RESEARCH ARTICLE

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Forecasting Coal Price Using Static and Dynamic Stochastic Model as Based for Indonesia's Mining Project Valuation with Real Option Method

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ABSTRACT

Indonesia's coal mining company is not only a capital-incentive business that needs high investment at the start of the project but also a cost-incentive business that needs high operational costs along the project. The most important parameter needed to determine the project value is assuming uncertainty of coal price in the future. This condition forces mining entrepreneurs to forecast future coal prices with the assumption. One of the approaches is using the Stochastic Model to predict price fluctuation in the future. There are two models: the static model, which uses 50 percentiles of historical data, and the dynamic model, which uses Monte Carlo simulation with normal distribution as the fluctuation of the percentile. Using the Real Options Method, this approach could make a difference in project valuation. This difference could give insight into the mining project valuation.

Keywords: Coal price, dynamic stochastic model, forecasting, real option method, static stochastic model.

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I. Introduction

Mining is known as a capital-intensive business with non-renewable products and has a high risk. It takes considerable capital to start this business, which is done for exploration activities, infrastructure development, provision of other supporting facilities, mining operations, and coal processing to post-mining. Because coal is a non-renewable resource, the exploitation process that will be carried out must be able to provide optimal value. For this reason, comprehensive financial planning is needed to review, estimate, and ensure project returns and generate profits.

In the third position, Indonesia is known as the largest coal-producing country in the world. Indonesia's coal production in 2020 will reach 562.5 million tons. In 2021, Indonesia's coal production will be 610.2 million tons. Meanwhile, based on the Statistical Review of World Energy, Indonesia's proven coal reserves are only 34.8 billion tons, far less than India and China.

Indonesia is the largest exporting country despite having the most negligible coal reserves among the five other countries (United States, China, India, and Australia). The Ministry of Energy and Mineral Resources noted that Indonesia's coal exports reached 318.75 million tons. Indonesia's coal production is intended for export, and the rest is for domestic purposes.

If Indonesia consistently dredges coal within this range, the Ministry of Energy and Mineral Resources has predicted that Indonesia's coal reserves will run out within the next 20 years.

Generally, mining companies in Indonesia actively participate in the utilization of coal resources. Coal Reserve has been classified based on the level of detail completed in the mine planning and confidence in the coal Resource. The Measure and Indicated Coal Resource are reported inclusive of those coal Resources modified to produce the Coal Reserve (that is, Coal Reserves are not additional to Coal Resource). One of the mining areas that will be exploited is Block XYZ. The total coal reserve at block XYZ is 64.5 million, with 56.4 million proven coal and 8.1 million probable coals.

II. Business Issue

Like the coal mining industry in general, besides being a capital and technology-intensive business, mining activities are influenced by many factors of uncertainty. This condition forces every mining entrepreneur to manage it properly. Uncertainty factors that may arise are both internal and external. Internal factors are based on the availability of resources owned and can be controlled by the company. At the same time, external factors are influenced by conditions outside the company, cannot be controlled directly by the company, and affect business continuity.

External factors that often arise that significantly affect the economic assessment process of a mining project are the volatility of coal prices, fuel prices, demand and availability of coal stocks in the market, economic growth, regulations and policies in the fields of environment, operations, taxation, global political instability. and local, social, and technological risks. The most influential factor is the price of coal. Coal price fluctuations can be seen in Fig. 1.

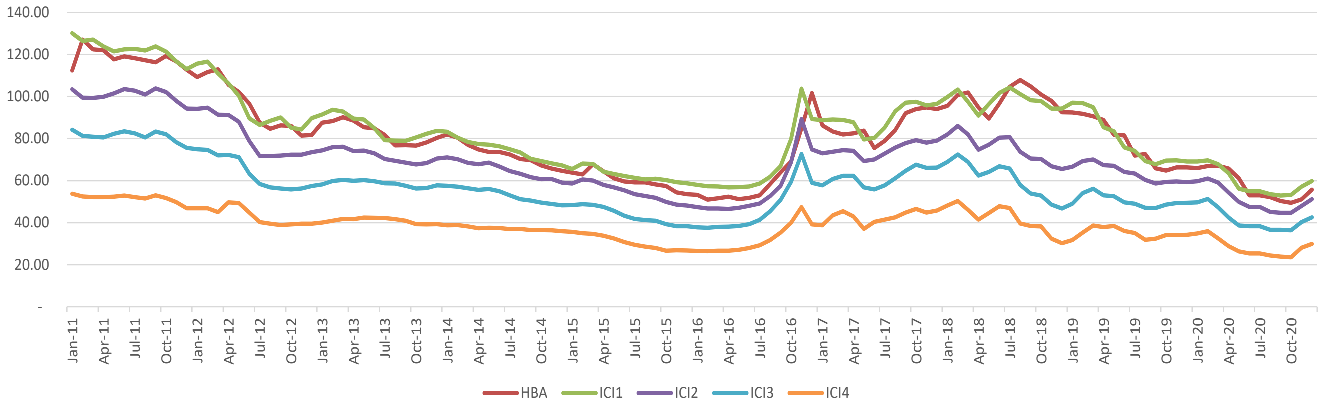

Fig. 1. Historical Indonesia Coal Price (Source: Argus, 2022).

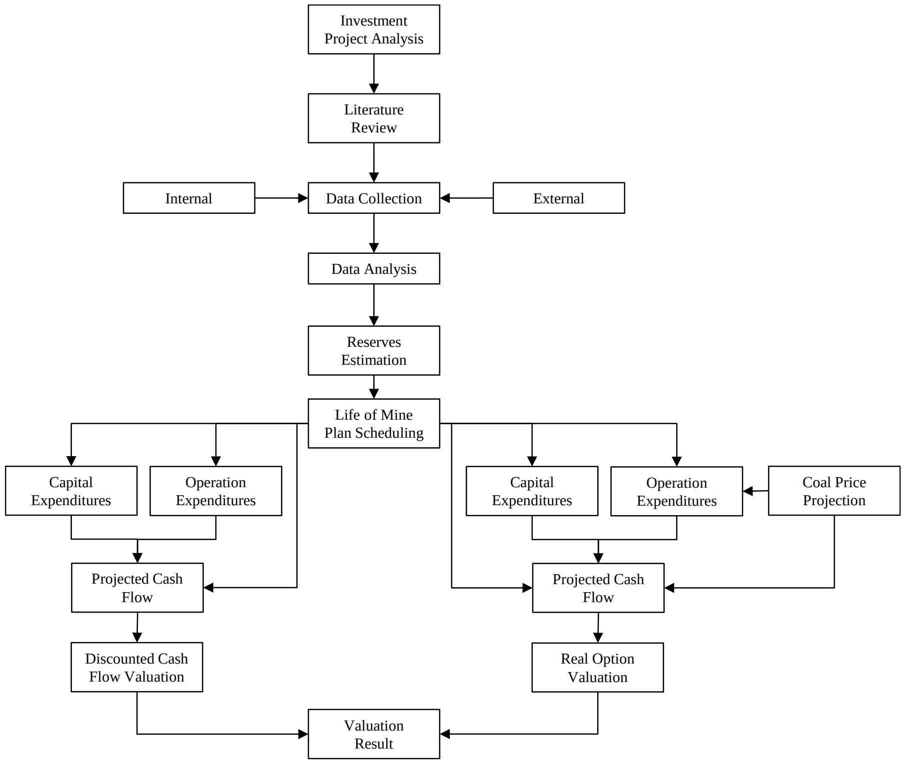

Fig. 2. Research methodology.

Given these risks and uncertainties, a forecasting model is needed to consider the risks and uncertainties from planning to implementing mining activities. Every change in the selling price of coal must be included in the investment evaluation. Then, the economic evaluation will influence the company's decision-making to invest and determine the company's goals to optimize shareholder wealth.

The method generally used by Indonesia's coal companies at this time is the DCF method, which generally cannot capture the uncertainty that exists in coal commodities well and does not have the flexibility to make decisions under conditions of uncertainty. Unlike DCF, the Real Option Valuation (ROV) method provides flexibility in using several options. The ROV model focuses more on describing the uncertainty, particularly the managerial flexibility inherited in many investments. Real choices give companies the opportunity but not the obligation to take action. Such project options usually include abandoning, delaying, or expanding investment.

The ROV method considers strategic managerial options under uncertainty and flexibility in several options at different conditions and times. Decisions can be made when the level of uncertainty is gradually identified and can be overcome by internal and external factors.

III. Research Methodology

The issue in this research is to conduct a study for the coal price model used at block XYZ mining project valuation, a greenfield project with limited technical and investment options. From these business issues, a study will be conducted regarding the stochastic forecasting model that might provide the needed adequate coal price model. The next step is to create a technical option and perform an economic valuation. The current valuation method used is DCF, where the price assumption used is static from the beginning to the end of the project, and all existing decisions cannot be canceled without options. Due to these conditions, an alternative valuation method is carried out. Accurate option valuation (ROV) is the alternative method that will be used to compare the valuation with the currently used method. This ROV method allows management to expand, abandon, or delay the project. After that, risk analysis will also be carried out on several uncertainty factors with sensitivity analysis, and the five most significant factors will be carried out in worst, base, and best scenario analysis. All valuation results are then analyzed, and the best option to maximize shareholder wealth is recommended. The research method used can be seen in Fig. 2, which focused on the coal price projection process.

IV. Literature Review

According to Haq (2018), while the average duration of a coal mining operation is over five years, the lack of market data limits that allow for determining coal prices for only two to five years creates challenges for coal price estimates. For this reason, a forward pricing model is required, allowing the model to compile data on market behavior while examining future commodity prices. The lognormal single-factor stochastic process model is one of the models employed.

The mathematical equations for this model, which employ the lognormal single-factor stochastic process, are given in (1).

$$dS = \left[\alpha^* + \frac{1}{2}\sigma_s^2 - \gamma \ln\left(\frac{S}{S^*}\right)\right] Sdt + \sigma_s S\, dz \quad (1)$$

Where:
S = current commodity price,
S* = long-term median price,
α* = growth rate of median price (%),
σs = short-term price volatility (%),
γ = reversion factor = ln(2)/ half-life,
dz = standard winner increment = $\varepsilon\sqrt{dt}$,
ε = standard normal random variable,

There are two ways to do the stochastic price model, which are discussed in the following sections.

A. Static Stochastic Price Model

The Z% confidence interval statistical method is used to carry out the stochastic process. The static price model was employed in this study, and 50 percentiles from historical coal price data from January 2011 to December 2021 were used. Several formulas are derived from the single-factor stochastic lognormal model in determining the forward price with the static stochastic model.

Associated price variance at time t (Var (t)) given in (2).

$$Var(t) = \frac{\sigma_s^2}{2\gamma}(1 - \exp(-2\gamma t)) \quad (2)$$

Short-term median price (St) formula is given in (3).

$$Med[St] = S^* \left[\frac{S}{S^*} \times\ exp\left(\frac{\propto}{\gamma}(1 - exp^{-\gamma t})\right)\right]^{\exp(-\gamma t)} \quad (3)$$

Expected price (E0[St]) formula is given in (4).

$$E_0[S_t] = Med[St] \times \exp(0.5 \times Var(t)) \quad (4)$$

Risk Discount Factor (RDF) formula is given in (5).

$$RDF_t = \exp\left[-\frac{P_{risk} \times \sigma}{\gamma} \times (1 - \exp(-\gamma t)\right] \quad (5)$$

Forward Price (Kt) formula is given in (6).

$$K_t = E_0[S_t] \times RDF_t \quad (6)$$

B. Dynamic Stochastic Price Model

Several additional formulas and a Monte Carlo simulation are integrated with the existing project financial model to determine the forward price with the dynamic stochastic model. We used an Excel add-on, SIP math, with randomization of 1,000 samples, and simulation with normal distribution input (mean = 0, stdev = 1). There are several formulas in addition to the static stochastic price model formula.

One period ahead (t+Δ) associated price variance is given in (7).

$$Var(t1) = \frac{\sigma_s^2}{2\gamma}(1 - \exp(-2\gamma t_1)) \quad (7)$$

One period ahead expected median price is given in (8).

$$Med[S_{t+\Delta}|S_t] = Med[S_{t+\Delta}] \times \left[\frac{S_t}{Med_0(S_t)}\right]^{\exp(-\gamma\Delta)} \quad (8)$$

Monte Carlo spot price outcome is given in (9).

$$S_{t+\Delta} = Med[S_{t+\Delta}|S_t] \times \exp(Monte\ Carlo\ draw\ \times \sqrt{Var(\Delta)} \quad (9)$$

Monte Carlo Forward price outcome (K_t) is given in (10).

$$K_t = S_{t+\Delta} \times RDF_t \quad (10)$$

According to Damodaran (2012), there are four approaches to valuation. The first is intrinsic valuation; every asset that generates cash flows has an intrinsic value that reflects both its cash flow potential and its risk' (Discounted Cash Flow valuation). The second probabilistic valuation considers a different and potentially more informative way of assessing and presenting the risk in investment rather than computing an expected value for an asset or firm that tries to capture the expected value across different possible outcomes. The third, relative valuation, values an asset based on how similar assets are priced in the market. The fourth, accurate option valuation, uses pricing models to measure the value of assets with option characteristics. There can be significant differences in outcomes, depending upon which approach is used—related to this research objective, DCF and ROV methods are used to compare the usage of coal price modeling.

V. Business Solution Alternatives

The revenue from this project came from producing and selling coal, and the coal price assumption is based on the quality of the coal. Several coal indexes are used based on coal quality, ranging from the lowest to the highest rank of product. As described in the previous chapter, there are limitations in projecting coal prices if only looking at market data, which are generally only available for the next 2-5 years, while projects have a relatively longer duration. For this reason, it is necessary to project coal prices long-term, known as the forward pricing method, using the stochastic process model. There are two ways to do the stochastic price model, which are discussed in the following sections.

A. Static Stochastic Price Model

The stochastic process is carried out using a statistical approach of Z% confidence interval; in this research, the static price model used the 50 percentiles from historical coal price data from January 2011 until December 2021. Several formulas are derived from the single-factor stochastic lognormal model in determining the forward price with the static stochastic model. Example for trial 65 in the first year (t=1), with:

Current spot price (S)	= $ 38.54 /ton
Long term price (S*)	= $ 37.61 /ton
Coal Median Trent (α)	= 2%
Price Volatility (σ)	= 34.2%
Reversion factor (γ)	= 0.69
Commodity price risk (P_(risk))	= 0

Associated price variance at time t (Var (t)) is given in (11):

$$Var(1) = \frac{17.7^2}{2x0.23}(1 - \exp(-2x0.23x1)) = 0.06 \tag{11}$$

Short-term median price (St) is given in (12).

$$Med[S1] = 37.61\left[\frac{38.54}{37.61} \times\ exp\left(\frac{2\%}{0.69}(1 - exp^{-0.69\times1})\right)\right]^{\exp(-0.69\times1)} = \$\ 38.35\ /ton \tag{12}$$

Expected price (E0[St]) is given in (13).

$$E_0[S_1] = 38.35 \times \exp(0.5 \times 0.06) \tag{13}$$

$$E_0[S_1] = \$39.58$$

Risk Discount Factor (RDF) is given in (14).

$$RDF_1 = exp[-\frac{0.30 \times\ 34.2}{0.69} \times (1 - \exp\ (-0.69 * 1)] = 0.93 \tag{14}$$

Forward Price (Kt) is given in (15).

$$K_1\ = \$39.58 \times 0.93 = 36.75 \tag{15}$$

As part of the review component for all valuation methods in this study, price assumptions are determined using the 1,000 sampled randomized-dynamic stochastic price model approach. Table I describes the calculation throughout five years.

TABLE I: Static Stochastic Price Model Trial

Year	0	1	2	3	4	5
Long-term median price	37.61	37.61	37.61	37.61	37.61	37.61
Associated price variance	0.00	0.06	0.08	0.08	0.08	0.08
Median price P50	38.54	38.35	38.05	37.85	37.73	37.68
Expected mean	38.54	39.58	39.58	39.45	39.35	39.30
90th percent P90	38.54	52.94	54.56	54.76	54.71	54.66
10th percent P10	38.54	27.78	26.53	26.16	26.02	25.97
Risk discount factor	1.00	0.93	0.89	0.88	0.87	0.87
Risk-adjusted price	38.54	36.75	35.41	34.65	34.24	34.03

B. Dynamic Stochastic Price Model

Several additional formulas and a Monte Carlo simulation are integrated with the existing project financial model to determine the forward price with the dynamic stochastic model. we used the excel add-on SIP math, with randomization of 1,000 samples, using simulation with normal distribution input (mean = 0, stdev = 1). The additional formula to the static stochastic price model is as follows:

One period ahead (t+Δ) associated price variance is given in (16).

$$Var(1) = \frac{34.2^2}{2x0.69}(1 - \exp(-2x0.69x1)) = 0.06 \tag{16}$$

One period ahead expected median price is given in (17).

$$Med[S_{t+\Delta}|S_t] = 38.05 \times \left[\frac{45.07}{38.35}\right]^{\exp(-0.69\times1)} = \$\ 41.25 \tag{17}$$

Monte Carlo spot price outcome is given in (18).

$$S_{t+\Delta} = 41.25 \times \exp(0.64\ \times SQRT(0.06) = \$\ 45.07 \tag{18}$$

Monte Carlo Forward price outcome (K_t) is given in (19).

$$K_t\ = 45.07 \times 0.93 = \$\ 41.85 \tag{19}$$

As part of the review component for all valuation methods in this study, price assumptions are determined using the 1,000 sampled randomized-dynamic stochastic price model approach. Table II described the calculation throughout five years.

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TABLE II: DYNAMIC STOCHASTIC PRICE MODEL

Year	0	1	2	3	4	5
Weiner increment Monte Carlo draws		0.64	-0.51	1.35	-1.05	1.23
1-period associated price variance	0.06	0.06	0.06	0.06	0.06	0.06
1-period expected median price	38.35	41.25	36.96	44.20	35.74	42.79
Price outcome	38.54	45.07	36.28	51.94	33.97	48.69
Risk-adjusted price outcome	38.54	41.85	32.46	45.61	29.55	42.17

To compare between these two calculations, looking at Fig. 4 and Fig. 5 that display the 1,000 price paths that have been made with Percentile 10 (P10), Percentile 50 (P50), and Percentile 90 (P90), illustrating the assumption of yearly coal price forward. In confidence, 85% confidence is at $25/ton and $60 ton. The percentile between these two options also differs one from another.

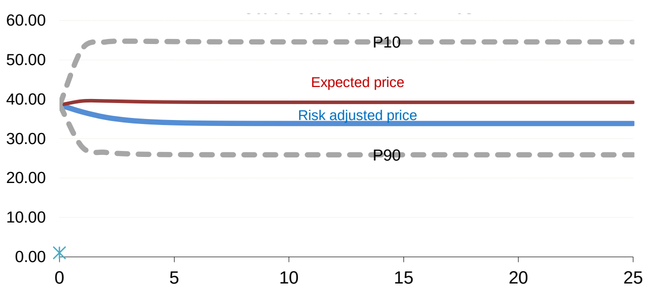

Fig. 4. Static 25-year price model trial.

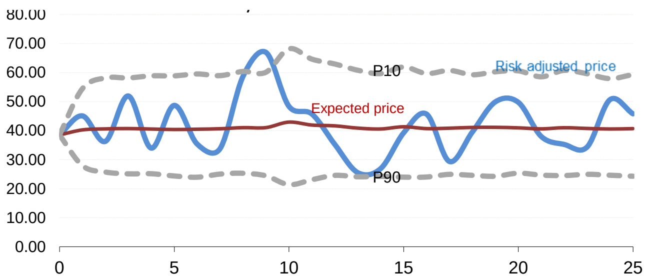

Fig. 5. Dynamic 25-year price model trial.

VI. STUDY CASE

In this research, the NPV calculation will compare the static stochastic price model and the dynamic stochastic price model. The study case will require several pieces of data as the base of the scenario analysis, such as capital expenditures, operating expenses, cost of equity, and cost of capital. The base scenario would consist of two alternatives: Alternative 1 would use the current road and coal handling infrastructure that was already built with longer distances, and Alternative 2 would build new infrastructure such as road and coal handling with shorter distances.

This research compares financial calculation on the Real Option Valuation methods with static and dynamic coal forward to provide comprehensive results. In this research, the risk adjustments on the ROV method are made at sources of uncertainty from the start of the valuation process, which is the coal price, by using 2.46% price risk and time adjustments to net cash flow at the end of the process by 7.20% as a result from risk-free rate and residual risk premium.

On the other hand, the options presented in the real option valuation include technical options that may be carried out to maximize the potential value that can be provided by the two resource maximization options (12-year production plan), as follows:

1. Ignore opportunities to expand and maximize resources (Abandon Option).
2. Postpone project investment (Delay Option).
3. Accelerate project investment (Expand Option).

The option to abandon is created by not increasing assets, which results in no increase in production capacity and sticks to the base plan with a four-year mining period. The Delay option emerged with the consideration of delaying investment, which resulted in delays in implementing the option to increase production capacity. On the other hand, the expansion option appears with accelerated investment in time and value, which accelerates and increases the project area's annual production capacity.

Using SIP Math software, a Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP) are used to calculate the Real Option valuation in this research. Two Real Option Methods are to be calculated using static and dynamic forward coal. The financial analysis of Real Option valuation is displayed in Table III and Table IV.

TABLE III: PROJECT'S ECONOMICAL ANALYSIS OF REAL OPTION METHOD USING STATIC COAL FORWARD

Real Option	Unit	Alternative 1	Alternative 2
Base			
NPV	USD millions	-2.14	184.64
IRR	%	0%	38%
PBP	Year	11.7	4.1
Delay			
NPV	USD millions	-8.68	164.35
IRR	%	-2%	27%
PBP	Year	12.9	5.1
Expand			
NPV	USD millions	9.21	92.09
IRR	%	4%	23%
PBP	Year	8.6	5.2

TABLE IV: PROJECT'S ECONOMICAL ANALYSIS OF REAL OPTION METHOD USING DYNAMIC COAL FORWARD

Real Option	Unit	Alternative 1	Alternative 2
Base			
NPV	USD millions	-26.97	196.05
IRR	%	-4%	32%
PBP	Year	11.5	8.3
Delay			
NPV	USD millions	-59.33	142.87
IRR	%	-11%	20%
PBP	Year	28.0	8.5
Expand			
NPV	USD millions	-22.14	92.06
IRR	%	-6%	20%
PBP	Year	10.0	5.6

Based on these two pricing models, the dynamic pricing model result relatively has a lower NPV, lower IRR, and longer PBP. Due to the price fluctuation on random Monte Carlo Simulation, this condition has a longer duration of coal price, far below the static price. Another consideration is the timing of the pricing when placed in a time of high production; this condition will have a multiplier effect, including conditions when the production is low, but the price is high. These conditions are the result of potential real-world simulations that could happen in a mining project.

VII. Conclusions and Implementations

A. Conclusions

Mining is known as a capital-intensive business with non-renewable products and has a high risk. It takes considerable capital to start this business, which is done for exploration activities, infrastructure development, provision of other supporting facilities, mining operations, and coal processing to post-mining. Because coal is a non-renewable resource, the exploitation process that will be carried out must be able to provide optimal value. For this reason, comprehensive financial planning is needed to review, estimate, and ensure project returns and generate profits. This research aims to provide the best possible feasibility study to operate the planned mining project, with various options that may arise in project implementation.

Based on the calculations that have been carried out on the two existing alternatives, alternative 2 provides a better NPV value than alternative 1, so alternative 2 will be chosen. The NPV value with the Static ROV method is $184.64 million, while the Dynamic ROV method is $196.05 million.

By using real options valuation on the selected alternative, it was found that the right option that management can take is the base option, which is following the planning that has been done, not with the option of delay, abandonment, or expansion.

From the results of the above calculations, the calculation with dynamic ROV produces the highest NPV. Still, it has the disadvantage of a long payback period, while the static ROV method produces a moderate NPV but has a reasonably faster payback period.

B. Recommendations and Implementation

For the company, based on all the results of calculations that have been carried out previously, from the two alternatives available in this block XYZ project, it is recommended to choose alternative 2, namely the option to invest in the northern area, where based on the calculations that have been done, alternative 2 meets the criteria. The company should also commence important contractor management to control the contractor mining rate and fluctuations in coal and fuel prices and implement efficiency to reduce production costs to continue generating positive margins.

For future research, the following are a few recommendations to be made in order to improve the outcomes of future studies on the same topic based on the findings as future research is recommended for the income variable using several models of coal commodity prices to better understand the uncertainty of coal commodity prices in the future, such as GARCH, ARCH, or other time series forecasting. Future research is recommended to perform various Real Option Valuation methods, namely using the Optionality Modeling method based on decision tree analysis, financial option analogy, binomial lattice, and fuzzy payoff.

The updated implementation plan for tactical activities before commencing mining operations in block XYZ is shown in Table V.

TABLE V: Project's Implementation Plan

No	Activities	DIC	0	1	2	3	4	5	6	7	8	9	10	11	12
1.	Mine plan finalization														
1.1.	Life of mine plan scheduling	Mine plan	■												
1.2.	Technical option recommendation	Mine plan	■												
1.3.	Submit to RKAB for government approval	Mine plan	■												
2.	Construction														
2.1.	Socialization to society	External	■									■			
2.2.	Land acquisition	Land	■	■	■	■									
2.3.	License use of forest area (IPPKH)	License	■												
2.4.	Contractor selection by tender	Mine contract	■												
2.5.	Equipment mobilization	Contractor	■	■	■										
2.6.	Infrastructure and facilities development	Contractor	■	■											
3.	Mining operation														
3.1.	Land clearing	Contractor		■	■	■	■	■	■	■	■	■	■	■	■
3.2.	Overburden removal	Contractor		■	■	■	■	■	■	■	■	■	■	■	■
3.3.	Coal getting and hauling	Contractor		■	■	■	■	■	■	■	■	■	■	■	■
3.4.	Coal processing	CPP		■	■	■	■	■	■	■	■	■	■	■	■
3.5.	Coal barging and transshipment	Shipping			■	■	■	■	■	■	■	■	■	■	■
3.6.	Redamation	Contractor		■	■	■	■	■	■	■	■	■	■	■	■
3.7.	Community development program	CSR		■	■	■	■	■	■	■	■	■	■	■	■
4.	Post-operation														
4.1.	Revegetation	Environment			■	■	■	■	■	■	■	■	■	■	■
4.2.	Mine closure	Mine closure										■	■	■	■
4.3.	Demobilization	Contractor										■	■	■	■

Conflict of Interest

The authors declare that they do not have any conflict of interest.

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