reserves [22]:

a) Beneath the river;
b) Reserves along national, provincial, district/city, and arterial roads;
c) Reserves located between mining business permit areas and mining business permit areas specifically designated for adjacent production operations;
d) Reserves that require supporting infrastructure, such as bridges and tunnels, in order to conduct mining operations, and/or
e) Reserve blocks are located in forest areas.

## 3 Methodology

Financial analysis generates a set of financial models for the pit of Pit P marginal in each of the two scenarios. The analysis begins by creating a pro forma income statement and balance sheet based on financial assumptions, and then calculates the incremental free cash flow by calculating the Free Cash Flow to Firm (FCFF) and Free Cash Flow to Equity (FCFE). Then, determine the Weighted Average Cost of Capital (WACC) for each component of the capital structure of the project. After determining the discount rate, conduct a feasibility analysis using all acceptable criteria for net present value (NPV) and internal rate of return (IRR). Then, conduct a sensitivity analysis to determine the impact of changes in input factors and risk variables. Finally, a risk assessment is conducted, all possible outcomes are viewed, and the risk's impact is analyzed using Monte Carlo simulation.

## 4 Result and Discussion

Capital budgeting is the process of assessing and selecting long-term investments that are consistent with the firm's goal of maximizing owner wealth. This procedure is designed to help the business achieve its objective of optimising shareholder wealth [10]. The payback period, discounted payback period, net present value (NPV), profitability index (PI), internal rate of return (IRR), and modified internal rate of return (MIRR) are six techniques that are frequently used to evaluate long-term asset investments [18].

### 4.1 Investment

The initial investment will cover the cost of river diverting and compensating for land compensation. For scenario 1, the total investment in river diversion is US$16.2 million. Meanwhile, scenario 2 requires an investment of US$12.3 million. This difference is due to the lower surface topography of scenario 2 compared to scenario 1. This is primarily due to the fact that the cut material in scenario 2 is less than scenario 1. The dimensions of the channel's bottom width are remarkably similar in all scenarios. This two-year river diversion project will begin in 2024 (at 50% completion) and conclude in 2025 (50 percent). Meanwhile, the first year's land investment will be financed entirely in 2024. Capital expenditures (Capex) on sustainability will be required to support production beginning in 2026. This sustainability capex includes the following infrastructure development (see Table 3): sediment pond, shift change area, mobile hut, drone, and other minor infrastructure and equipment.

**Table 3.** Sustainibility Capex of River Diversion (Source: Company‘s Internal Data)

| Year | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|
| Value (US$) | 369,776 | 608,447 | 791,626 | 609,622 | 590,958 | 789,406 |

The river diversion investment and associated investments are to be entirely funded (100%) by the company's equity. In this financial model, all assets will be depreciated straight-line after completion until the Pit P pit is completed in 2031. Thus, at the project's conclusion, no salvage value is recorded; only the change in working capital is recorded.

### 4.2 Physical Production

The overburden removal plan, coal production, waste hauling distance, coal hauling distance, and coal quality are all detailed in Table 4. The financial viability of the Pit P Marginal pit will be determined using physical production parameters and assumptions. For all scenarios, the physical production of this project is identical.

**Table 4.** Physical Production of Pit P Marginal Pit

| SUMMARY | Units | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | Total |
|---|---|---|---|---|---|---|---|---|
| Waste | 000 000 bcm | 14.6 | 23.3 | 29.6 | 22.6 | 15.1 | 11.1 | 116.1 |
| Coal Mined | 000 000 ton | 1.6 | 2.7 | 3.5 | 2.7 | 2.6 | 3.5 | 16.5 |
| Stripping Ratio | bcm/t | 9.0 | 8.7 | 8.5 | 8.5 | 5.8 | 3.2 | 7.1 |
| Waste Distance | km | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 |
| Coal Hauling Distance | km | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 |
| Land Clearing | ha | 60.3 | 60.3 | 60.3 | 60.3 | 60.3 | 0 | 301.5 |
| Topsoil | 000 bcm | 603 | 603 | 603 | 603 | 603 | 0 | 3,015 |

| SUMMARY | Units | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | Total |
|---|---|---|---|---|---|---|---|---|
| Topsoil Distance | km | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Calorific Value | kcal/kg (gar) | 4,414 | 4,364 | 4,351 | 4,352 | 4,373 | 4,402 | 4,374 |

### 4.3 Project‘s Revenue

The forecasted coal price is based on actual data from 2009 to 2020 and is calculated using the moving average (MA) technique in combination with the exponential smoothing technique. Actual coal's historical price is 6322 gar (GC Newcastle Index [11] is shown in Table 5.

**Table 5.** Actual Coal Price Index (6322 Gar) Historical Data (Source: GC Newcastle Index)

| Year | Actual Coal Price Index (6322 Gar) US$/ton |
|---|---|
| 2009 | 72.3 |
| 2010 | 98.9 |
| 2011 | 121.4 |
| 2012 | 97.0 |
| 2013 | 85.3 |
| 2014 | 70.8 |
| 2015 | 59.2 |
| 2016 | 66.1 |
| 2017 | 88.5 |
| 2018 | 107.3 |
| 2019 | 77.8 |
| 2020 | 59.8 |

By reducing random fluctuations, a moving average technique may be beneficial for forecasting. Each time a new forecast is created, the oldest period is removed from the average and the most recent period is included [14]. The formula for a simple moving average is:

$$\mathrm{F_t} = ((\mathrm{A_{t-1}}) + (\mathrm{A_{t-2}}) + (\mathrm{A_{t-3}}) + \cdots + (\mathrm{A_{t-3}}))/\mathrm{n} \quad (1)$$

Where:
$F_t$ = Forecast for the coming period
$n$ = Number of periods to be averaged
$A_{t-1}$ = Actual occurrence in the past period
$A_{t-2}$ , $A_{t-3}$, and $A_{t-n}$ =Actual occurrences two periods ago, three periods ago, and so on.

Exponential smoothing is a forecasting technique in which the oldest observation is eliminated and a new forecast is created with each new piece of data provided. In many (maybe most) cases, current events are more indicative of the future than those from the distant past [14]. The equation for a single exponential smoothing forecast is simply:

$$F_t = (F_{t-1} + \alpha( (A_{t-1} - F_{t-1}) \quad (2)$$

Where:
$F_t$ = The exponentially smoothed forecast for period t
$F_{t-1}$ = The exponentially smoothed forecast made for the prior period
$A_{t-1}$ = The Actual data in the prior period
$\alpha$ = The desired response rate, or smoothing constant

Several steps are taken to forecast coal price forecasts:

a) Compare and analyze the difference between actual and forecasted data when using the two-year (MA2), three-year (MA3), or four-year moving average approaches (MA4).
b) From the results of the three methods described above, calculate the root mean square error (RMSE).
c) Run a regression on the result with the lowest root mean square error.
d) Using exponential smoothing, validate the forecasting technique and derive a regression from it.
e) By combining MA 3 and the exponential smoothing technique, a lower root mean square error can be obtained.

The Root Mean Square Error (RMSE) is a measure of the residuals' standard deviation (prediction errors). The root mean square error is frequently used to validate experimental results in climatology, forecasting, and regression analysis. The formula is as follows [6].

$$RMSE = \left( \sum_{i=1}^{n} \left( Z_{fi} - Z_{0i} \right)^2 / N \right)^{1/2} \quad (3)$$

Where:

$RMSE$ = Root Mean Square Error
$\Sigma_t$ = Summation
$(Z_{fi} - Z_{oi})^2$ = Differences between Actual and Projection, squared
$N$ = Amount of Sample

According to the root mean square error (RMSE) values in Table 6, the MA 3 technique in combination with exponential smoothing produces the smallest value. A smaller root mean square error is generally preferable to a larger one.

**Table 6** RMSE Test

| | MA(3yrs) + Exp. Smoothing | MA (2yrs) | MA (3yrs) | MA (4yrs) |
|---|---|---|---|---|
| RMSE | 10.22 | 24.16 | 23.37 | 24.07 |

The coal recovery factor plays a critical part in determining coal revenue. This coal recovery represents the actual coal that will be obtained, as compared to the model-generated data. The company's coal recovery rate is 104 percent based on historical data (2012-2020). The royalty assumption in this financial model is based on data sounded to the government by the Indonesian Coal Mining Association (APBI) in 2021 [2].

**Table 7.** Royalty Tariff Sounded by APBI (Source: (APBI-ICMA, 2021)

| Coal Price Index (CP) for 6322 Gar ($/ton) | Royalty Export (%) | Royalty Domestic for Electricity (%) |
|---|---|---|
| CP <70 | 14% | 14% |
| 70 ≤ CP< 80 | 16% | 14% |
| 80 ≤CP<90 | 18% | 14% |
| CP ≥90 | 20% | 14% |

The gross revenue for the project is calculated by multiplying the coal selling price (FOB) in calories by the volume of coal to be sold. It has taken into account the factor of coal recovery. While gross revenue is calculated by subtracting royalties paid to the government

from gross revenue, net revenue is calculated by subtracting royalties paid to the government from gross revenue. Table 8 details the revenue generated by this project. Net revenue totals US$702 million. Revenue estimations for this project are similar for all scenarios.

**Table 8.** Revenue Projection of Pit P Marginal Pit (2026-2031)

| Year | Coal (000 ton) | Coal Recovery (%) | Calorie (Gar) | Discount Price (%) | Coal Price for 6322 Gar ($/t) | FOB Price ($/t) | Net Revenue (000 US$) |
|---|---|---|---|---|---|---|---|
| | a | b | c | d* | e | f = (c/6322) x d x e | R= a x b x f x (1-Royalty**) |
| 2026 | 1,619 | 104.3% | 4,414 | 86.9% | 73.34 | 44.47 | 63,418 |
| 2027 | 2,663 | 104.3% | 4,364 | 86.9% | 85.71 | 51.39 | 118,441 |
| 2028 | 3,465 | 104.3% | 4,351 | 86.9% | 89.30 | 53.37 | 160,052 |
| 2029 | 2,668 | 104.3% | 4,352 | 86.9% | 84.56 | 50.56 | 116,751 |
| 2030 | 2,587 | 104.3% | 4,373 | 86.9% | 77.74 | 46.71 | 106,448 |
| 2031 | 3,455 | 104.3% | 4,402 | 86.9% | 74.67 | 45.16 | 137,473 |
| **Overall** | **16,457** | **104.3%** | **4,374** | **86.9%** | **78.23** | **48.95** | **702,583** |

**Source: PT PQR's internal data.*

*** Royalty proportions are as follows: export sales (75%), domestic sales (25%).*

### 4.4 Corporate Tax and Profit Sharing

Following the acquisition of a permit for continuation of mining operations pursuant to new regulation (Law No. 3/2020), PT PQR will be converted to a continuation of mining operations in the form of a Special Mining Business Permit (IUPK) [20]. With an IUPK status, the tax rate is determined by regulation (Law No. 2/2020); pursuant to article 1 letter b of Law No. 2/2020, corporate tax will be applied at a rate of 20% beginning in 2022 [19]. According to Article 129 paragraph 1 of Law No. 3/2020 on mineral and coal mining, IUPK holders are required to pay the central government 4% (four percent) of net profit since production and the local government 6% (six percent) of net profit since production [20]. As a result, the company of the IUPK will be charged a total of 10% profit sharing on the net profit figure in this financial model.

### 4.5 Operationg Cost and Cash Flow

The cost of mining operations and other expenses is 3.68 dollars per bcm of total material. It will be projected at a 1.48 percent annual rate of increase. This rate of increase is based on the average data from one of the company's contractors over the last four years (2016-2019). Selling expenses are assumed to be 2.22 percent of revenue. This figure is based on the average of the company's four-year sales expense history (2016-2019). The cash flow is then prepared in preparation for a WACC analysis of financial feasibility. The chart in Figure 4 illustrates the annual free cash flow to the firm (FCFF) and free cash flow to equity (FCFE) for each scenario under scenario one. The graphic analysis indicates that the project will begin providing positive FCFF and FCFE values in 2027. FCFF and FCFE will be used to conduct a capital budgeting analysis, which will provide information on the financial viability of the project.

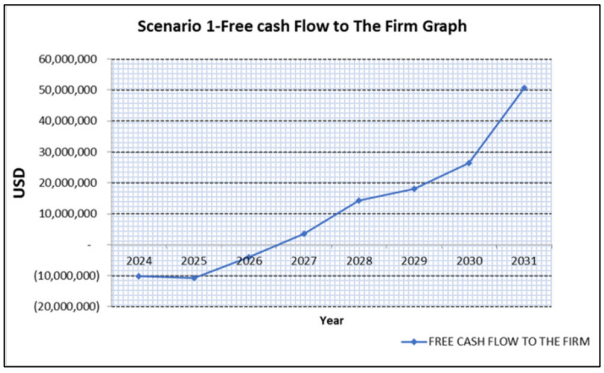


**Fig..4** FCFF Graph of Pit P Marginal Pit for Scenario 1

The chart in Figure 5 shows the scenario 2 project's annual free cash flow to the firm (FCFF) and free cash flow to equity (FCFE) for each scenario.

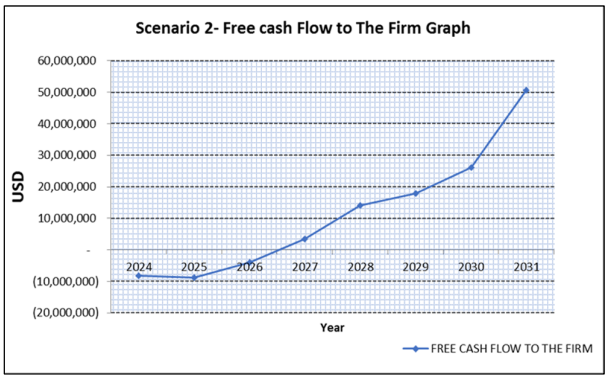


**Fig. 5.** FCFF and Graph of Pit P Marginal Pit for Scenario 2

### 4.6 Weighted Average Cost of Capital WACC

The business risk associated with a project is reflected in the discount rate, which is the rate of return required to compensate capital providers (bondholders and owners) for the risk they bear. The discount rate is the required rate of return from the investor's position. The discount rate is the cost of capital, or how much it costs the firm to raise a dollar of fresh capital [10]. Three general techniques exist for estimating equity risk premiums. One strategy is to survey subgroups of investors and managers to ascertain their future expectations for equity returns. The second approach is to examine historical returns on equities in comparison to riskless assets and estimate the expectation using this historical premium. Thirdly, we will attempt to estimate a forward-looking premium using current market rates or asset prices; these are referred to as implied premiums [8]. According to Damodaran's table of Country Default Spreads and Risk Premiums published on January 8, 2021, Indonesia's total risk premium is 6.56% [8]. Due to the fact that PT.PQR is not a publicly listed company, the beta (β) is calculated using the Damodaran table. The beta used to calculate the cost of equity is

derived from Damodaran's table that was published in January 2021 associated companies table (coal and related energy). The beta factor that will be utilized is 0.83[9]. The Indonesia 10 Years Government Bond uses a 6.427% yield [4]. Then, using the foregoing components, the cost of equity ($r_E$) may be computed, and the result obtained using the CAPM technique is as follows [7]:

$$r_E = R_F + [\beta \times ERP] \quad (4)$$
$r_E$ = 6.427% + [0.83 × (6.56%)]
$r_E$ = 11.87%

The cost of debt ($r_D$) will be assumed using Indonesia's State Owned Bank's interest rate on investment loans in US Dollars (USD) as of July 2021, 4.16% [5]. This value will be used to determine the cost of debt. Scenario 1 and 2 of the project are assumed to be funded fully (100%) through company equity. The WACC is determined as follows:

$$WACC = \left(w_D \times r_D(1 - Tax\ Rate)\right) + (w_E \times r_E) \quad (5)$$
WACC = (0%×4.16% (1-20%) + (100%×11.87%)
WACC = 11.87%

### 4.7 Capital Budgeting Analysis (CBA)

Capital budgeting analysis will be used to determine the financial viability of the project in this study. The feasibility of the project will be determined using the NPV and IRR techniques. The present value of the incremental FCFF is then calculated using a discount rate of 11.87 percent to determine the opportunity cost incurred by the Pit P marginal as a result of the river diversion project.

a) Net Present Value (NPV)
   The NPV Formula is a sophisticated capital budgeting technique that is calculated by subtracting the initial investment ($CF_0$) from the present value of the project's cash inflows ($CF_t$) discounted at the firm's cost of capital (r) [10]. The NPV of scenario 1 is calculated to be US$35.6 million. Meanwhile, the net present value (NPV) of scenario 2 is US$38.7 million.
b) Internal Rate of Return (IRR)
   The discount rate at which the net present value of cash inflows equals the initial investment is the rate of return that the company will earn if it invests in the project and receives the specified cash inflows [10]. As per the calculation, the IRR for scenario 1 is 34.9 %. In comparison, the IRR for scenario 2 is 39.9 %. The result of the financial feasibility analysis is provided in Table 9. The NPV is larger than zero 0 and the IRR is greater than the cost of capital.

**Table 9.** Pit P Marginal Financial Feasibility Study from FCFF

| Techniques | Scenario 1 | Scenario 2 |
|---|---|---|
| NPV | US$35.6 Million | US$38.7 Million |
| IRR | 34.9% | 39.9% |

All scenarios for the project are feasible. The financial value of scenario 2 is higher than that of scenario 1. However, further decision-making requires risk analysis. While scenario

2 appears to be more financially viable than scenario 1, the risk of failure may be greater, thereby increasing the likelihood of project delays and failure.

### 4.8 Risk Analysis

This risk analysis will examine eight variables to determine their sensitivity to the project's net present value. These include investments in river diversion, land compensation, sustainability capital, coal recovery, operating costs, the coal price for 6322 Gar, an escalation rate, and selling and marketing expenses.

#### 4.8.1 Sensitivity Analysis

Sensitivity analysis of financial options evaluates the effect of a change in one of the solution's critical parameters (underlying asset value, volatility, exercise price, interest rate, time to maturity, dividends, and etch) [13]. Sensitivity analysis helps companies to forecast future events by taking a range of possible outcomes into account. Scenario analysis can be used to identify business trends, risk events, technical advances, government legislation, and consumer preferences, among other things [1]. The study conducts sensitivity analysis on the base scenario using a swing factor of plus or minus 20%. The NPV value is then calculated using the swing factor values. The output of the sensitivity analysis for scenario 1 is shown in Figure 6 in the form of a Tornado chart.

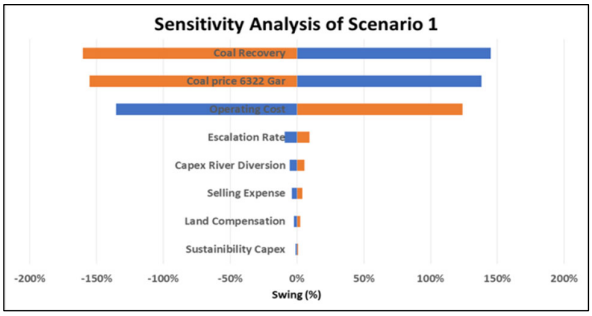


**Fig. 6.** Tornado Chart Produced as a Result of the Sensitivity Analysis for Scenario 1

The output of the sensitivity analysis for scenario 2 is shown in Figure 7 in the form of a Tornado chart.

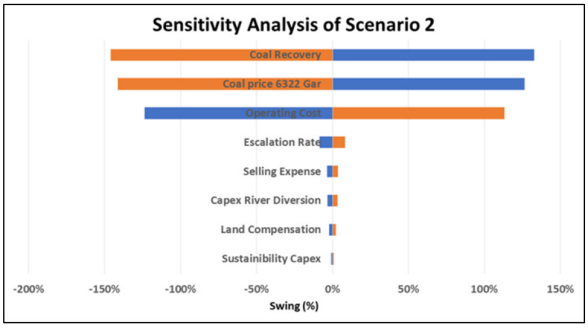


**Fig. 7.** Tornado Chart Produced as a Result of the Sensitivity Analysis for Scenario 2

Scenarios 1 and 2 communicate the same three critical variables that have a significant impact on the project's feasibility. Coal recovery, coal price, and operating cost are the three critical variables influencing the feasibility of the marginal Pit P project.

### 4.8.2 Monte Carlo Simulation

A Monte Carlo simulation program generates random values for uncertain variables repeatedly in order to simulate a model. Once these inputs are established, the Monte Carlo program can quickly run a few or thousands of simulations [10]. Three phases are required for a Monte Carlo simulation [7]:

a) We establish probability distributions for each of the important inputs to the cash flows, as well as their parameters—the average and standard deviation, for example, if the distribution is a normal distribution.
b) In each simulation, we select one outcome from each distribution and use this selection to estimate the present value of the cash flows.
c) Following a series of simulations, we should have a distribution of present values. The mean of this distribution should correlate to the project's expected value, and the standard deviation of the distribution can be used to represent the variance in the value to value alternatives on the project.

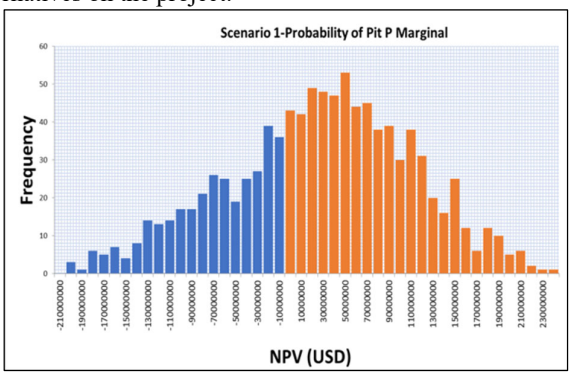


**Fig. 8.** NPV Probability of Pit P Marginal (Monte Carlo Simulation) for Scenario 1

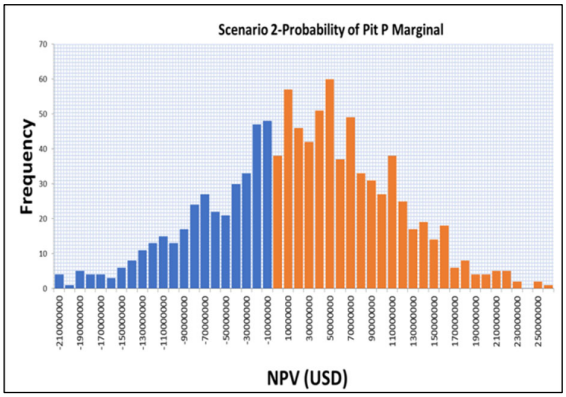


**Fig.9** NPV Probability of Pit P Marginal (Monte Carlo Simulation) for Scenario 2

**Table 10.** Statistics of Scenario 1 and Scenario 2 from Monte Carlo Simulation

| Description | Scenario 1 | Scenario 2 |
|---|---|---|
| Mean | 23,190,182 | 82,579,245 |
| Standard Deviation | 15,177,524 | 85,838,510 |
| Prob NPV<0 | 38.9% | 43.0% |

According to Table 10, risk analysis of scenario 1 indicates that the project has a 39 percent probability of failing if the NPV is less than zero, or a 61 percent estimated probability of succeeding. Meanwhile, risk analysis of scenario 2 reveals a 43% probability of failure with a negative net present value (NPV) or a projected probability of success of 57 percent. As the Monte Carlo simulation indicates, scenario 2 is more risky than scenario 1. A higher coefficient of variation (CV) indicates that an investment will be more volatile than expected returns. Given that investors seek to maximize returns while minimizing risk, one might expect them to gravitate toward investments with a low coefficient of variation [CV] [10]. Table 11 shows the coefficient of variation for each scenario.

**Table 11.** Coefficient of Variation (CV) of Scenario 1 and Scenario 2

| Investment | Mean of NPV (US$) | Standard Deviation of NPV (US$) | CV=SD/Mean |
|---|---|---|---|
| Scenario 1 | 23,190,182 | 82,579,245 | 3.56 |
| Scenario 2 | 15,177,524 | 85,838,510 | 5.66 |

According to the table above, scenario 1 is the more favorable and has lesser risk. Scenario 1 is the preferable option, given the company's prior experience with swamp areas. Scenario 2 could result in a delay in the commencement of mining operations if a failure occurs in the river diversion area, necessitating reconstruction work on the river diversion project. However, the risk management document must include the three sensitive variables (coal recovery, coal price, and operational cost) from scenario 1 to ensure that action plans are carried out effectively and that the risk management document does its job of mitigating the impact and possibility of hazards. It is expected that with a well-defined, quantifiable, and well-monitored mitigation risk in place, the 39 percent NPV 0 occurrence can be avoided or minimized. 16.6 million tons of coal in Pit P could be upgraded to reserve status from marginal reserve status. The addition of Pit P as a reserve increases the company's reserves and increases production from 2026 to 2031 (see Fig. 10). More output results in increased company profits, which eventually results in increased income for the government. The additional state income of scenario 1 raised by this project is expected to be US$182 million (only from royalty, corporate tax, and profit sharing contributions). Further research needs to be conducted to provide details on the risk management document. Mitigation actions must be developed to manage three critical variables: coal recovery, coal price, and operational cost. This is critical when beginning the implementation phase of the project. Thus, risk may be measured and evaluated in order to reduce project failures.

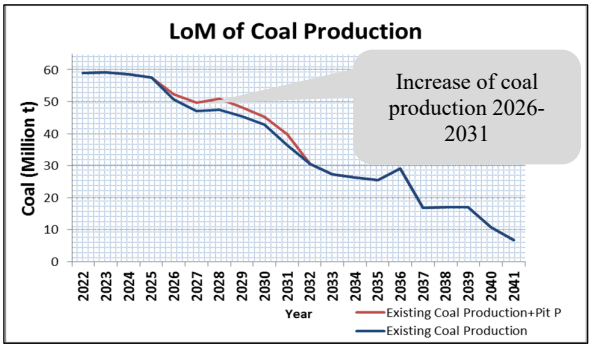


**Fig. 10.** Projection of Company's Production Level When Coal Price Low by Adding Pit P

## 5 Conclusion

Scenario 1 of river diversion (North) is recommended and more favorable for some reasons: the risk analysis of scenario 1 indicates that it has a 61 percent possibility of success, which is greater than scenario 2's 57%. Scenario 1 has a lower coefficient of variation at 3.56 and therefore is safer than scenario 2 at 5.66, and 50% of the area of scenario 2 is located in a swampy condition with soft materials. The company has considerable experience dealing with landslides and bulging, which occurred in 2019 while operating in swampy areas. As a result, the risk of landslide projects is quite high in scenario 2.

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