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REAL OPTION VALUATION OF COAL MINING PROJECT USING BINOMIAL LATTICE MODEL

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Abstract

GMB Mine coal project has postponed from 2016 to 2019 and plan to commence the operation in 2020 with total potential coal 106.79 million tonnes as Base Scenario. However, the coal price continues to drop to US $33/t when the construction process just to start. The decrease production scenarios have developed which are Medium Scenario with total coal 56.21 million tonnes and Low Scenario with total coal 36.54 million tonnes. The existing valuation method is Discounted Cash Flow valuation with assume that all outcomes are static and all decisions made are irrevocable compare to Real options valuation with binomial lattices model that gives flexibility using options. DCF valuation with RADR 9.09% resulted the Low Scenario as the highest NPV as US $11.28 million. While ROV with binomial lattice model with risk free rate 7.34% result US $67.80 million. This result show that DCF valuation tend to understate the value of assets and unable to properly capture the value that are uncertain at the initial decision. Strategic managerial flexibility as part of the ROV has undertaken to evaluate embedded options that are relevant to anticipate the decline of coal price. The highest NPV resulted from Base Scenario with combining option to defer the investment for one year and abandon of the project that obtained US $68.86 million. The expanded value from managerial flexibility obtained US $57.58 million if the initial coal price to commence the mine is between range US $18/t – US $34.3/t.

Keywords: Real Options, Binomial Lattice, Discounted Cash Flow, Managerial Flexibility.

1. Background and Business Issue

PT. ABC, as a coal mining company, will participate actively in the utilization of coal reserves as natural resources. PT. ABC has been mining coal since 1992 to exploit coal reserves in its mining authorization area with estimated of remaining coal reserves as of 1 January 2019 as 440 million tonnes. Based on original plan, GMB Mine as part of PT. ABC area with 14,624 ha, should start the mine in 2017 but the activity has been postponed due to land acquisition problems and the rejection of some residents around the mining area. The plan then re-schedule to commence the operation in 2020 with total coal produce 106.79 million tonnes for 20 years of economic life. During this delay period, the assumed situations of the GMB Mine project feasibility study have changed for both internal and external factors. The coal price continues to drop at the end of 2019 when the construction process just to start. PT. ABC's Top Management consider to evaluate the valuation of GMB Mine to reduce the possibility of loss and the magnitude of profit and also return on capital can be estimated properly. The decrease production scenarios have developed which are Medium Scenario with total production plan as 56.21 million tonnes and Low Scenario with decrease the total production to 36.54 million tonnes.

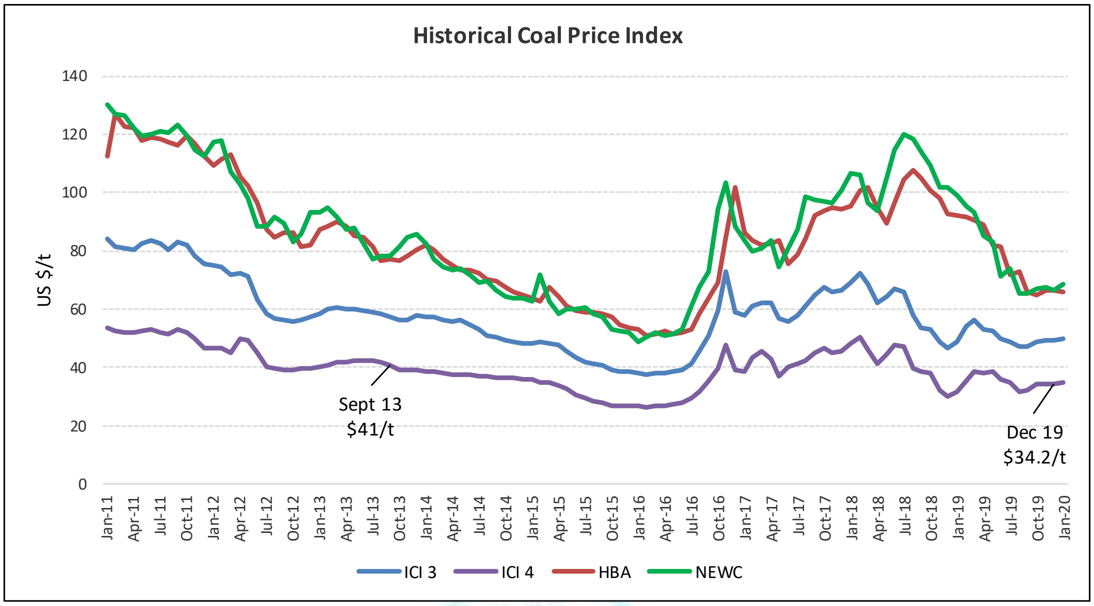


Figure 1. Historical Coal Price since 2011

2. Methodology

The following key concepts and the relationships between them that need to be studied to get a comprehensive understanding to solve the problem in this paper.

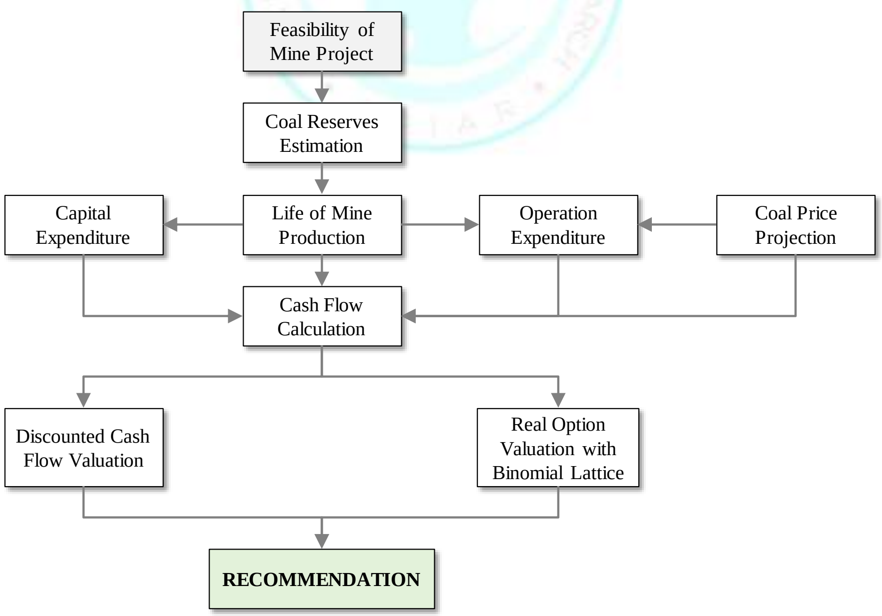


Figure 2. Conceptual Framework

3. Discounted Cash Flow Valuation

DCF valuation attempts to figure out the value of an investment today, based on projections of how much money it will generate in the future by apply discount rate. The discount rate will be a function of the riskiness of the estimated cash flows, with higher rates for riskier assets and lower rates for safer projects (Damodaran, 2012: 21). A popular approach for risk adjustment involves the use of risk-adjusted discount rates (RADR) to close examination for NPV (Gitman & Zutter, 2015: 524). Analysts might use CAPM or WACC of the firm as the RADR in the DCF valuation. the RADR that will use in this paper is WACC with additional risk premium which is additional return that investors require to compensate them for bearing risk. Country Risk Premium (CRP) will added as additional risk premium associated with investing in international companies rather than domestically. Geopolitical and macroeconomic factors that need to be considered such as political instability, volatile exchange rates and economic turmoil have caused investors to be wary of foreign investment opportunities and therefore require a premium for investment. Since the risk premium calculated in this manner is applicable to equity investing, CRP in this case will added into CAPM calculation become:

$$Ke = Rc + Rf + \beta\,(Rm\text{-}Rf)$$

where:

Ke	=	Cost of Equity
Rf	=	Risk-free rate of return, commonly measured by the return on 10 years Indonesia Government Bond Pricing Agency (IBPA)
β	=	Beta coefficient; sensitivity of the expected stock return to the market return. If a stock is riskier than the market, it will have a beta greater than one
Rm	=	Market rate of return; commonly use geometric average return (popularly called geometric mean) to determine the performance results of an investment or portfolio that are compounded. $\mu_{geometric} = [(1+R_1)(1+R_2)\ldots(1+R_n)]^{1/n} - 1$ Where: $R_1 \ldots R_n$ are the continuously compounded return of an asset in the market where $R_n = \ln(\text{Market}_{(t)}/\text{Market}_{(t-1)})$
Rc	=	Country Risk Premium (CRP)

The DCF valuation method of calculating project net present value is widely used (Block, 2007: 261). In mining industry, The Australasian Institute of Mining and Metallurgy (The AusIMM) as the preeminent organization representing professionals in the minerals sector in the Australasian region and one of the most influential organization in the mining industry worldwide, has been used DCF valuation as base guidelines for technical economic evaluation in mineral industry projects. The AusIMM suggested to follow framework with use of the four cash streams in capital budgeting model, leading to Net Cash Flow and value measures such as NPV.

Table 1. Four Cash Streams

Cash Stream	Items
1	**Revenue** = Sales x Price +/- debtors
2	**Capital** (cash spent not commitments)
3	**Operating Costs** = Consumptions x Costs (including related taxes) +/- Working Capital
4	**Taxes** = Company Income Tax + Government Royalties (if not in operating costs) +/- adjustments for cash payment dates

Source: The AusIMM, 2012

According to Guidelines for Technical Economic Evaluation in Mineral Industry Projects released by The AusIMM, 2012: 6, DCF valuation practices are easy to understand and fast to adopt. Due to the nature of DCF calculation, the method is extremely sensitive to small changes in the discount rate and the growth rate assumption.

4. Real Option Valuation with Binomial Lattice Model

ROV approach is a modern methodology of strategic managerial options for economic evaluation of certain projects under uncertainty and management's flexibility in exercising or abandoning these options at different points in time (Mun, 2002: 10). Marco Diaz explained that ROV *highlights the managerial flexibility (the "option") fair value to respond optimally to the changing scenario characterized by the uncertainty which traders incorporate into their strategies to maximize profits. ROV complements (not substitutes) the traditional corporate tools for economic evaluation, DCF valuation rule. The diffusion in corporations of sophisticated tools like ROV takes time and training* (2004: 94).

Binomial Lattices model use discrete time dynamics that developed by Cox, Ross, and Rubinstein (1979) and more recently covered by Mun, (2002), is much more capable of handling early exercise because it considers the cash flows at each time events rather than just the cash flows at expiration. The most important characteristic of the binomial lattice technique limiting its practical application is that the level of complexity grows very rapidly with the number of uncertainties (Dimitrakopoulos, 2007: 2). Mun explained although sometimes computationally stressful, binomial lattices are easy to implement, easy to explain and require no more than simple algebra. They are also highly flexible in that they can be tweaked easily to accommodate most types of real options problems but require significant computing power and time-steps to obtain good approximations.

The binomial lattices are based upon a simple formulation for the asset price process in which the asset, in any time period, can move to one of two possible prices.

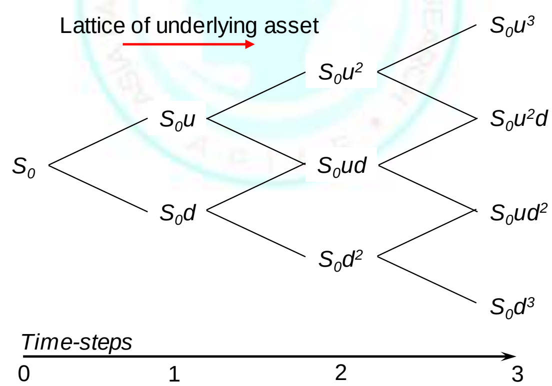


Figure 3. Binomial Lattice of the Underlying Asset Value

The basic inputs for the binomial lattice approach are the present value of the underlying asset (S), volatility of the natural logarithm of the underlying free cash flow returns in percent (σ), time to expiration in years (t), and risk-free rate (R_f). Time-steps or stepping time is simply the time scale between steps. The volatility measure is an annualized value; multiplying it by the square root of time-steps breaks it down into the time-step's equivalent volatility. The down factor is simply the reciprocal of the up factor. In addition, the higher the volatility measure, the higher the up and down factors. The basic formulas to develop binomial lattices model are:

$u = e^{\sigma\sqrt{\delta t}}$ and $d = e^{-\sigma\sqrt{\delta t}} = \frac{1}{u}$

$$p = \frac{e^{(R_f)(\delta t)} - d}{u - d}$$

where:

u and d = Up and down factors

p = Risk-neutral probability measure

δt = Square root of time-steps or stepping time

Only two factor levels (hence the name "binomial"), the up factor is simply the exponential function of the cash flow volatility multiplied by the square root of time-steps (δt).
Mun, (2002: 155-157) explain there are three steps involved to utilize binomial lattice:

1. The first step is to solve the binomial lattice equations with to calculation of the up step size, down step size, and risk-free probability
2. Then specifying the period and build at each node of the tree forward based on the evolution of the underlying asset's present value of future cash flows
3. Third step is starting with the last period and working back from the right side to the left side to obtain an option value at the farthest left node of the lattice called backward induction. The value placed in terminal node is the maximum of zero and the difference between value S and exercise price X

Terminal value = Maximum(S - X,0)

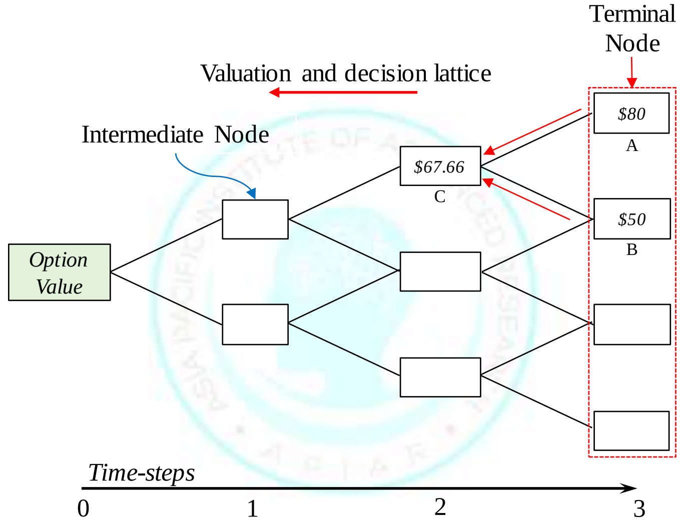


Figure 4. Backward Induction

Disallowing negative values reflects the holder's right to refuse to exercise an option with negative value. Then calculation of intermediate nodes using risk-free probability through:

$$Intermediate\ value = [(p)up + (1-p)down]e^{(-R_f)(\delta t)}$$

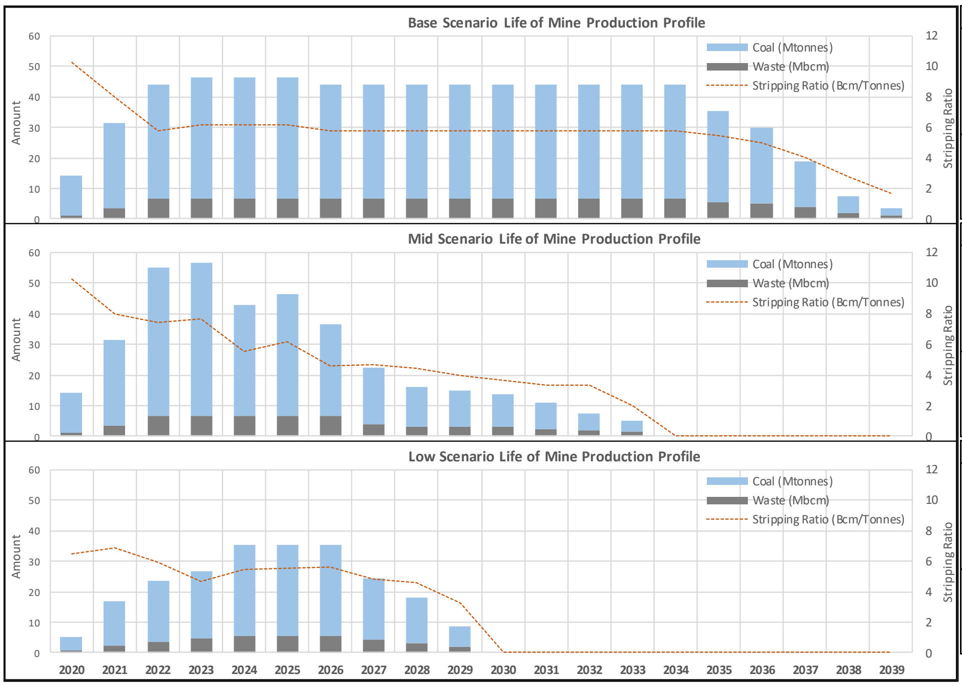
Real options models give two linked outputs, the investment opportunity value and the optimal decision rule (the threshold for the optimal option exercise) (Dias, 2004: 94). Among the relevant options to anticipate the decline of coal price, in this paper consider the option to expand the production, the option to defer the investment (timing option), and the option to abandon that explained by Damodaran as below:

- Option to Expand. The option to expand can be evaluated at the time of analyze the initial project. If commodity prices or other market conditions turn more favorable than expected, management can expand the scale of production (2012: 548)
- Option to Abandon. When investing in new projects, companies worry about the risk that the investment will not pay off and that actual cash flows will not measure up to expectations. Having the option to abandon a project that does not pay off can be valuable, especially on projects with a significant potential for losses (2012: 557)

- Option to Defer. Rational decision makers will not exercise the option with negative NPV, so that if the decision makers wait and see the scenario of uncertain conditions (e.g. commodity price), the development right values maximum equal to zero, because no obligation to invest. It is an option and managerial flexibility (2012: 533).

5. Life of Mine Production Profile

The company's basis for starting this project was Feasibility Study in 2014 that undertaken by third party. Geology condition for GMB Mine is moderate with syncline asymmetry of total 29 seams of coal deposits and coal dip between 10-25 degree. At the end of December 2019, total of 316 boreholes have been drilled. With additional future drilling in Eastern part of deposit and pit optimization, the potential coal increase to 106.79 million tonnes and reported as part of updated Strategic Mine Plan PT. ABC and plan to commence the mine in 2020. Due to the dropped of the coal price in the middle of construction process, production reduction scenarios will evaluate further as part of managerial flexibility.



Description	Unit	Total
Waste	M bcm	613.91
Coal Getting	M tonnes	106.79
Strip Ratio	bcm/tonnes	5.75
Waste Distance	km	2.22
Coal Distance	km	6.55
CV (Ar)	%	4,081
TM (Ar)	%	35.62
Ash (Ar)	%	3.71
TS (Ar)	Kcal/Kg	0.40

Description	Unit	Total
Waste	M bcm	317.93
Coal Getting	M tonnes	56.21
Strip Ratio	bcm/tonnes	5.66
Waste Distance	km	2.34
Coal Distance	km	5.99
CV (Ar)	%	4,136
TM (Ar)	%	35.09
Ash (Ar)	%	3.70
TS (Ar)	Kcal/Kg	0.42

Description	Unit	Total
Waste	M bcm	192.96
Coal Getting	M tonnes	36.54
Strip Ratio	bcm/tonnes	5.28
Waste Distance	km	2.23
Coal Distance	km	5.78
CV (Ar)	%	4,030
TM (Ar)	%	36.59
Ash (Ar)	%	3.20
TS (Ar)	Kcal/Kg	0.31

Figure 5. Life of Mine Production Profile for Each Scenario

6. Result and Discussion

A lot of studies have shown that the investment is highly sensitive to uncertainty over the future value of the project. Moreover, the conventional NPV rule ignores the value of creating options that enable the company to undertake other investments in the future should market conditions turn favorable. The real option valuation promises to establish a richer framework, who should be enabled to address these issues in a more transparent and coherent way. The fundamental premise behind the use of ROV is that DCF valuation tend to understate the value of assets that provide payoffs that are contingent on the occurrence of an event (Damodaran, 2012: 29).

According to Samis et al., 2006: 287-288, the DCF method calculates the present value of cash flow by applying a combined time and risk discount factor to represent risk and uncertainty in the life of a project. In the absence of managerial flexibility, the first step in ROV is to apply a risk discount factor to each uncertain cash flow element which is commodity price arising in any one period. Then net cash flow present value calculated by discounting the risk adjusted net cash flow for time at the riskless interest rate. The comparison of both methods show below.

Table 2. Comparison Value Calculation between DCF and Real Option

DCF Valuation	RO Valuation
Commodity Price x Output = Revenue	Commodity Price x Risk discount factor x Output = Revenue
- Operational Cost	- Operational Cost
Operating Profit	Operating Profit
- Capex	- Capex
Net Cash Flow	Net Cash Flow
* (Time + Risk discount factor)	* (Time discount factor)
Present Value of net cash flow	**Present Value of net cash flow**

Several market data from 2011 until 2019 used to assist data for project valuation. 10 Years Indonesia Government Bond yield use to calculate risk free rate, *Rf*. The oil price converts to Mean of Platts Singapore (MOPS) which is the average of a set of Singapore-based oil product price assessments published by Platts as a global energy, petrochemicals, metals and agriculture information provider and a division of S&P Global with factor 1.20. Vendor premium to MOPS got 10% and cost for Freight and Handling US $0.029/l obtained the fuel price at Site as US $0.506/litre. Inflation rate data from Bank Indonesia use to projection the increase of General and Administration costs every year.

Table 3. Market Data

Market Data	Geometric Mean
10Y Indonesia Bond Yield	7.34%
Brent Crude Oil (US $/Bbl)	57.38
Inflation Rate	4.76%
Asset Return in Indonesia Stock Market	0.51%
ICI4 Annualize Volatility	19.75%

Monthly market returns assist data for Market Rate of Return, Rm, in CAPM. Volatility will use as price risk discount factor in ROV calculation.

The first step to solve the binomial lattice equations is calculation of the up step size, down step size, and risk-free probability to define underlying asset value.

$$u = e^{\sigma\sqrt{\delta t}} = e^{19.75\sqrt{1}} = 1.22$$

$$d = \frac{1}{u} = \frac{1}{1.22} = 0.82$$

$$p_u = \frac{e^{(R_f)(\delta t)} - d}{u - d} = \frac{e^{(7.454)(1)} - 0.82}{1.22 - 0.82} = 64.5\%$$

$$p_d = 1 - 64.5\% = 35.5\%$$

The first cash stream to calculate is Revenue. Refer to Feasibility Study 2014, the coal price assumption was US $41/t. During the project postponed, the ICI 4 coal price fluctuated and dropped 17% to US $34.2/t by the end of December 2019. DCF valuation uses more pesimist coal price assumption with flat US $33/t along the life of mine. While in ROV with binomial lattice model, the coal price will discount first with annualize coal price volatility.

$$Coal\ Price\ After\ Discount = \frac{Coal\ Index}{(1+\sigma_{annual})} = \frac{33}{(1+19.75\%)} = US\ \$27.56/t$$

Microsoft Excel already support for binomial lattice calculation with BINOM.DIST function that returns the individual term binomial distribution probability.

Table 4. Coal Price Probability for Each Lattice

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	100.0%	41.3%	26.5%	17.0%	10.9%	7.0%	4.5%	2.9%	1.9%	1.2%	0.8%	0.5%	0.3%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
2		45.9%	44.3%	37.9%	30.5%	23.5%	17.6%	12.9%	9.3%	6.7%	4.7%	3.3%	2.3%	1.6%	1.1%	0.8%	0.5%	0.3%	0.2%	0.2%
3			24.6%	31.7%	33.9%	32.7%	29.4%	25.2%	20.8%	16.7%	13.1%	10.1%	7.7%	5.8%	4.3%	3.1%	2.3%	1.6%	1.2%	0.8%
4				11.7%	18.9%	24.2%	27.3%	28.0%	27.0%	24.8%	21.9%	18.8%	15.7%	12.8%	10.3%	8.1%	6.3%	4.9%	3.7%	2.8%
5					5.2%	10.1%	15.2%	19.5%	22.5%	24.1%	24.4%	23.5%	21.8%	19.6%	17.2%	14.7%	12.4%	10.2%	8.3%	6.7%
6						2.3%	5.1%	8.7%	12.5%	16.1%	19.0%	20.9%	21.8%	21.8%	21.0%	19.6%	17.9%	15.9%	13.9%	11.9%
7							0.9%	2.4%	4.7%	7.5%	10.6%	13.6%	16.2%	18.2%	19.5%	20.0%	19.9%	19.2%	18.0%	16.5%
8								0.4%	1.1%	2.4%	4.2%	6.5%	9.0%	11.6%	14.0%	15.9%	17.4%	18.3%	18.6%	18.4%
9									0.2%	0.5%	1.2%	2.3%	3.8%	5.6%	7.8%	10.0%	12.1%	14.0%	15.5%	16.6%
10										0.1%	0.2%	0.6%	1.2%	2.1%	3.4%	4.9%	6.7%	8.7%	10.6%	12.3%
11											0.0%	0.1%	0.3%	0.6%	1.1%	1.9%	3.0%	4.3%	5.9%	7.6%
12												0.0%	0.0%	0.1%	0.3%	0.6%	1.1%	1.8%	2.7%	3.8%
13													0.0%	0.0%	0.1%	0.1%	0.3%	0.6%	1.0%	1.6%
14														0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.5%
15															0.0%	0.0%	0.0%	0.0%	0.1%	0.2%
16																0.0%	0.0%	0.0%	0.0%	0.0%
17																	0.0%	0.0%	0.0%	0.0%
18																		0.0%	0.0%	0.0%
19																			0.0%	0.0%
20																				0.0%

Results of future coal price obtained as shown in Table 5. Coal price upward for 2021 US $33.57/t obtained from: *Price* 2021_u = *Price 2020* x *u* = 27.56 x 1.22 = 33.57, while

Price 2021_d = *Price 2020* x *d* = 27.56 x 0.82 = 22.62, and so on.

Table 5. Binomial Lattice Future Coal Price

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
1	27.56	33.57	40.90	49.83	60.71	73.96	90.11	109.78	133.75	162.95	198.52	241.86	294.66	358.99	437.37	532.85	649.17	790.89	963.55	1173.91
2		22.62	27.56	33.57	40.90	49.83	60.71	73.96	90.11	109.78	133.75	162.95	198.52	241.86	294.66	358.99	437.37	532.85	649.17	790.89
3			18.57	22.62	27.56	33.57	40.90	49.83	60.71	73.96	90.11	109.78	133.75	162.95	198.52	241.86	294.66	358.99	437.37	532.85
4				15.24	18.57	22.62	27.56	33.57	40.90	49.83	60.71	73.96	90.11	109.78	133.75	162.95	198.52	241.86	294.66	358.99
5					12.51	15.24	18.57	22.62	27.56	33.57	40.90	49.83	60.71	73.96	90.11	109.78	133.75	162.95	198.52	241.86
6						10.27	12.51	15.24	18.57	22.62	27.56	33.57	40.90	49.83	60.71	73.96	90.11	109.78	133.75	162.95
7							8.43	10.27	12.51	15.24	18.57	22.62	27.56	33.57	40.90	49.83	60.71	73.96	90.11	109.78
8								6.92	8.43	10.27	12.51	15.24	18.57	22.62	27.56	33.57	40.90	49.83	60.71	73.96
9									5.68	6.92	8.43	10.27	12.51	15.24	18.57	22.62	27.56	33.57	40.90	49.83
10										4.66	5.68	6.92	8.43	10.27	12.51	15.24	18.57	22.62	27.56	33.57
11											3.83	4.66	5.68	6.92	8.43	10.27	12.51	15.24	18.57	22.62
12												3.14	3.83	4.66	5.68	6.92	8.43	10.27	12.51	15.24
13													2.58	3.14	3.83	4.66	5.68	6.92	8.43	10.27
14														2.12	2.58	3.14	3.83	4.66	5.68	6.92
15															1.74	2.12	2.58	3.14	3.83	4.66
16																1.43	1.74	2.12	2.58	3.14
17																	1.17	1.43	1.74	2.12
18																		0.96	1.17	1.43
19																			0.79	0.96
20																				0.65

Second cash stream is calculation of capital spend for initial project. Capitalizing asset require the company to spread the value of the expend over the useful life of the asset with formula:

$$Capex = \Delta PP\&E + (Depreciation/Amortization\ /Depletion)$$

where: *ΔPP&E* = Change in Property, plant, and equipment.

Depreciation use straight line method that assume 8 years of useful life of all assets. Depletion similar like depreciation and commonly used to the gradual exhaustion of natural resources such as mining, timber, petroleum, and other companies engaged in natural resource extraction. Depletion can be calculated on a cost or percentage basis with Units of Production method formula that calculated by which costs of natural resources are allocated to depletion over the period that make up the life of the asset.

Table 6. Capital Expenditure for Base Scenario

DESCRIPTION	UNIT	TOTAL	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Capital Expenditure	USD million	**40.6**	8.0	2.8	2.3	5.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.4	1.3	0.9	0.2	0.1
Infrastructure	USD million	**9.8**	5.61	-	-	4.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustainable	USD million	**10.7**	0.13	0.35	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50	0.38	0.20	0.13
Exploration	USD million	**15.5**	0.19	0.53	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.83	0.75	0.56	-	-
Land	USD million	**4.6**	2.07	1.90	0.66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Depreciation and Depletion Expenses		**51.4**	0.19	1.23	1.75	1.90	2.57	2.73	2.89	3.07	3.25	2.72	2.89	3.03	2.69	2.89	3.16	3.08	3.19	2.93	2.16	1.52
Depreciation	USD million	**20.4**	-	0.72	0.76	0.84	1.44	1.52	1.60	1.69	1.77	1.13	1.17	1.17	0.65	0.65	0.65	0.65	0.64	0.62	0.58	0.53
Depletion	USD million	**31.1**	0.19	0.52	0.99	1.06	1.13	1.20	1.29	1.38	1.48	1.59	1.72	1.86	2.04	2.24	2.51	2.43	2.55	2.31	1.58	0.99

Table 7. Capital Expenditure for Mid & Low Scenario

Mid Scenario

DESCRIPTION	UNIT	TOTAL	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Capital Expenditure	USD million	**23.8**	8.0	2.8	2.3	1.6	1.6	1.6	1.6	1.0	0.8	0.8	0.8	0.6	0.2	0.2
Infrastructure	USD million	**5.6**	5.61	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustainable	USD million	**5.6**	0.13	0.35	0.65	0.65	0.65	0.65	0.65	0.40	0.30	0.30	0.30	0.25	0.18	0.17
Exploration	USD million	**7.9**	0.19	0.53	0.98	0.98	0.98	0.98	0.98	0.60	0.45	0.45	0.45	0.38	-	-
Land	USD million	**4.6**	2.07	1.90	0.66	-	-	-	-	-	-	-	-	-	-	-
Depreciation and Depletion Expenses		**27.1**	0.18	1.22	1.77	1.99	2.23	2.51	2.85	2.46	2.30	1.74	1.88	1.80	1.55	1.44
Depreciation	USD million	**11.2**	-	0.72	0.76	0.84	0.92	1.01	1.09	1.17	1.22	0.54	0.53	0.49	0.44	0.38
Depletion	USD million	**15.8**	0.18	0.51	1.00	1.15	1.31	1.51	1.76	1.29	1.09	1.20	1.35	1.32	1.11	1.07

Low Scenario

DESCRIPTION	UNIT	TOTAL	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Capital Expenditure	USD million	**18.6**	7.9	2.4	1.5	1.2	1.4	1.4	1.3	1.0	0.3	0.2
Infrastructure	USD million	**5.6**	5.61	-	-	-	-	-	-	-	-	-
Sustainable	USD million	**3.7**	0.07	0.21	0.34	0.47	0.55	0.54	0.53	0.42	0.32	0.20
Exploration	USD million	**4.7**	0.10	0.32	0.51	0.70	0.82	0.81	0.80	0.62	-	-
Land	USD million	**4.6**	2.07	1.90	0.66	-	-	-	-	-	-	-
Depreciation and Depletion Expenses		**18.7**	0.09	0.99	1.22	1.52	1.85	2.13	2.47	2.56	2.66	1.39
Depreciation	USD million	**9.3**	-	0.71	0.74	0.78	0.84	0.91	0.97	1.04	1.09	0.42
Depletion	USD million	**9.4**	0.09	0.28	0.48	0.74	1.01	1.23	1.50	1.52	1.57	0.97

Third cash stream is calculation of operating costs. Mining costs are based on existing contracts for mining which costs incurred in production that are directly related to coal mining activities starting at the mining front until the coal is transported to the ROM Stockpile in the port.

Table 8. Tier Mining Rate

		TIER		
		Low	**Medium**	**High**
Index	**Unit**	ICI 4	ICI 4	ICI 4
Price Ranges		20.0 - 30.0	>30.0 - 37.5	>37.5
Overburden Rate	usd /bcm	1.250	1.357	1.466
Coal Rate	usd /tonne	1.600	1.862	2.011
Contract Distance				
Contract Waste Distance	km	1.50	1.50	1.50
Contract Coal Distance	km	5.50	5.50	5.50
Distance adjustment				
Waste Overhaul Rate	usd /bcm /km	0.264	0.264	0.264
Coal Overhaul Rate	usd /ton /km	0.085	0.085	0.085
Fuel Ratio				
Waste Fuel Ratio	ltr/bcm	0.660	0.660	0.660
Coal Fuel Ratio	ltr/tonne	0.650	0.650	0.650
Variation Fuel Ratio				
Waste Overdistance Fuel Ratio	ltr/bcm/km	0.240	0.240	0.240
Coal Overdistance Fuel Ratio	ltr/tonne/km	0.040	0.040	0.040

Mining costs are based on existing contracts for mining which costs incurred in production that are directly related to coal mining activities starting at the mining front until the coal is transported to the ROM Stockpile in the port. PT. ABC uses mining contractors to support their operational activities. Mining rate to calculate mining cost will refer to Indonesian Coal Indexes (ICI) after fuel adjustment. There are three tiers used refers to ICI 4. Coal price US $33/t in first year that also become reference for tier rate used to calculate operating costs in the first year.

Four stream calculate Royalty as 13.50% of the revenue in FOB price or sale point price to the Government. Corporate tax rate in respect the annual profit is 45%. Result calculation of the Earnings before Interest, Tax and Depreciation & Amortization (EBITDA) margin or operating profits that earned from producing and selling products and does not consider financial and tax costs shown in Figure 6 with average earning US$ 5.02/t for Base Scenario, US$ 5.40/t for Mid Scenario and US$ 6.31/t for Low Scenario. EBITDA less by depreciation and depletion first before tax deduction applied. Depreciation and depletion value added back after tax deduction and less the capex to result projected cash flow for DCF valuation in each scenario. While with Data Table function in Microsoft Excel will calculate second step of binomial lattice cash flow.

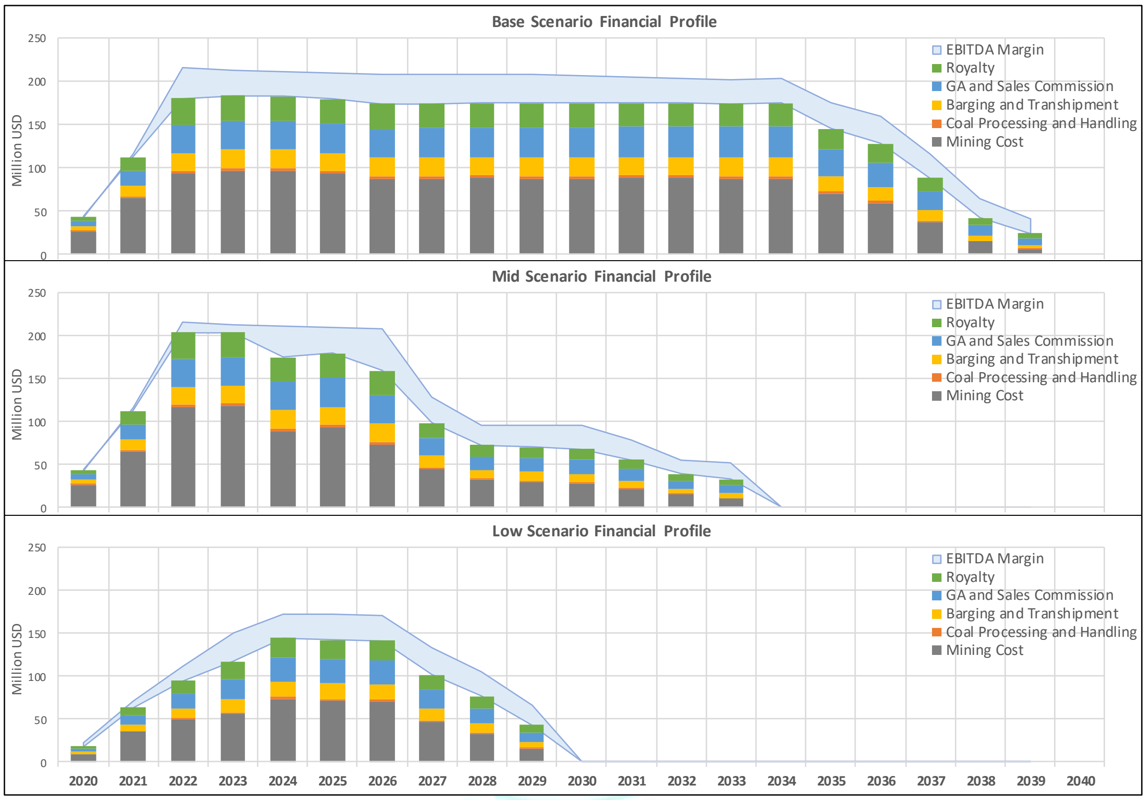


Figure 6. Cash Flow Profile for Each Scenario

Table 9. Binomial Lattice Cash Flow for Each Scenario

Base Scenario

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
1	-14.48	-3.91	3.38	2.88	11.40	16.68	23.32	30.83	40.07	51.28
2		-9.66	-2.28	-3.47	3.75	7.40	12.02	17.09	23.33	30.81
3			-7.89	-9.18	-2.50	1.15	4.41	7.83	12.05	17.02
4				-2.18	-7.89	-4.73	-1.58	1.59	4.46	7.73
5					1.02	2.23	-6.98	-4.27	-1.76	1.47
6						-0.97	0.68	2.22	-7.15	-4.23
7							-2.70	-1.26	0.56	2.05
8								-4.03	-2.81	-1.29
9									-5.08	-4.07
10										-5.94
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

	2030	2031	2032	2033	2034	2035	2036	2037	2038	2
1	64.58	79.89	98.90	122.06	152.34	193.28	235.83	284.64	357.85	451
2	39.77	50.10	62.88	78.51	98.97	126.66	155.63	188.92	238.86	302
3	23.06	30.03	38.61	49.16	63.01	81.77	101.59	124.43	158.70	201
4	11.80	16.51	22.26	29.39	38.78	51.54	65.19	80.98	104.69	134
5	4.21	7.40	11.24	16.07	22.46	31.16	40.66	51.71	68.30	88
6	-1.90	1.15	3.82	7.10	11.46	17.44	24.14	31.99	43.78	57
7	-7.28	-4.71	-2.24	0.87	4.05	8.19	13.00	18.70	27.27	36
8	0.39	2.03	-7.49	-4.88	-2.18	1.96	5.50	9.75	16.14	22
9	-2.98	-1.48	0.35	1.86	-7.42	-3.87	-0.08	3.72	8.64	13
10	-5.25	-4.19	-2.93	-1.60	0.30	2.16	-5.47	-0.98	3.84	7
11	-6.78	-6.02	-5.14	-4.27	-2.97	-1.59	0.69	2.55	-0.25	3
12		-7.25	-6.62	-6.07	-5.17	-4.36	-2.65	-0.93	1.78	2
13			-7.62	-7.28	-6.66	-6.23	-4.90	-3.58	-1.54	0
14				-8.09	-7.65	-7.49	-6.41	-5.36	-3.78	-2
15					-8.33	-8.34	-7.43	-6.56	-5.29	-4
16						-8.91	-8.12	-7.37	-6.31	-5
17							-8.58	-7.92	-6.99	-6
18								-8.29	-7.45	-7
19									-7.76	-7
20										-8

Mid Scenario

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
1	-14.48	-3.91	1.32	5.22	11.95	16.59	24.61	32.47	42.06	53.71	67.42	83.09	102.59	127.07
2		-9.66	-5.84	-2.35	4.30	7.31	13.31	18.73	25.32	33.25	42.61	53.31	66.57	83.51
3			-11.27	-8.05	-1.29	1.05	5.70	9.47	14.05	19.46	25.90	33.24	42.30	54.17
4				2.00	-6.74	-4.73	0.68	3.23	6.45	10.16	14.64	19.72	25.95	34.40
5					0.86	2.14	-4.84	-1.54	1.67	3.91	7.05	10.61	14.93	21.08
6						-0.97	0.68	2.57	-3.76	-0.10	2.24	4.47	7.51	12.10
7							-2.70	-0.63	1.44	2.49	-2.47	0.78	2.79	6.06
8								-3.40	-1.93	-0.41	1.21	2.48	-1.56	2.45
9									-4.21	-3.19	-2.11	-0.48	1.61	2.67
10										-5.07	-4.38	-3.19	-1.48	-0.15
11											-5.91	-5.02	-3.69	-2.81
12												-6.25	-5.17	-4.61
13													-6.17	-5.82
14														-6.63

Low Scenario

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
1	-7.68	-1.11	3.42	8.68	11.46	16.86	23.24	32.41	43.07	55.62
2		-6.80	-2.12	2.48	4.00	7.80	12.14	18.81	26.40	35.22
3			-7.53	-1.94	-1.50	1.69	4.66	9.64	15.18	21.47
4				2.21	-6.80	-3.43	-0.86	3.47	7.61	12.21
5					0.80	2.25	-6.17	-1.05	2.88	5.97
6						-0.52	1.25	2.77	-2.17	2.39
7							-1.97	-0.28	2.37	3.29
8								-3.01	-0.97	0.88
9									-3.23	-1.90
10										-3.77

Since PT. ABC uses its own capital to financing the development of GMB Mine, WACC equal to cost of equity for DCF valuation. CAPM calculated after additional CRP for Indonesia as 2.80%. Value of beta equal to 1 means the trend of assets return assume equal to market due to PT. ABC has been delisting from stock since 2017. Market Rate of Return, Rm, calculated from monthly market return as 0.51% and projected to annualize obtained 6.29%.

$Ke = 2.80 + 7.34 + 1\,(6.29 - 7.34) = 9.09\%$

DCF valuation use this as a combined time and risk discount factor to calculate NPV while ROV use 10Y Bond Yield as time discount factor.

The highest NPV result for DCF valuation obtained US $11.28 million and IRR 26.61% for Low Scenario. The complete result as shown below.

Table 10. NPV & IRR of DCF Valuation for Each Scenario

Parameter (Price $33/t)	Unit	Base	Mid	Low
NPV DCF Valuation	USD million	6.05	8.50	11.28
IRR DCF Valuation	%	4.72	7.77	26.61
EBITDA	USD million	535.69	303.63	230.66
Economic Life	Years	20.00	14.00	10.00
ANPV	USD million	0.67	1.10	1.76

All scenarios resulted positive NPV means the company will earn a return greater than its cost of capital. But if we compare the RADR used as 9.09% with the IRR in this DCF valuation, only Low Scenario that above the IRR so that will potentially select. This also supported by the highest ANPV result for Low Scenario. If we calculate with the previous 2014 coal price as US$41/t, Base Scenario return to the highest NPV and potentially consider to be selected.

Table 11. NPV & IRR of DCF Valuation at Price US $41/t

Parameter (Price $41/t)	Unit	Base	Mid	Low
NPV DCF Valuation	USD million	32.26	31.35	29.33
IRR DCF Valuation	%	38.95	40.43	144.63
EBITDA	USD million	1,084.46	596.69	418.55
Economic Life	Years	20.00	14.00	10.00
ANPV	USD million	3.56	4.05	4.59

Coal price down 19.5% to US $33/t resulting in decrease GMB Mine valuation as US $20.08 million and show project value is very sensitive to the changes of the coal price as part of uncertainties from external factors. What-If Analysis in Microsoft Excel found that the limit coal price for IRR lower than 9.09% that means no scenario will be selected and potentially abandon the GMB Mine until the coal price recover based on DCF valuation is US $30.94/t. Coal price become the biggest slope line which means the most sensitive and must pay highest attention as signal any overwhelming potential future concerns during.

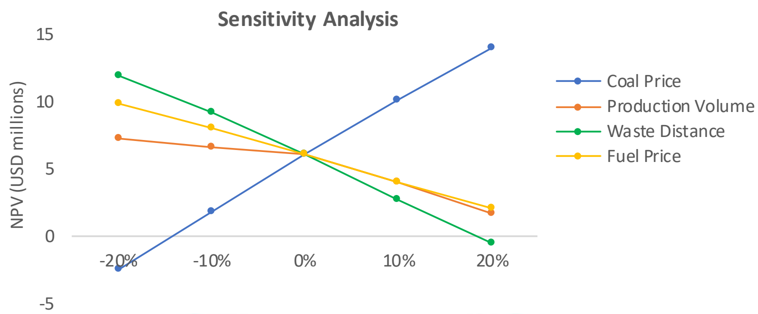


Figure 7. Sensitivity Analysis

The last step to complete binomial lattice valuation is backward induction to obtain an option value at the farthest left node of the lattice.

Table 12. Backward Induction Results for Base and Mid Scenario

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
67.80	117.74	164.63	211.90	268.50	326.15	389.07	456.79	529.26	605.35	683.37	761.13	836.08	903.02	955.14	980.54	960.47	883.24	729.03	451.83
	35.47	69.40	103.34	145.08	185.82	229.98	277.27	327.83	380.92	435.52	490.10	542.92	590.56	628.36	648.30	637.70	588.47	487.15	302.50
		10.80	29.49	59.98	90.42	122.39	156.16	192.07	229.71	268.54	307.49	345.41	380.04	408.21	424.46	420.23	389.88	324.19	201.89
			3.11	8.33	25.10	48.10	73.63	100.20	127.68	156.01	184.47	212.34	238.21	259.88	273.66	273.73	256.08	214.40	134.10
				0.93	3.58	3.16	16.82	36.25	58.01	79.80	101.49	122.69	142.65	159.95	172.06	175.02	165.94	140.43	88.43
					-6.70	-1.62	0.23	-1.83	9.85	26.35	44.59	62.00	78.26	92.63	103.61	108.52	105.21	90.60	57.66
						-14.28	-7.34	-2.69	-1.74	-5.05	4.68	18.99	34.05	47.22	57.50	63.71	64.29	57.02	36.93
							-21.60	-13.42	-6.63	-2.32	-1.72	-5.94	2.56	14.75	26.28	33.57	36.72	34.40	22.97
								-28.64	-19.94	-11.89	-5.05	-0.58	0.04	-4.17	3.60	12.70	18.28	19.16	13.56
									-34.88	-26.29	-17.68	-9.66	-2.86	2.00	3.28	-0.38	5.50	9.29	7.22
										-39.64	-31.40	-23.14	-15.08	-7.37	-0.78	4.05	5.40	2.76	3.38
											-42.22	-34.63	-26.97	-19.20	-11.80	-4.86	0.41	3.59	2.98
												-42.78	-35.63	-28.24	-20.93	-13.60	-7.36	-2.43	0.07
													-41.51	-34.39	-27.19	-19.68	-12.91	-7.00	-2.77
														-38.54	-31.41	-23.78	-16.65	-10.08	-4.68
															-34.26	-26.54	-19.17	-12.16	-5.97
																-28.40	-20.86	-13.56	-6.84
																	-22.01	-14.50	-7.42
																		-15.13	-7.82
																			-8.08

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
30.32	68.41	100.89	132.10	163.48	192.53	221.14	245.27	264.16	274.55	272.09	251.49	206.46	127.07
	11.57	35.82	61.57	87.17	109.00	130.86	149.29	164.22	173.45	174.10	162.56	134.59	83.51
		-0.61	14.45	35.27	52.94	70.16	84.65	96.89	105.33	108.08	102.65	86.17	54.17
			6.03	4.18	14.63	29.70	41.43	51.62	59.45	63.60	62.29	53.55	34.40
				4.61	6.49	4.77	12.68	21.92	28.78	33.69	35.09	31.58	21.08
					-0.40	4.49	6.09	3.32	9.06	14.15	16.92	16.77	12.10
						-6.35	0.47	4.59	4.99	2.07	5.37	7.23	6.06
							-11.82	-4.93	0.50	3.79	4.00	0.79	2.45
								-16.41	-9.87	-4.09	0.58	3.16	2.67
									-18.90	-12.70	-6.99	-2.50	-0.15
										-18.71	-12.43	-6.90	-2.81
											-16.10	-9.87	-4.61
												-11.87	-5.82
													-6.63

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
18.23	41.62	60.70	77.14	89.71	100.45	105.80	103.33	88.09	55.62
	3.02	19.22	33.34	44.34	54.42	60.85	62.20	54.63	35.22
		-5.05	4.13	12.98	23.31	30.63	34.49	32.10	21.47
			0.03	-5.11	1.59	9.85	16.01	16.91	12.21
				2.61	2.23	-2.63	3.40	7.25	5.97
					1.43	4.66	4.52	0.35	2.39
						-2.53	2.14	4.63	3.29
							-5.53	-1.07	0.88
								-5.62	-1.90
									-3.77

The NPV results comparison of binomial lattice for each scenario show below.

Table 13. NPV ROV from Backward Induction

Parameter	Unit	Base	Mid	Low
NPV ROV	USD million	67.80	30.32	18.23

The highest NPV is Base Scenario with US $67.80 million or 6 times higher from the highest NPV of DCF valuation. This NPV result show that DCF valuation tend to understate the value of assets and unable to properly capture the value that are uncertain at the time of the initial decision. DCF valuation also ignore the option to mine 70.25 million tonnes of coal with SR 5.99 and EBITDA US $305 million as the discrepancy of coal produce between Base Scenario and Low Scenario.

Strategic managerial flexibility as part of the ROV to respond the uncertainty to maximize profits, has undertaken to evaluate embedded options that are relevant to anticipate the decline of coal price. The purpose of abandon option especially if market conditions decline severely is to capture the value for the underlying assets and in high uncertainties industries, the option to shut down at no additional cost is valuable. This option ignores negative cash flow and the value set to maximum zero. Backward induction step then applied to obtain very left end NPV.

Table 14. NPV ROV for Abandon Option

Parameter	Unit	Base	Mid	Low
NPV ROV Abandon Option	USD million	68.17	30.39	19.08

Defer option will delay investment for one year until more information acquired with cost that have to expend included maintenance cost, standby cost, sump pumping and pit preparation before operation commence which assumed as much US $1 million per year. There are two coal prices that will become initial price in defer option in year 2021 which are upside price US $33.57/t and downside price US $22.62/t so will have two backward inductions.

Table 15. Backward Induction for Defer & Abandon Option Base Scenario

NPV	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
104.74	104.74	158.99	209.29	261.27	322.90	385.70	453.55	525.61	601.34	678.94	755.71	828.39	893.06	942.36	966.80	950.42	868.58	704.84	432.29
-1.0		62.82	101.08	138.07	182.79	226.81	274.25	324.48	377.30	431.48	485.33	536.59	582.63	618.58	638.01	630.20	578.58	472.03	292.50
103.74			28.66	53.95	87.90	119.61	153.37	188.93	226.32	264.72	303.11	339.91	373.33	400.17	416.05	413.71	381.96	313.09	194.83
				3.99	23.84	46.27	71.59	97.44	124.51	152.34	180.34	207.40	232.32	253.02	266.51	267.86	249.49	206.01	129.03
					5.34	3.57	16.89	35.06	55.60	76.40	97.54	118.10	137.32	153.89	165.76	169.59	160.24	133.87	84.70
						2.82	3.09	0.17	10.47	24.71	41.24	57.71	73.26	87.10	97.88	103.39	100.11	85.26	54.83
							0.26	2.39	3.00	0.00	5.06	15.90	29.51	41.93	52.16	58.79	59.59	52.51	34.71
								0.00	0.00	2.15	2.64	0.00	1.29	10.05	20.82	28.77	32.30	30.45	21.16
									0.00	0.00	0.00	1.83	2.50	0.00	0.00	7.41	14.03	15.59	12.02
										0.00	0.00	0.00	0.00	1.90	2.87	0.00	0.87	5.93	5.87
											0.00	0.00	0.00	0.00	0.00	2.44	3.37	0.00	2.28
												0.00	0.00	0.00	0.00	0.00	0.46	2.69	3.08
													0.00	0.00	0.00	0.00	0.00	0.00	0.00
														0.00	0.00	0.00	0.00	0.00	0.00
															0.00	0.00	0.00	0.00	0.00
																0.00	0.00	0.00	0.00
																	0.00	0.00	0.00
																		0.00	0.00
																			0.00

$$NPV = (64.2\% \times 103.74 + 35.8\% \times 20.32)/(1 + 7.34\%) = US\ \$68.86\ millions$$

NPV	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
21.32	21.32	61.01	98.93	135.59	179.98	223.71	270.86	320.81	373.35	427.23	480.77	531.70	577.38	612.93	631.95	623.70	571.60	464.54	284.46
-1.0		4.63	27.10	51.98	85.48	116.76	150.14	185.35	222.41	260.49	298.55	335.01	368.08	394.53	409.99	407.21	374.98	305.60	186.79
20.32			2.98	2.85	22.25	44.13	68.83	94.18	120.79	148.21	175.82	202.51	227.07	247.38	260.45	261.36	242.51	198.52	120.99
				0.00	4.77	2.64	15.40	32.67	52.48	72.67	93.24	113.32	132.10	148.25	159.70	163.09	153.26	126.37	76.66
					0.86	2.76	2.99	0.00	8.88	22.05	37.73	53.41	68.27	81.56	91.85	96.89	93.13	77.77	46.79
						0.00	0.26	2.39	3.00	0.00	3.39	13.11	25.57	36.90	46.37	52.36	52.62	45.02	26.67
							0.00	0.00	0.00	2.15	2.63	0.00	0.00	7.24	16.13	22.92	25.56	22.96	13.11
								0.00	0.00	0.00	0.00	1.81	2.47	0.00	0.00	3.84	8.56	8.82	3.98
									0.00	0.00	0.00	0.00	0.00	1.79	2.70	0.00	0.00	1.66	0.00
										0.00	0.00	0.00	0.00	0.00	0.00	1.92	2.76	0.00	0.00
											0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00
												0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
													0.00	0.00	0.00	0.00	0.00	0.00	0.00
														0.00	0.00	0.00	0.00	0.00	0.00
															0.00	0.00	0.00	0.00	0.00
																0.00	0.00	0.00	0.00
																	0.00	0.00	0.00
																		0.00	0.00
																			0.00

The very left hand highest NPV of combining the defer and abandon option result US $68.86 million from Base Scenario.

Table 16. NPV ROV for Defer and Abandon Option

Parameter	Unit	Base	Mid	Low
NPV ROV Defer and Abandon Option	USD million	68.86	39.59	24.62

The quantification of investment timing flexibility and operating flexibility was first solved by Brennan and Schwartz (1985) using option pricing techniques that found, for mineral assets, the additional value created through optimally executed managerial flexibility can be "priced" just as American stock options are priced as demonstrated:

Expanded value = DCF Value + Option Premium

The expanded value from Table 16 result US $57.58 million (US $68.86 million – US $11.28 million) for GMB Mine. Breakeven coal price between option to action now and combine option to defer investment and abandon operation comes from difference between both NPV that equal to zero or intersection between two lines in price US $34.3/t.

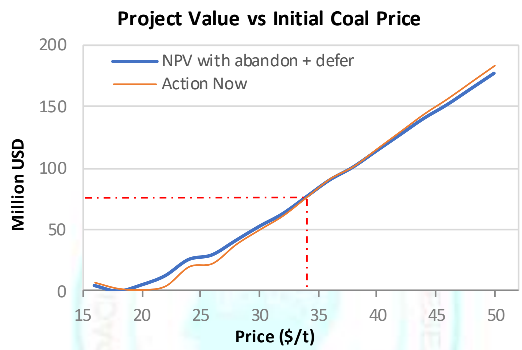


Figure 8. Managerial Flexibility Breakeven Price

Implementation of combine option obtain higher NPV compare to other options as along as the initial coal price to commence the mine is between range US $18/t – US $34.3/t.

7. Conclusion

DCF valuation still suitable to use in short range plan that are somewhat deterministic where the analyst can predict the near future more confident and more accurate because the longer the horizon, the harder it is to fully predict all the unknowns, and hence, management can create value by being able to successfully initiate and execute strategic options. Strategic options suit uses modern methodology real options valuation (ROV) with binomial lattice model that works well for complex options with number of risks and multiple expiration dates and also consider managerial flexibility under uncertainty for economic evaluation of an assets.

GMB Mine study case calculation by DCF valuation and ROV with binomial lattice, recommend to stick implement the Base Scenario with strategic option to defer investment and abandon operation if not economic financially due to obtained highest NPV as US $ 68.86 million in the situation of coal price decline to US $33/t that between range US $18/t – US $34.3/t.

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