Economic Analysis of Coal Mining Project Using Real Option Valuation Method

Review of Integrative Business & Economics Research

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ABSTRACT

The economic valuation of coal projects is critical to their continuation. The most widely used method today is Discounted Cash Flow (DCF) valuation. However, there is a modern valuation methodology known as the Real Option (RO) Method that allows management flexibility to control risk for high uncertainty variables. At the valuation stage, the risk is modeled and adjusted for calculation at the source of uncertainty, and time risk is applied to the project's final cash flow. In comparison, the DCF method charges all risks to the project's final cash flow. This paper values a coal mining project using Modern Asset Pricing (MAP) as a form of RO valuation and compares the result with DCF valuation. The outcomes, deterministic RO (USD 272.89 million) and probabilistic RO (USD 194.38 million), have lower Net Present Value (NPV) than deterministic DCF (USD 61.3 million) and probabilistic DCF (USD 121.19 million), respectively. Finally, management will consider the project continuation, involving a risk-accepting action using the DCF valuation result or cancel the investment due to the RO valuation result, which accommodates the risk of price uncertainty. Then, it may be used as a reference for future planning projects, complement DCF valuation, and even prioritize future investments.

Keywords: Discounted Cash Flow, Uncertainty, Real Option, Flexibility.

1. INTRODUCTION

The most important aspect in a mining project, especially for coal, is economic valuation, but many variables greatly influence it, such as coal price volatility. It makes planning a valuation calculation crucial in describing conditions that may occur in the future, including considering the risks. The valuation calculation widely used today is the NPV with the DCF method, which will describe the value of a project in the present time. However, the DCF method is considered to have a limitation in determining the actual project value, mainly because of the use of a single risk factor known as the discount rate and imposed on the overall cash flow. As a result of applying the same discount rate to all projects, more risky ones may be overvalued compared to less risky ones. It also results in the same treatment of revenue and cost from a project, where the most significant risk should be in the revenue that is influenced by the commodity price. In general, factors that affect revenue (e.g., commodity prices, grades, exchange rates, etc.) are much more critical to project performance and value than factors that affect capital and operating costs (Guj, 2006a, p 111).

A price fluctuation is considered an uncertainty. While assessing a project should eliminate this uncertainty, especially for a coal mining project with an enormous investment value. After entering it, an investor hopes for profit, not such a loss. Commodity prices significantly influence the profit. However, the problem is wildly fluctuating commodity prices, both in the short and long-term periods. Therefore, industries based on natural resources, especially coal mining, should consider commodity volatility in assessing a project. In contrast, the cost aspect is relative and can be controlled internally either by operating savings or arranging a contract related to the cost itself.

In the valuation stage, especially financial evaluation, it is crucial to evaluate and mitigate the economic risk of commodity price volatility. So, this project will provide better information for a valuation calculation using the RO method, which is considered to be able to capture this issue compared to the limited capabilities possessed by the conventional DCF method.

The project's value from both DCF and RO calculations will be compared to provide an overview of the risks to be faced, which is illustrated by the difference in the project value of the two resulting calculations. Later, it can help management in making decisions related to the implementation of a project. Then it can be developed as a tool to analyze the risk profile of management, whether risk-neutral or risk-averse. Moreover, it can also assist in determining the discount rate that is to be used by a company following the risk profile of activity on a particular project.

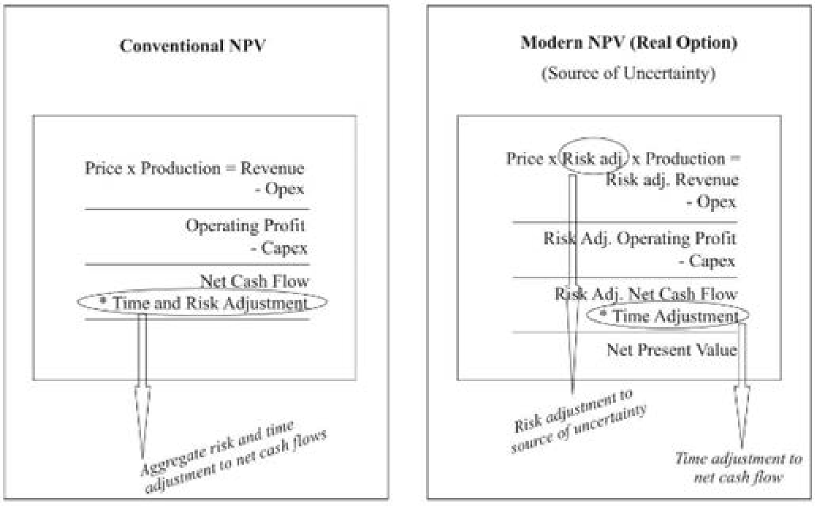
2. REVIEW OF LITERATURE

2.1. Discounted Cash Flow (DCF) vs Real Option (RO)

As briefly mentioned previously, DCF analysis is susceptible to bias because it frequently uses a single risk-adjusted discount rate (RADR) to compare the values of projects with varying risk characteristics (Salahor, 1998). RADR use can skew decisions against investing in the present to preserve recurring costs and overvalue future revenue inflows even though they are subject to an increasingly greater level of risk in the future (Salahor, 1998).

Essentially, as will be demonstrated, the source of bias can be eliminated by discounting the less risky project operating costs at a lower rate than the riskier revenue. There are numerous Real Option Valuation models available, but this project focuses on the valuation model developed by Samis, Laughton, and Poulin (2003) to address realistic project valuation problems. The DCF and RO methods of valuation are theoretically equivalent and have the same limitations. However, they differ in their approach to project cash flow risk adjustment. The DCF method uses an aggregate risk adjustment procedure that applies risk and time adjustments to net cash flow. In contrast, in RO, the risk is modeled and adjusted for calculation at the source of uncertainty and will be subjected to time risk at the final cash flow of a project.

Figure 1. Discounted Cash Flow and Real Option Disparity (Samis et al, 2003)



2.2. Modern Asset Pricing as Form of Real Option Valuation (ROV)

Besides as an assessment technique, the initial paradigm of Real Options valuation is about changing our perspective on the value of a project. The old paradigm uses a deterministic assumption that can not be changed throughout the project. In contrast, in a new paradigm, management flexibility can be accommodated to react to conditions that occur in the project, including commodity price volatility. This price volatility is assessed as an incremented risk. The calculation must be separated from other variables, especially cash flow, because cash flow should no longer be subject to risk and only consider the risk-free rate of interest to compensate for the time value of money.

This evaluation technique is a simplified version of real options valuation (Samis, 2001; Salahor, 1998, p 15; Laughton, 1998), known as modern asset pricing (MAP). MAP is generally simple to implement. It provides reliable and conservative project value estimates under several assumptions that the risk is linked to the volatility of commodity prices. More advanced forms of ROV involve neutralizing project volatility, which does not come from commodity prices alone. It also includes all other sources of risk for the overall cash flows.

The additional steps of Modern Asset Pricing besides the commonly used in DCF are as follows:

- Discounts the uncertain project cash-flow determinants (e.g., the output prices), using discounting structures appropriate for each determinant, and, if needed, construct a distribution around these discounted determinants.
- These discounted cash-flow determinants (or the distribution around them) are filtered through the project structure to find the different parts of the project value.

Because the discounting is done at the level of the cash-flow determinants, there is no need to determine or use a project discount rate anymore, except for a risk-free rate at the end of the cash flow to appreciate the time value of money. The MAP approach employs a revenue discount rate that considers coal price volatility, a risk parameter, coal price mean reversion, and time (Emhjellen and Alaoze, 2003).

The precise scope of an ROV is somewhat ambiguous. However, it typically refers to MAP application in situations where asset managers retain some future asset management flexibility. For this paper, we define ROV as the application of MAP in situations where the asset valuation and policy for future asset management are conducted concurrently.

2.3. Value of Commodity Price Risk and Price Forecasting

The critical factor in project valuation is forecasting future prices and estimating the coal price risk discounts in Real Option valuation. If the coal price is based on a long-term contract, it is called risk neutralized, but when sales depend on the spot price, it will generate price risk.

The risk discount rate (RMin) between the expected spot and the future prices is a function of the commodity price risk (Salahor, 1998). The higher the price volatility (σMin) and the further in time delivery date, the greater the markdown. The ratio of RMin to σMin is the percentage discount on price risk per unit of price volatility and is referred to as the 'commodity price risk' or *PRisk* (Salahor, 1998). This commodity price risk is defined in Equation 1:

$$\boldsymbol{Commodity\ Price\ Risk} = \boldsymbol{P}_{\mathbf{Risk}} = \frac{\mathbf{R}_{\mathbf{Min}}}{\boldsymbol{\sigma}_{\mathbf{Min}}} = \frac{(\boldsymbol{R}_{\mathbf{Mkt}} - \boldsymbol{R}_{\boldsymbol{f}})\ \boldsymbol{x}\ \boldsymbol{\rho}_{\mathbf{Min\ ,\ Mkt}}}{\boldsymbol{\sigma}_{\mathbf{Mkt}}} \qquad (1)$$

The *Prisk* is defined as unexpected changes in the price of raw materials that can reduce the producer's profit margin. It reflects markets' inherent tendency to increase the risk discount on a given series of cash flows in proportion to their volatility and the time horizon over which they will be received. By following the approach as specified in Guj and Garzon (2007), we calculate successively:

- The correlation between market index movements and coal price daily or commonly is called β (ρMin, Mkt).
- The annual volatility of market index ($\boldsymbol{\sigma_{Mkt}}$).
- The average risk premium is defined as the difference between the return on the portfolio market ($\boldsymbol{R_{Mkt}}$) and the risk-free rate of return ($\boldsymbol{R_f}$).
- The parameter $\boldsymbol{R_{Min}}$ is the discount rate for the risk between the expected spot price and the future price. The spot price indicates the price value for immediate delivery of raw material, while the future price indicates the price value for delivery of raw material at maturity.
- The parameter $\boldsymbol{\sigma_{Min}}$ is the volatility of the coal price.

Once the P_{Risk} *is* estimated, the next step is to determine the discount factor for price risk (*RDF*). To calculate the RDF, we need to determine the commodity price reversion factor. This factor, noted ϒ (Blais et al., 2005), is defined by the following Equation 2:

$$\boldsymbol{\Upsilon} = \frac{\boldsymbol{ln}\ (\mathbf{2})}{\boldsymbol{half-life}} \qquad (2)$$

Where half-life is the period required for the price of a commodity to return to its average level following a price shock, this parameter thus measures the rate of return to the mean commodity price. It is consistent with market conditions that react by increasing supply when prices rise and decreasing supply when prices fall, ensuring that price volatility will always exist but will subside due to market reverting forces.

After that, the risk discount factor (RDF) could be calculated using Equation 3 presented by Samis, Poulin, and Blais (2005):

$$\boldsymbol{RDF} = \boldsymbol{e}\left(-\frac{\boldsymbol{P}_{\text{Risk}}\,\text{x}\,\sigma_{Min}}{\Upsilon}\right)\boldsymbol{x}\,(\boldsymbol{1} - \boldsymbol{e}^{-\Upsilon x t}) \qquad (3)$$

The risk discount factor will then be applied to future coal price forecasts. Because the futures prices of projects with a longer life must be forecasted, the forecast of coal prices could be using the ARIMA or ARCH/GARCH models. The models are considered to capture the volatility clustering (Ashok Patil et al., 2017), primarily historical coal prices, to conduct risk management processes by predicting volatility changes. As a result, a high level of accuracy for valuation is obtained, which can help reduce economic risk. They forecast portfolio asset losses in the future; these potential losses are quantified through future financial variable volatility forecast (Reider, 2009).

Forecasting will be based on time-series data. Several methods are available and will be chosen based on the suitability of the test result. This forecasting is accomplished in several stages: the exponential smoothing method, stationarity test, and ARIMA test. Then, the heteroscedasticity effect should be checked to determine whether the ARCH/GARCH method can be used for forecasting. If a heteroscedasticity effect is detected, the ARCH and GARCH methods can be used. Otherwise, only the ARIMA method should be used.

ARIMA, or Autoregressive Integrated Moving Average, is a statistical technique for forecasting future trends using historical data. ARIMA considers past performance under the assumption that there is a residual effect on past values that affects current or future values:

- *Autoregression (AR)*: is a mathematical term that refers to a model in which a changing variable regresses on its own lagged, or prior, values..
- *Integrated (I):* Convert the data from a time series to a stationary series, by differencing the raw observations with replacing values between data values and their precedence values..
- *Moving average (MA)*: incorporates the relationship between an observation and a residual error resulting from the application of a moving average model to lagged observations.

ARIMA combines autoregressive and moving average characteristics. For example, an AR(1) autoregressive process is one in which the current value is determined by the immediately preceding value, whereas an AR(2) autoregressive process determines the current value by the previous two values. A moving average is a statistical technique for analyzing data points involving creating a series of averages of different subsets of the entire data set to eliminate the influence of outliers. ARIMA models can forecast using trends, cycles, seasonality, and other non-static types of data due to this combination of techniques.

ARCH (autoregressive conditionally heteroscedastic) was introduced by Engle (1982). This method can be used for heteroscedastic data that is shown inconstant variance error. The error of the variance's function can be used to describe data volatility. The change in variance over the time series will be modeled using this method, whereas GARCH (Generalized Autoregressive Conditional Heteroscedasticity) is an extension of the ARCH model that incorporates a moving average and autoregressive component.

3. METHODOLOGY

Generally, the method used in this project is to perform an economic analysis with the Discounted Cash Flow method and Modern Asset Pricing as a form of Real Option method, which will be compared with each final calculation result. The stages are as follows:

- DCF Valuation :
  - Forecasting price using the ARIMA or ARCH/GARCH method according to the appropriated test results.
  - Using forecasted price as input price in the calculation of revenue.
  - Discounting project cash flow using risk and time adjusted rate (CAPM) to obtain NPV value

- MAP Valuation :
  - Calculate and Determine the risk into price risk discount factor and time risk (risk-free rate).
  - Forecasting price using the ARIMA or ARCH/GARCH method according to the appropriated test results and then discounting the price using calculated price risk discount factor.
  - Discounting project cash flow using risk free-rate as time risk to obtain NPV value.

Data assumptions that to be used for the calculation are taken from one of the coal companies in Kalimantan-Indonesia with the following data:

- Production Schedule
  The life of mine of coal project is fifteen years start 2022-2036. Support infrastructure will assume to be constructed in 2021 and follow with mine production for the next year. Coal quality and data physical related to mine production are given by the geology and scheduling process that has been done before. Details of the production schedule can be seen in Appendix 1, while coal quality production data is in Appendix 2.

- Royalty
  Incurred royalty is assumed for the type of IUPK (Izin Usaha Pertambangan Khusus) permit, mentioned in Republic of Indonesia Regulation No.11/2020. However, the value is still in the formation stage. It will be listed in the derivative law of government regulation, the assumption already sounding by APBI-ICMA (Asosiasi Pertambangan Batubara Indonesia – Indonesian Coal Mining Association) with tiers scheme depending on average HBA Coal Price per year. The following table illustrates the value:

Table 1. Royalty Rate Illustration

Royalty	14%	16%	18%	20%
Coal Price ($/t)	<70	70-80	80-90	>90

- Freight and Marketing Commission
  This assumption is based on the company's historical data and contract agreements with several freight providers and marketing agents who sell the company's coal. The annual value of this contract is 2.25% of revenue.

- Capital Expenditure (Capex)
  Capital expenditure stands for infrastructure that must be built to support the coal mine operation. It assumes to be constructed in 2021 with details as follow:

Table 2. Details of Capital Expenditure

	Cost (k$)
Water Treatment Pond	7,166
Water Treatment Cut Slot	1,679
Coal Haul Road	15,125
Workshop, Office, Warehouse	869
Power Station and Electric Line	1,421
Civil Infrastructure	5,043
Land Compensation	3,397
Trans Kalimantan Roads Diversion	14,437
Rejuvenation Existing Asset	27,413
Total	76,550

- Operation Expenditure (Opex)
  Operating expenditure is a cost incurred to run the coal mine project. Operating expenditure consists of variable costs and fixed costs. There is also an administrative fee for the government. Details of operation expenditure are as follow:
  - Variable Cost
    The variable cost includes two types of activities: fuel-related and non-fuel-related. The non-fuel-based activity experienced a 1.2 percent yearly escalation factor (based on historical company). While for the fuel-based activity is the proportion from base condition fuel price to the future fuel price assumption of 0.65$/litre, the following table summarizes the specifics of variable cost on base condition:
  - Fixed Cost
    Fixed cost considering all processing activity consisting of coal crush, coal convey, power station, and overhead. Although the costs of each activity are fixed, the data used in this project is a part of the company's overall project in a similar area, and each project also utilizes the same processing infrastructure and company resources included in the fixed cost component. So the proportional unit fix cost should be determined by the amount of coal produced by each project, particularly when assessing the economic value of individual projects. Apart from that, because the plan of total coal production number of all projects produced by the company varies year to year, it affects each project's proportional fixed cost value annually. Details of proportional unit fixed cost per year can be seen in Table 4.

Table 3. Details of Variable Cost

	Period	0
	Year	2021
Unit Operating Cost		
Non Fuel Based		
TopSoil Dozing (include Clearing and Spreading)	$/bcm topsoil	0.30
Topsoil Loaded	$/bcm topsoil	0.24
Topsoil Hauling	$/bcm/hr topsoil	2.87
Topsoil Support	$/bcm topsoil	0.15
Topsoil Other	$/bcm topsoil	0.23
TopsoilRoadMtce	$/bcm/km topsoil	0.03
OB Drilling	$/bcm - OB Blasted	0.04
OB Explosives	$/bcm - OB Blasted	0.24
OB Drill Blast Other	$/bcm - OB Blasted	0.02
OB Dozing	$/bcm OB	0.10
OB Support	$/bcm OB	0.06
OB Loading	$/bcm OB	0.29
OB Hauling	$/bcm/hr OB	1.03
OB Other	$/bcm OB	0.18
OB Road Mtce	$/bcm/km OB	0.02
OB Pump and Dredging	$/bcm OB	0.07
Coal Drill	$/t coal blast	0.10
Coal Explosives	$/t coal blast	0.09
Coal Loading (Prime)	$/t coal mined	0.37
Coal Loading (Rehandle)	$/t coal mined	0.17
Primary Unit Coal Hauling	$/t/hr coal mined	0.52
Coal Haul Reclaim	$/t/hr coal mined	1.03
Coal Dozing	$/t coal mined	0.18
Coal RoadMtce	$/t/km coal mined	0.03
Coal Support	$/t coal mined	0.22
Coal Mining Other Costs	$/t coal mined	0.03
Fuel Based	**$/ltr**	0.692
TopSoil Dozing (include Clearing and Spreading)_Fuel Based	$/bcm topsoil	0.14
Topsoil Loaded_Fuel Based	$/bcm topsoil	0.11
Topsoil Hauling_Fuel Based	$/bcm/hr topsoil	0.90
Topsoil Support_Fuel Based	$/bcm topsoil	0.02
Topsoil Other_Fuel Based	$/bcm topsoil	-
TopsoilRoadMtce _Fuel Based	$/bcm/km topsoil	0.01
OB Drilling_Fuel Based	$/bcm - OB Blasted	0.01
OB Explosives_Fuel Based	$/bcm - OB Blasted	-
OB Drill Blast Other_Fuel Based	$/bcm - OB Blasted	0.00
OB Dozing_Fuel Based	$/bcm OB	0.06
OB Support_Fuel Based	$/bcm OB	0.02
OB Loading_Fuel Based	$/bcm OB	0.19
OB Hauling_Fuel Based	$/bcm/hr OB	1.07
OB Other_Fuel Based	$/bcm OB	0.02
OB Road Mtce_Fuel Based	$/bcm/km OB	0.01
OB Pump and Dredging_Fuel Based	$/bcm OB	0.04
Coal Drill_Fuel Based	$/t coal blast	0.01
Coal Explosives_Fuel Based	$/t coal blast	-
Coal Loading (Prime)_Fuel Based	$/t coal mined	0.13
Coal Loading (Rehandle)_Fuel Based	$/t coal mined	0.09
Primary Unit Coal Hauling_Fuel Based	$/t/hr coal mined	0.38
Coal Haul Reclaim_Fuel Based	$/t/hr coal mined	0.75
Coal Dozing_Fuel Based	$/t coal mined	0.11
Coal RoadMtce_Fuel Based	$/t/km coal mined	0.01
Coal Support_Fuel Based	$/t coal mined	0.05

Table 4. Proportional Unit Fix Cost

	Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Fix Cost ($/t)		5.18	4.45	4.28	4.00	3.75	5.84	6.47	5.43	5.06	5.70	5.80	6.68	7.60	8.32	8.40	9.41

- Marketing Logistic and Demurrage
  Fees levied by the shipping company against the importer, in this case, the company for failure to load the coal bulk to the ship within the agreed time frame, and marketing logistics refers to third-party port services. Marketing logistic and Demurrage rate number is assumed 0.8 $/ton that based on the historical company.

- Tax Rate
  According to Republic of Indonesia Regulation No.2/2020, the corporate tax rate is 20% of the profit and will be charged starting in 2022, once the project generates profit.

- Depreciation
  The straight-line depreciation method was used in this study because investment is frequently a fixed asset whose functionality is unaffected by the quantity or rate of production. The total production has already been accommodated during the preparation stage, for example, water treatment pond, workshop, office, haul road, and others. As a result, the asset's life is assumed to be equivalent to the project's duration and has no salvage value.

- Profit Sharing
  Profit sharing incurred is 10% from profit after tax for IUPK permit based on Republic of Indonesia regulation No.3/2020.

- Pemberlakuan Tarif Pajak Bahan Bakar Kendaraan Bermotor - PBBKB (Fuel Tax)
  Fuel tax rate is 7.5% for non-subsidized fuel based on Government Regulation Kalimantan Timur No.11/2011.

All of the data above will be used to develop a calculating model. However, we should establish a discount rate model, a price risk discount factor, a risk-free rate, and a coal price forecasting model.

3.1. Determine of Discount Rate, Price Risk Discount Factor, and Risk-Free Rate

As indicated above, the price risk discount factor is calculated using the derivative formula of the Capital Asset Pricing Model (CAPM) method like mentioned in Chapter 2, with the following variables contributing:

Table 5. Input Variables

Items	**Source**	**Value**
Risk Free Rate (R_F)	Indonesia 10Y Government Bond http://www.worldgovernmentbonds.com	6.54%
β	http://pages.stern.nyu.edu/	0.83
Total Equity Risk Premium ($(r_m - R_F)$)]	http://pages.stern.nyu.edu/	6.56%
Volatility Market (***σ mkt)***	JKSE Index 2009 - 2020	16.42%
Price Reversion Half-Life (years)	Company assumption based on historical coal prices	3
Short-term coal price volatility	Based on annual historical coal prices	24.47%

The discount rate for DCF valuation is also calculated using the CAPM method, as shown in Equation 4.

$$r_e = R_F + [\beta \times (r_m - R_F)] \qquad (4)$$

Where:
r_e = Required return on asset
R_F = Risk-free rate of return
B = Beta coefficient for asset
r_m = Return on the market portfolio of assets

3.2. Coal Price Forecasting

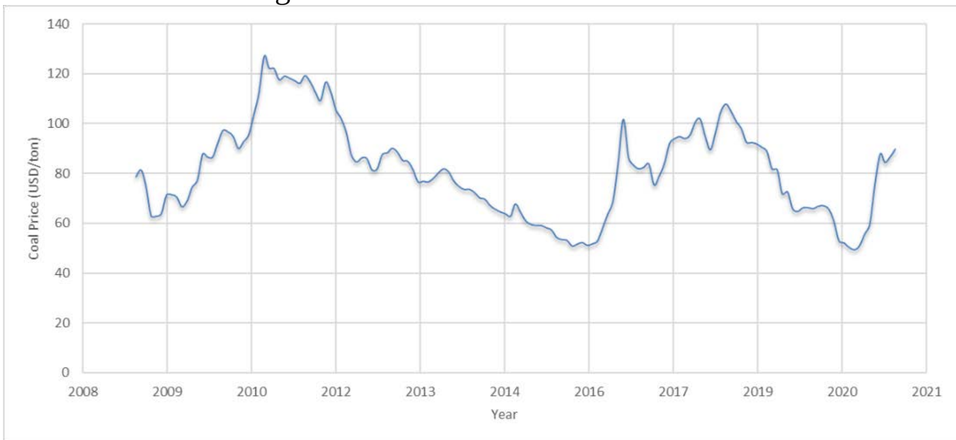
The forecast is based on monthly historical data for coal prices from January 2009 to May 2021, which is used to calculate coal price volatility and a discount factor for coal price risk. The Indonesian Ministry of Energy and Mineral Resources publishes the historical actual coal price, called HBA (Harga Batubara Acuan), which serves as a reference coal price. This price is then used to calculate the product price, referred to as HPB (Harga Patokan Batubara). The conversion from HBA to HPB depends on coal quality and is then calculated using Equation 5. It is critical to note that publicly available coal price forecasts are only available for five years, so the forward price must be estimated after this period.

$$\text{HPB Marker} = (\text{HBA} * K * A) - (B + U) \qquad (5)$$

Where :
HPB = Harga Patokan Batubara / Product Coal Price (USD/ton)
HBA = Harga Batubara Acuan / Reference Coal Price (USD/ton)
K = Coal Calorific Value/6322
A = (100 – Total Moisture) / (100 – 8)
B = (Sulphur Content – 0.8) * 4 (USD/ton)
U = (Ash Content – 15) * 0.4 (USD/ton)

Forecasting with ARIMA and ARCH/GARCH models will be used in this project, with all fitness tests requiring a critical value of 5% Z alpha, and the entire process is carried out through the use of the Eviews program. The fitness test results are used to determine which model will be used as the final model.

Figure 2. HBA Historical Coal Price



3.3. Sensitivity and Scenario Analysis

To ascertain the effect of variables on the project's value, we conducted additional sensitivity and scenario analysis. This section can also be used to mitigate the economic and financial risk associated with price and operating cost uncertainty. We use these two variables because they have the greatest impact on the value of coal mining projects, that are commonly classified as operating expenditure intensive. The swing rate used in this study was 20%, which was determined through interviews with internal company parties. The sensitivity analysis assumption is that when one variable is changed, the other variable remains constant in the base condition (ceteris paribus).
In this study, Monte Carlo Simulation was also used to conduct scenario analysis. Based on their historical data, it can be used to determine the effect of a combination of changing variables on different swings in a key parameter. In scenario analysis, a combination of changes in the values of several randomly selected variables can occur within the allowed range. The distribution pattern used for each variable is log-normal for coal price and triangular for operating cost variables. The assumption is that coal prices will not fall below zero and are triangular for operating cost variables, as the assumption is that costs incurred are almost entirely within the company's control. The simulation is run 1,000 times, and the following table summarizes the condition variables used in the Monte Carlo simulation.

Table 6. Condition Variable for Monte Carlo Simulation

Variable	Distribution	Variable Value			
		Triangular		Lognormal	
		Min	Max	P50	P90
Coal Price	Log Normal			Forecasting Coal Price	127.05
Operating Cost	Triangular	-12%	45%		

The minimum and maximum values for operating costs are obtained from historical company data. It is described as the average value of all total operating costs except for fixed costs. The author is performing Monte Carlo Simulations using the SIPmath Modeler Tools in Microsoft Excel.

4. RESULT ANALYSIS

As mentioned in Chapter 3, before creating the calculation model, there are several steps to take. The first step determines the price risk discount factor to get a discounted price for RO valuation. Before that, we have to calculate first the required return on an asset or commonly known as the discount rate that will be incurred for DCF valuation using the CAPM method or capital asset pricing model with the following formula:

$$
\begin{aligned}
r_e &= R_F + [\beta \times (r_m - R_F)] \\
&= R_F + [\beta \times \textit{Total equity risk premium}] \\
&= 6.54\% + [0.83 \times 6.56\%] \\
&= 11.98\%
\end{aligned}
$$

Where r_e stands for the discount rate, the result value is about 11.98%.

Then continue to calculate the price risk discount factor, and the first stage is to calculate commodity price risk, which means the coal price risk. The detailed calculations are as follows:

$$
\begin{aligned}
P_{Risk} &= R_{Min} / \sigma_{Min} = ((R_{Mkt} - R_f) \ x \ \rho_{Min,Mkt}) / \sigma_{Mkt} \\
&= (\textit{Total equity risk premium} \ x \ \beta) / \sigma_{Mkt} \\
&= (6.56\% \ x \ 0.83) / 16.42\% \\
&= 33.16\%
\end{aligned}
$$

$$
\begin{aligned}
\textit{Reversion factor} &= \ln(2) / \textit{halflife} \\
&= \ln(2) / 3 \\
&= 0.23
\end{aligned}
$$

Thus, the Risk Discount Factor for each year can be calculated, yielding the following result:

Table 7. Annual Risk Discount Factor

Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Risk discount factor	1.00	0.93	0.88	0.84	0.82	0.79	0.78	0.76	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.72

Following the determination of DCF and RO valuation risk factors, the next step is to forecast coal prices using historical data from Chapter 3. The first step of the forecasting process is to make the above data stationary since there is an indication of non-stationary as described by the inconsistency of time series average data. In this case, we used the EViews program to perform a stationary analysis using the Augmented Dickey-Fuller (ADF) test and discovered that the data series is stationary using the first difference root test.

After that, the test for the best ARIMA model is conducted and the results are as follow:

Table 8. ARIMA Model Options

Model	Model of Significance	Adj. R-Square	Heteroscedastic Test
ARIMA (1,1,0)	Significance	0.094558	Significance
ARIMA (0,1,1)	Significance	0.093100	Significance
ARIMA (1,1,1)	Not Significance	0.091373	Significance

The model with the highest significance and adjusted R-Square value should be chosen. As indicated in the table above, ARIMA (110) will be the best model to use as a starting point for the later step calculation. Based on the heteroscedastic test for the ARCH and GARCH models, it turns out that the data has a heteroscedastic effect. When we talk about heteroscedasticity, we are referring to the fact that variances change over time. As a result, we will implement the ARCH/GARCH method to make the forecast because it can handle heteroscedastic series data. The following step is to assess the optimal ARCH/GARCH model to be used in the forecasting process. The test results are as follows.

Table 9. ARCH/GARCH Model Options

Model	Model of Significance	Adj. R-Square	Heteroscedastic Test
GARCH (1,0)	Significance	0.093571	Not Significance
GARCH (1,1)	Not Significance	0.082441	Not Significance

As can be seen from the table above, the best model is GARCH (1,0) which is synonymous with ARCH because it has a significant model, the highest adjusted R-Square, and no residual heteroscedastic effect. The equation of the ARCH model as generated in EViews can be seen as follow:

Figure 3. EViews's ARCH Model

Dependent Variable: D(HBA_PRICE_HISTORY_MONTHLY)
Method: ML ARCH - Normal distribution (OPG - BHHH / Marquardt steps)
Date: 06/14/21 Time: 00:29
Sample (adjusted): 2009M03 2021M05
Included observations: 147 after adjustments
Failure to improve likelihood (non-zero gradients) after 284 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2

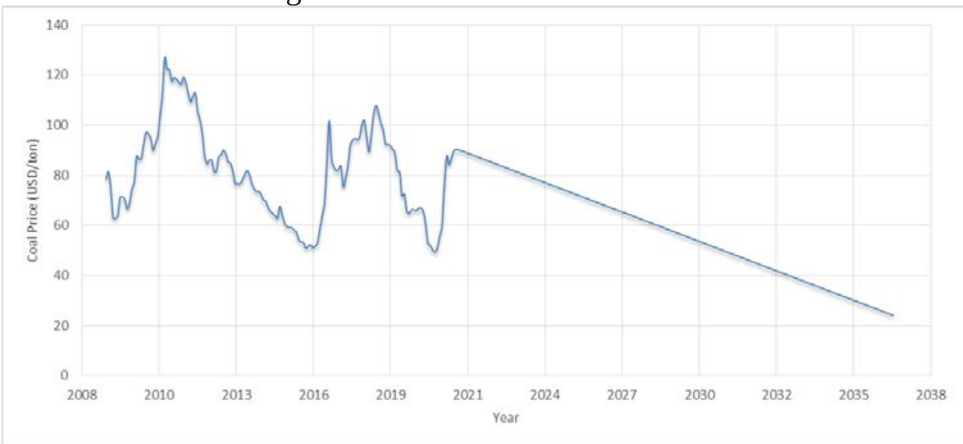
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.356952	0.559452	-0.638039	0.5234
AR(1)	0.270340	0.069411	3.894778	0.0001
Variance Equation				
C	15.53757	1.910991	8.130633	0.0000
RESID(-1)^2	0.171429	0.075008	2.285480	0.0223

R-squared	0.099779	Mean dependent var	0.057075
Adjusted R-squared	0.093571	S.D. dependent var	4.879146
S.E. of regression	4.645268	Akaike info criterion	5.816509
Sum squared resid	3128.885	Schwarz criterion	5.897881
Log likelihood	-423.5134	Hannan-Quinn criter.	5.849571
Durbin-Watson stat	1.813522		

Inverted AR Roots	.27

The result of the forecast can be seen in the figure below:

Figure 4. HBA Coal Price Forecast



Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Coal Price Forecast ($/t)	87.59	86.19	81.90	77.62	73.34	69.05	64.77	60.49	56.20	51.92	47.64	43.35	39.07	34.79	30.50	26.22

After obtaining all of the components for the valuation model, we use it to calculate economic valuations using both the DCF and RO methods. The details of the cash flow model are shown in Tables 10 and 11 (next page).

After establishing a base model for DCF and RO valuation that shows NPV RO (USD-272.89 million) is lower than DCF valuation (USD 61.3 million), the project's final step is to conduct sensitivity and scenario analysis to absorb the possibility of project risk. The following table summarizes the results of the sensitivity analysis.

Table 12. Sensitivity Analysis DCF Valuation

Variable	Variable Value			NPV (M$)			
	Downside	Base	Upside	Downside	Base	Upside	Range
Coal Price	-20%	Base	20%	(122.33)	61.30	245.58	600%
Operating Cost	-20%	Base	20%	263.56	61.30	-158.77	689%

Table 13. Sensitivity Analysis RO Valuation

Variable	Variable Value			NPV (M$)			
	Downside	Base	Upside	Downside	Base	Upside	Range
Coal Price	-20%	Base	20%	(464.83)	(272.89)	(65.94)	146%
Operating Cost	-20%	Base	20%	35.75	(272.89)	(581.53)	226%

As shown in the table above, there are significant differences in the range of NPV between DCF and RO valuations, particularly in the coal price variable. In DCF valuation, the risk of coal price volatility is greater than the risk of coal price in RO valuation because the risk of coal price volatility is already mitigated. It is also demonstrated how RO valuation can capture the uncertainty associated with an uncontrollable coal price. The RO valuation reveals a new insight that companies should prioritize managing operations carefully since they significantly impact the project's value, with the NPV range that indicates the risk rank is nearly twice as large as the coal price risk.

Table 10. Discounted Cash Flow Model Valuation

Discount Rate (Risk andTime adjusted)	11.98%																	
Period		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Year		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	
Cash Flow																		
Wt. Average Product CV	CV(gar)	-	4,569	4,612	4,226	4,269	4,193	4,292	4,412	4,421	4,402	4,297	4,180	4,122	4,142	4,156	4,209	
Wt. Average Product Price	$/PROD t	-	53.74	52.35	43.97	42.50	38.69	38.14	37.33	35.12	32.87	29.71	26.57	24.36	23.07	21.28	19.80	
Revenue FOB	K$	-	273,265	301,262	367,387	533,377	308,779	304,089	300,443	283,816	265,308	238,891	142,707	101,499	150,340	124,177	154,914	
Royalty	K$	-	46,455	51,215	62,456	90,674	52,492	51,695	51,075	48,249	45,102	40,612	24,260	17,255	25,558	21,110	26,335	
Freight and Commision	K$	-	6,148	6,778	8,266	12,001	6,948	6,842	6,760	6,386	5,969	5,375	3,211	2,284	3,383	2,794	3,486	**2021-2036**
Revenue After Royalty & Sales Commision	K$	-	220,662	243,269	296,665	430,702	249,339	245,552	242,608	229,181	214,236	192,905	115,236	81,960	121,399	100,273	125,093	3,109,080
OPEX(Pit Cost)	K$	-	138,524	125,325	183,385	290,922	249,691	259,536	238,065	214,209	242,975	248,759	167,484	111,910	147,972	132,416	163,471	2,914,644
OPEX PPN		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selling expense ($0.8/ton)	K$	-	4,068	5,063.80	7,352	11,044	7,023	7,016	7,083	7,112	7,102	7,075	4,727	3,666	5,736	5,135	6,884	96,087
Depreciation and Amortization	K$	-	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	76,550
Profit Before Tax	K$	-	72,967	107,777	100,824	123,633	(12,479)	(26,103)	(7,643)	2,756	(40,944)	(68,033)	(62,079)	(38,719)	(37,412)	(42,381)	(50,365)	21,799
Tax Payment	K$	-	14,593	21,555	20,165	24,727	-	-	-	551	-	-	-	-	-	-	-	81,591
Profit After Tax	K$	-	58,373	86,222	80,659	98,907	(12,479)	(26,103)	(7,643)	2,205	(40,944)	(68,033)	(62,079)	(38,719)	(37,412)	(42,381)	(50,365)	(59,793)
Profit Sharing	K$	-	5,837	8,622	8,066	9,891	-	-	-	221	-	-	-	-	-	-	-	32,637
Profit After Tax & Profit Sharing	K$	-	52,536	77,599	72,593	89,016	(12,479)	(26,103)	(7,643)	1,985	(40,944)	(68,033)	(62,079)	(38,719)	(37,412)	(42,381)	(50,365)	(92,429)
Add Back Depreciation and Amortization	k$	-	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	76,550
Capex	k$	76,550	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	76,550
NET CASH FLOW	k$	**(76,550)**	**57,639**	**82,703**	**77,696**	**94,119**	**(7,375)**	**(21,000)**	**(2,540)**	**7,088**	**(35,841)**	**(62,929)**	**(56,976)**	**(33,616)**	**(32,309)**	**(37,278)**	**(45,262)**	(92,429)
Cumm. Cash Flow	k$	(76,550)	(18,911)	63,792	141,489	235,608	228,233	207,233	204,693	211,781	175,940	113,010	56,035	22,419	(9,890)	(47,168)	(92,429)	(47,168)
Margin Profit After Tax and Profit Sharing	$/t	-	10.33	13.49	8.69	7.09	(1.56)	(3.27)	(0.95)	0.25	(5.07)	(8.46)	(11.56)	(9.29)	(5.74)	(7.26)	(6.44)	(0.55)
Margin Net Cash Flow	$/t	-	11.33	14.37	9.30	7.50	(0.92)	(2.63)	(0.32)	0.88	(4.44)	(7.83)	(10.61)	(8.07)	(4.96)	(6.39)	(5.79)	(0.84)
Present Value Factor	%	100%	89%	80%	71%	64%	57%	51%	45%	40%	36%	32%	29%	26%	23%	21%	18%	
Discounted Cash Flow	k$	**(76,550)**	**51,471**	**65,948**	**55,325**	**59,847**	**(4,188)**	**(10,648)**	**(1,150)**	**2,866**	**(12,940)**	**(20,289)**	**(16,404)**	**(8,642)**	**(7,417)**	**(7,642)**	**(8,286)**	
NPV	**M$**	**61.30**																

Table 11. Real Option Model Valuation

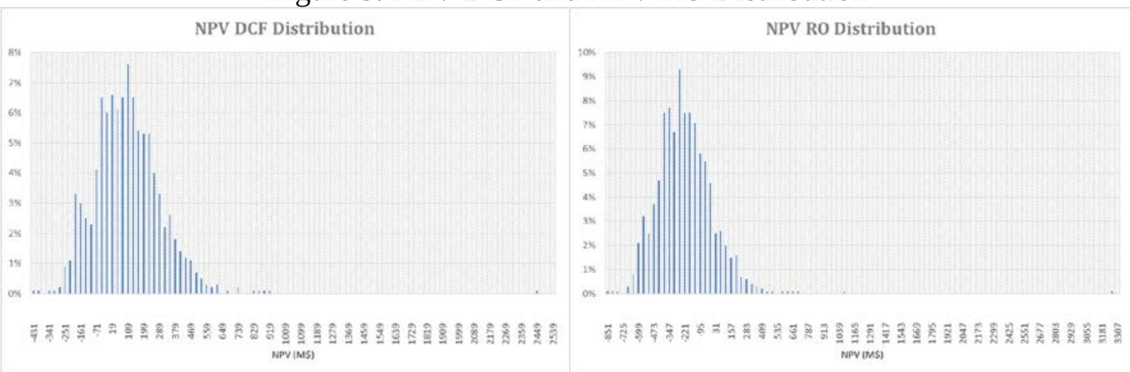
Discount Rate (Risk Free)	6.54%																	
Period		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Year		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	
Cash Flow																		
Wt. Average Product CV	CV(gar)	-	4,569	4,612	4,226	4,269	4,193	4,292	4,412	4,421	4,402	4,297	4,180	4,122	4,142	4,156	4,209	
Wt. Average Product Price	$/PROD t	-	50.51	46.98	38.21	35.92	31.95	31.02	29.90	27.90	26.04	23.55	21.14	19.54	18.71	17.41	16.40	
Revenue FOB	K$	-	256,861	270,333	319,232	450,761	255,003	247,282	240,704	225,469	210,181	189,352	113,536	81,381	121,956	101,605	128,325	
Royalty	K$	-	43,666	45,957	54,269	76,629	43,351	42,038	40,920	38,330	35,731	32,190	19,301	13,835	20,732	17,273	21,815	
Freight and Commision	K$	-	5,779	6,082	7,183	10,142	5,738	5,564	5,416	5,073	4,729	4,260	2,555	1,831	2,744	2,286	2,887	**2021-2036**
Revenue After Royalty & Sales Commision	K$	-	207,415	218,294	257,780	363,989	205,915	199,680	194,368	182,066	169,721	152,902	91,680	65,716	98,479	82,046	103,622	2,593,675
OPEX(Pit Cost)	K$	-	138,524	125,325	183,385	290,922	249,691	259,536	238,065	214,209	242,975	248,759	167,484	111,910	147,972	132,416	163,471	2,914,644
OPEX PPN		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selling expense/Demurage ($0.8/ton)	K$	-	4,068	5,064	7,352	11,044	7,023	7,016	7,083	7,112	7,102	7,075	4,727	3,666	5,736	5,135	6,884	96,087
Depreciation and Amortization	K$	-	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	76,550
Profit Before Tax	K$	-	59,720	82,801	61,939	56,921	(55,903)	(71,975)	(55,883)	(44,358)	(85,459)	(108,035)	(85,634)	(54,964)	(60,332)	(60,608)	(71,836)	(493,607)
Tax Payment	K$	-	11,944	16,560	12,388	11,384	-	-	-	-	-	-	-	-	-	-	-	52,276
Profit After Tax	K$	-	47,776	66,241	49,551	45,537	(55,903)	(71,975)	(55,883)	(44,358)	(85,459)	(108,035)	(85,634)	(54,964)	(60,332)	(60,608)	(71,836)	(545,883)
Profit Sharing	K$	-	4,778	6,624	4,955	4,554	-	-	-	-	-	-	-	-	-	-	-	20,911
Profit After Tax & Profit Sharing	K$	-	42,999	59,617	44,596	40,983	(55,903)	(71,975)	(55,883)	(44,358)	(85,459)	(108,035)	(85,634)	(54,964)	(60,332)	(60,608)	(71,836)	(566,794)
Add Back Depreciation and Amortization	k$	-	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	5,103	76,550
Capex	k$	76,550	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	76,550
NET CASH FLOW	k$	**(76,550)**	**48,102**	**64,720**	**49,699**	**46,086**	**(50,799)**	**(66,871)**	**(50,780)**	**(39,255)**	**(80,356)**	**(102,932)**	**(80,531)**	**(49,861)**	**(55,229)**	**(55,505)**	**(66,733)**	(566,794)
Cumm. Cash Flow	k$	(76,550)	(28,448)	36,272	85,971	132,058	81,258	14,387	(36,393)	(75,648)	(156,003)	(258,935)	(339,466)	(389,327)	(444,556)	(500,061)	(566,794)	(500,061)
Margin Profit After Tax and Profit Sharing	$/t	-	8.46	10.36	5.34	3.27	(7.00)	(9.03)	(6.94)	(5.49)	(10.59)	(13.44)	(15.94)	(13.19)	(9.26)	(10.39)	(9.18)	(4.98)
Margin Net Cash Flow	$/t	-	9.46	11.25	5.95	3.67	(6.36)	(8.39)	(6.31)	(4.86)	(9.96)	(12.80)	(14.99)	(11.97)	(8.47)	(9.51)	(8.53)	(5.17)
Present Value Factor	%	100%	94%	88%	83%	78%	73%	68%	64%	60%	57%	53%	50%	47%	44%	41%	39%	
Discounted Cash Flow	k$	**(76,550)**	**45,149**	**57,018**	**41,097**	**35,770**	**(37,008)**	**(45,726)**	**(32,591)**	**(23,648)**	**(45,436)**	**(54,629)**	**(40,117)**	**(23,313)**	**(24,238)**	**(22,864)**	**(25,802)**	
NPV	**M$**	**(272.89)**																

The selected NPV is taken as the average of 1,000 run-time NPV values for scenario analysis under the conditions specified in Chapter 3. The following table summarizes the Monte Carlo Simulation results.

Table 14. Monte Carlo Simulation Result

Condition	NPV(M$)	
	DCF	RO
Base Case	61.30	(272.89)
Mean	121.19	(194.38)
Median	110.01	(217.02)
Minimum	(431.37)	(851.06)
Maximum	2470.88	3302.47
Standard Deviation	198.93	245.96

Figure 5. NPV DCF and NPV RO Distribution



For Monte Carlo Simulations, the more simulations performed, the more accurate the results. As it happens, the NPV RO (USD-194.38 million) is still less than the DCF valuation (USD 121.19 million).

5. CONCLUSION AND DISCUSSION

The results of the calculation show that the total NPV values of DCF (USD 61.3 million) and RO (USD-272.89 million) in deterministic valuation are less than the amount of their initial investment, while the total NPV of DCF (USD121.19 million) and RO (USD-194.38 million) in probabilistic valuation are limited to DCF that provides a positive return on investment. All of the valuation outcomes provide a different perspective on evaluating the project. However, it is highly dependent on the pricing used. If we use only positive cash flow periods that stand for management flexibility, the project should be stopped or delayed and wait for increased coal prices. In this case, the condition occurs in fifth-year periods after the initial investment when the project start suffers from negative cash flow. If we compare the NPV value for this point in deterministic valuation, DCF valuation will receive USD151.85 million while RO only acquires USD65.48 million. However, we will emphasize the variance value of DCF and RO valuations, which RO valuation can be used as a consideration or complement to the traditional valuation system. Management can even use it to prioritize future investments that will be financed. Eventually, this becomes critical, especially when determining the sustainability of a project whether management will take the results of the NPV value of DCF deterministic valuation in the fifth year following an investment that indicates an ROI (return on investment) of 98% and implies an action that accepts risk or will cancel the investment due to recognizing the ROI -14% from RO valuation, which accommodates the risk of price uncertainty.

On the other hand, if we adhere to probabilistic valuation, we should accept the entire cash flow of a project with a net present value of USD121.19 million and a return on investment of 58% based on DCF valuation, or RO valuation with an NPV value of USD-194.38 million and an ROI value of -354%. However, this is merely a project value overview that can be presented to management. Confidence in management that is frequently derived from experience is required to determine whether to continue with this investment or pursue other more likely opportunities to generate substantial profits. Finally, all aspects should be confirmed and considered, not only about financial variables but also technical, social, and other issues related to the project.
Comparisons between the conventional DCF and RO valuation methods that are widely known today usually focus on the ability of each method to calculate the added value of project flexibility, which is shown by management actions in managing and responding to the occurring issues. However, this does not really reflect a fundamental difference between DCF and RO. Basically, the difference is the way each method in managing the risk. With the appropriate risk assessment, the strategy to be developed is expected to be capable of determining the real project value. The difference in the value of the project shown from the calculation results of the two methods greatly affects the corporate valuation policy, especially in ensuring that the investment value issued has been allocated efficiently, as indicated by an increase in return on investment.

A robust valuation is needed to accommodate all issues, especially the existing risks, and place them properly in the calculation to achieve that condition. So, the calculation results obtained may represent the actual return that will be obtained. Thus, it would be better if further research related to the comparison between DCF and RO methods focused on which method is better at accounting for project risk than on their relative abilities to value management flexibility.

Besides that, some of these things really depend on the pricing used, tax, and royalty policies of a country where an asset is invested. So, determining the price to be used is the main key in the valuation calculation, especially when using the Modern Asset Pricing method. All assumptions used in the calculation, especially price volatility, risk parameters, reversion factor of coal price, and time, are very important. As much as possible to accommodate all issues that will occur in the future. The existing history may be insufficient to describe these conditions, and additional research is urgently needed on this subject.

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APPENDIX

Appendix 1. Production and Physical Data of Coal Project

	Years	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Units	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
	Production Days	365	365	365	366	365	365	365	366	365	365	365	366	365	365	365	366
Total OB Removed	kbcm	-	38,021	24,810	31,075	60,617	46,444	46,444	46,672	46,544	46,544	46,544	28,381	19,448	19,448	14,185	10,212
OB Removed Normal	kbcm		38,021	24,810	31,075	60,617	46,444	46,444	46,672	46,544	46,544	46,544	28,381	19,448	19,448	14,185	10,212
Coal Exposed	kt		5,085	5,754	8,355	12,550	7,981	7,972	8,049	8,082	8,071	8,040	5,372	4,166	6,518	5,835	7,822
S.R. (Coal Exposed)	bcm/t	-	7.5	4.3	3.7	4.8	5.8	5.8	5.8	5.8	5.8	5.8	5.3	4.7	3.0	2.4	1.3
Cumm S.R.	bcm/t	-	7.5	5.8	4.9	4.9	5.1	5.2	5.3	5.3	5.4	5.4	5.4	5.4	5.2	5.1	4.8
TOTAL	kt	-	5,085	5,754	8,355	12,550	7,981	7,972	8,049	8,082	8,071	8,040	5,372	4,166	6,518	5,835	7,822
Thickness	m		7.7	10.8	14.6	14.6	14.6	12.0	7.9	8.3	8.7	8.8	9.0	11.7	15.5	15.3	18.8
Ash	% (gar)		3.9	3.1	2.9	3.0	3.4	3.5	3.8	3.7	3.6	3.5	3.3	3.0	2.6	2.5	2.3
GCV	kcal/kg (gar)		4,569	4,612	4,226	4,269	4,193	4,292	4,412	4,421	4,402	4,297	4,180	4,122	4,142	4,156	4,209
SU	% (gar)		0.43	0.3	0.27	0.28	0.42	0.35	0.39	0.42	0.38	0.38	0.40	0.35	0.23	0.21	0.16
TM	% (gar)		29.73	30.1	34.42	33.84	34.67	33.58	32.04	32.02	32.32	33.53	35.01	35.93	36.16	36.12	35.97
IM	% (gar)		26.2	26.6	31.7	30.9	29.7	28.4	26.6	26.6	26.9	28.3	30.1	31.3	31.6	31.6	31.4
Coal Mined	kt	-	5,085	5,754	8,355	12,550	7,981	7,972	8,049	8,082	8,071	8,040	5,372	4,166	6,518	5,835	7,822
Inpit Closing Inventory	kt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Waste travel time	mins return		19.5	30.0	37.4	32.4	40.1	44.3	33.6	23.4	36.8	39.0	39.9	15.5	16.6	26.4	28.6
Waste haul distance (1-way)	m		3,171	4,722	7,231	6,254	6,600	6,475	5,884	2,903	5,228	5,932	6,060	2,898	2,906	4,102	4,176
Coal travel time Pit to CPP/Port	mins return		105.6	108.6	97.7	93.6	87.0	93.1	94.2	93.4	100.2	98.2	102.0	102.5	101.6	100.9	103.5
Coal haul distance Pit to CPP/Port	m		20,812	21,273	22,507	21,229	19,267	20,542	20,104	20,174	22,180	22,817	23,057	22,973	22,602	22,552	22,655
Waste cycle time (996BH + EH4500)	mins return	4.5	24.0	34.5	41.9	36.9	44.6	48.8	38.1	27.9	41.3	43.5	44.4	20.0	21.1	30.9	33.1
Coal cycle time - Pit to CPP/Beng S-P (EX2500 + 777)	mins return	8.0	113.6	116.6	105.7	101.6	95.0	101.1	102.2	101.4	108.2	106.2	110.0	110.5	109.6	108.9	111.5
Top Soil Loaded	kbcm	790	957	497	3,256	-	2,748	1,589	2,886	1,889	-	560	525	1,657	-	-	992
Tposoil Haul Cycle Time	mins	20	16	14	16	-	33	25	22	25	-	35	35	29	-	-	23
Topsoil Haul Distance	m	3,008	1,793	1,579	1,959	-	6,023	4,031	3,586	4,516	-	5,572	5,469	5,239	-	-	4,048

Appendix 2. Coal Quality Production

	Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Year	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**
Coal Production																	
Product A	kton	-	978	1,353	0	5	0	-	-	4	13	28	-	-	-	-	-
Product B	kton	-	1,511	1,740	26	193	236	688	1,977	2,045	1,877	975	16	2	5	4	-
Product C	kton	-	1,179	1,916	5,719	8,070	5,285	4,603	2,827	2,811	2,827	3,395	2,740	2,328	5,182	4,736	7,532
Product D	kton	-	1,144	590	2,433	4,071	2,315	2,402	2,705	2,731	2,914	3,277	2,418	1,784	1,287	1,087	279
Product E	kton	-	273	155	176	211	145	280	541	491	440	365	198	52	43	9	10
Total Production	**kton**	**-**	**5,085**	**5,754**	**8,355**	**12,550**	**7,981**	**7,972**	**8,049**	**8,082**	**8,071**	**8,040**	**5,372**	**4,166**	**6,518**	**5,835**	**7,822**
Product CV																	
Product A	CV (kcal/kg - GAR)	-	5,064	5,053	5,115	5,029	5,003	-	-	5,156	5,144	5,064	-	-	-	-	-
Product B	CV (kcal/kg - GAR)	-	4,839	4,866	4,717	4,675	4,720	4,682	4,750	4,791	4,773	4,797	4,855	4,729	4,743	4,744	-
Product C	CV (kcal/kg - GAR)	-	4,218	4,221	4,274	4,311	4,196	4,256	4,366	4,381	4,391	4,345	4,270	4,196	4,175	4,185	4,215
Product D	CV (kcal/kg - GAR)	-	4,176	4,183	4,124	4,177	4,147	4,279	4,276	4,249	4,228	4,126	4,089	4,032	4,014	4,027	4,045
Product E	CV (kcal/kg - GAR)	-	4,455	4,381	3,975	4,080	3,948	4,023	4,096	4,066	4,022	4,001	3,988	3,925	3,936	4,125	4,039
Wt. Average CV	**CV (kcal/kg - GAR)**	**-**	**4,569**	**4,612**	**4,226**	**4,269**	**4,193**	**4,292**	**4,412**	**4,421**	**4,402**	**4,297**	**4,180**	**4,122**	**4,142**	**4,156**	**4,209**
Product Total Moisture																	
Product A	TM (% on GAR)	-	25.36	25.86	19.38	26.14	26.74	-	-	19.78	19.82	20.20	-	-	-	-	-
Product B	TM (% on GAR)	-	26.30	27.22	24.67	28.28	27.93	29.52	29.29	29.09	29.39	28.90	21.84	23.36	23.06	23.08	-
Product C	TM (% on GAR)	-	34.52	35.01	34.37	33.91	35.70	35.07	33.71	33.45	33.23	33.66	34.48	35.58	36.04	35.99	35.96
Product D	TM (% on GAR)	-	33.85	32.73	34.87	34.20	33.31	32.53	32.90	33.19	33.67	35.16	35.97	36.51	36.83	36.77	36.72
Product E	TM (% on GAR)	-	26.39	27.61	31.37	29.61	29.97	28.19	29.08	29.76	30.44	31.17	31.69	32.25	32.52	29.79	25.18
Wt. Average Total Moisture	**TM (% on GAR)**	**-**	**29.73**	**30.07**	**34.42**	**33.84**	**34.67**	**33.58**	**32.04**	**32.02**	**32.32**	**33.53**	**35.01**	**35.93**	**36.16**	**36.12**	**35.97**
Product Sulphur																	
Product A	SU (% on GAR)	-	0.52	0.41	0.23	0.53	0.34	-	-	0.23	0.23	0.23	-	-	-	-	-
Product B	SU (% on GAR)	-	0.61	0.37	0.23	0.38	1.42	0.59	0.34	0.27	0.23	0.24	0.25	0.24	0.24	0.24	-
Product C	SU (% on GAR)	-	0.14	0.15	0.15	0.15	0.14	0.15	0.17	0.18	0.18	0.18	0.20	0.18	0.17	0.17	0.15
Product D	SU (% on GAR)	-	0.31	0.33	0.50	0.51	0.91	0.58	0.50	0.61	0.54	0.53	0.54	0.54	0.44	0.35	0.29
Product E	SU (% on GAR)	-	0.81	0.40	0.78	0.88	1.15	1.17	1.14	1.36	1.19	1.28	1.40	1.21	1.14	0.96	0.48
Wt. Average Sulphur	**SU (% on GAR)**	**-**	**0.43**	**0.30**	**0.27**	**0.28**	**0.42**	**0.35**	**0.39**	**0.42**	**0.38**	**0.38**	**0.40**	**0.35**	**0.23**	**0.21**	**0.16**
Product Ash																	
Product A	ASH (% on GAR)	-	3.09	2.78	6.44	3.06	2.68	-	-	6.17	6.25	6.52	-	-	-	-	-
Product B	ASH (% on GAR)	-	4.56	3.40	6.48	3.79	4.47	3.39	2.94	2.75	2.70	2.77	7.29	7.11	7.36	7.32	-
Product C	ASH (% on GAR)	-	2.12	2.10	2.34	2.35	2.21	2.34	2.51	2.53	2.59	2.63	2.60	2.43	2.34	2.37	2.26
Product D	ASH (% on GAR)	-	4.03	4.92	3.61	3.81	5.52	4.80	4.49	4.44	4.19	3.86	3.49	3.49	3.35	3.14	3.06
Product E	ASH (% on GAR)	-	9.43	9.09	9.46	9.98	11.45	11.91	10.37	10.32	9.99	9.45	9.26	9.48	9.14	9.70	13.68
Wt. Average Ash	**ASH (% on GAR)**	**-**	**3.86**	**3.13**	**2.88**	**2.97**	**3.41**	**3.51**	**3.81**	**3.70**	**3.60**	**3.47**	**3.26**	**2.97**	**2.59**	**2.53**	**2.30**