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INVESTMENT FEASIBILITY ASSESSMENT OF A NICKEL MINING PROJECT UNDER NICKEL PRICE UNCERTAINTY USING DISCOUNTED CASH FLOW AND REAL OPTION VALUATION WITH A COX–ROSS–RUBINSTEIN BINOMIAL LATTICE MODEL

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Abstract

Investment decisions in nickel mining projects are exposed to uncertainty, particularly fluctuations in nickel prices, which can affect expected project cash flows and investment timing. Conventional discounted cash flow (DCF) valuation provides a static assessment of project feasibility but does not explicitly capture managerial flexibility to postpone investment under changing market conditions. This study evaluates the feasibility of a nickel mining project by integrating DCF and real option valuation (ROV) under nickel price uncertainty. Historical nickel price data for 2021–2025 are used to characterize market price uncertainty, while a Cox–Ross–Rubinstein (CRR) binomial lattice model is applied to value the option to defer investment using risk-neutral probabilities and backward induction. The DCF analysis yields a net present value (NPV) of IDR 207.83 billion, an internal rate of return (IRR) of 61%, and a discounted payback period (DPP) of 1.77 years. The real options analysis produces an incremental option value of IDR 113.01 billion, resulting in an Expanded Net Present Value (ENPV) of IDR 320.84 billion, equivalent to approximately 54.37% above the DCF NPV. Sensitivity analysis of the nickel price indicates that the DCF NPV remains positive under a ±10% variation in the assumed nickel price, with estimated NPVs of IDR 115.16 billion, IDR 207.83 billion, and IDR 300.47 billion for the low, base, and high scenarios, respectively. These results indicate that the project remains economically feasible within the tested nickel-price range. At the same time, the real options approach provides additional value by incorporating the modeled flexibility to defer investment. However, the ROV and ENPV results remain conditional on the CRR parameters and the sources of uncertainty explicitly incorporated into the model.

Keywords: nickel mining; discounted cash flow; real options valuation; nickel price uncertainty; Cox–Ross–Rubinstein binomial lattice

Introduction

Nickel mining projects require substantial upfront investment and are exposed to considerable uncertainty in commodity prices. Changes in nickel prices directly affect project revenues and profitability, making price uncertainty an important consideration in mining investment evaluation. Conventional Discounted Cash Flow (DCF) analysis is widely used to assess project feasibility; however, it generally assumes predetermined cash flows and has limited ability to represent managerial flexibility when market conditions change (Savolainen, 2016).

Real Option Valuation (ROV) provides an alternative framework for valuing managerial flexibility, such as the option to defer, expand, or abandon an investment. In mining, commodity-price uncertainty is one of the major sources of uncertainty considered in real-options analysis.

Previous studies have demonstrated the relevance of real options for mining investment decisions, particularly when investment is irreversible, and management can wait for more information before committing capital (Savolainen, 2016). The Cox–Ross–Rubinstein (CRR) binomial model provides a discrete framework for representing the evolution of an underlying asset and valuing options through backward induction (Cox et al., 1979).

Recent studies on Indonesian nickel projects have applied DCF, sensitivity analysis, and real-options approaches to evaluate investment uncertainty. For example, recent studies on nickel have combined DCF with binomial-lattice or other real-options approaches to quantify managerial flexibility under nickel price uncertainty. However, a practical gap remains in explicitly linking nickel price uncertainty, project value evolution, managerial investment/deferral decisions, and incremental option value within a single project-level valuation framework. This is particularly important because the literature also shows that mining project valuation may be affected by multiple sources of uncertainty. At the same time, the definition of the managerial option and the exercise rule determine how flexibility translates into economic value (Savolainen, 2016).

This study addresses this gap by integrating DCF valuation with a CRR binomial-lattice real-options framework for a laterite nickel mining project in South Konawe, Southeast Sulawesi, Indonesia. The novelty lies in explicitly linking nickel-price uncertainty to project-value evolution, the investment/defer decision, incremental real-option value, and Expanded Net Present Value (ENPV) within one valuation framework.

The study aims to evaluate the economic feasibility of the nickel mining project using DCF, quantify the incremental value of managerial flexibility under nickel price uncertainty using the CRR model, and compare the conventional DCF NPV with the resulting real-option value and ENPV.

Materials And Method

Study Area

The study area is located in South Konawe Regency, Southeast Sulawesi Province, Indonesia, within the Southeast Sulawesi Ophiolite Belt (Figure 1). The deposit is a laterite nickel system developed from weathered ultramafic rocks, predominantly peridotite and dunite, under tropical weathering conditions. The lateritic profile generally comprises surface soil, limonite, saprolite, and relatively fresh bedrock (Prinaldi et al., 2025).

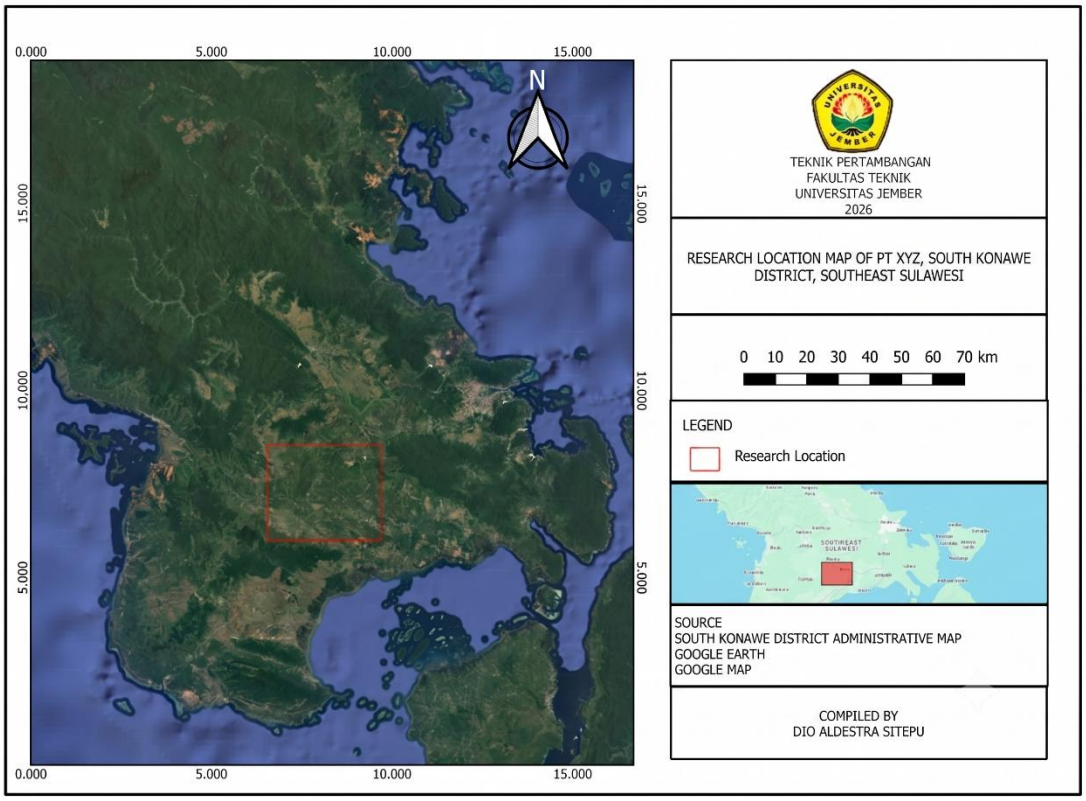

Figure 1 Location of the study area and nickel mining project in South Konawe, Southeast Sulawesi, Indonesia, showing the red polygon representing the project area

The project is planned to be developed using an open-pit mining method. The economic evaluation covers 2026–2030, comprising Year 0 as the initial project period and four operating years (Years 1–4) (Prinaldi et al., 2025). The project name and selected project-specific information are anonymized as PT XYZ to maintain confidentiality. The economic analysis is presented using aggregated project parameters sufficient to reproduce the valuation methodology without disclosing commercially sensitive information.

Research Data

This study uses a quantitative approach based on secondary technical and economic data. The available project model includes information on capital expenditure (CAPEX), operating expenditure (OPEX), nickel selling price, royalty, corporate income tax, interest on debt, depreciation, amortization, salvage value, and project cash flow. Historical nickel price data for 2021–2025 were used as the basis for representing commodity price uncertainty.

The reported economic assumptions include a 10% royalty rate, a 22% corporate income tax rate, and a WACC of 11.84%. The available documentation does not provide the complete capital structure and component inputs required to reproduce the WACC independently, nor does it provide the complete historical nickel-price series, observation frequency, number of observations, price type, data source, data-cleaning procedure, or exact volatility-estimation procedure (Table 1).

Table 1 Project cash-flow projection and discounted cash flow (DCF) valuation, including revenue, royalties, operating costs, financing costs, depreciation, amortization, taxes, net income after tax, project cash flow, discounted cash flow, and cumulative discounted cash flow over the project life.

Category	Parameter	Value / Status	Unit / Source
Project & Technical	Deposit type	Laterite nickel	Geological description
	Mining method	Open-pit	Project description
	Project period	2026–2030	Year
	Operating period	4 years (2027–2030)	Year
DCF Economic Inputs	Nickel selling price	Used in revenue calculation; detailed value not reported	Project economic data
	Initial project cost	143,562.90	million IDR; Year-0 cash flow
	Operating cost	See Table 1	million IDR/year
	Royalty	10	%
	Corporate income tax	22	%
	Debt interest	See Table 1	million IDR/year
	Depreciation	16,681.71	million IDR/year
	Amortization	2,776.65	million IDR/year
	Salvage value	16,681.71	million IDR
	Payment	38,069.65	million IDR/year
	WACC	11.84	%
Nickel Price Uncertainty	Historical nickel price	2021–2025	Historical price data

Source: Revenue and nickel selling price data refer to the Ministry of Energy and Mineral Resources (ESDM); royalty data refer to applicable ESDM mining regulations; project technical data refer to project data; CAPEX and OPEX refer to project economic data; depreciation and amortization are based on project accounting assumptions; corporate tax refers to applicable Indonesian tax regulations; and the cash-flow components are compiled based on the above data and assumptions.

The available project dataset does not provide detailed information on mineral resource classification, mineable reserve or tonnage, average nickel grade, cut-off grade, or annual production capacity. These parameters were therefore not included as numerical inputs in the present economic evaluation. Their absence reflects a limitation in the available project data and is considered in interpreting the study results.

Discounted Cash Flow (DCF)

The Discounted Cash Flow (DCF) method was applied to evaluate the economic feasibility of the nickel mining project based on projected project cash flows. The feasibility indicators include Net Present Value (NPV), Internal Rate of Return (IRR), and Discounted Payback Period (DPP).

Because the initial project outflow is already included as the Year 0 cash flow in Table 1, the NPV is expressed as:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - I_0$$

Where CF_t is the net cash flow in period t, r is the discount rate, t is the evaluation period, and I_0 is the initial project outflow. A project is considered economically feasible when NPV > 0.

The Internal Rate of Return (IRR) is the discount rate that makes the NPV equal to zero:

$$0 = \sum_{t=0}^{n} \frac{CF_t}{(1 + \mathrm{IRR})^t}$$

The discount rate is derived from the Weighted Average Cost of Capital (WACC):

$$WACC = \left(\frac{E}{D+E} \times k_e\right) + \left(\frac{D}{D+E} \times k_d \times (1-T)\right)$$

where E is equity, D is debt, V is total capital, R_e is the cost of equity, R_d is the cost of debt, and T is the corporate income tax rate. The reported WACC used in the original DCF model is 11.84% (Shou, 2022; Savolainen, 2016).

Cash-Flow Construction

The project cash-flow model separates revenue, royalty, net revenue, operating expenditure, interest expense, depreciation, amortization, tax, salvage value, and other financing-related cash-flow components. Depreciation and amortization are non-cash accounting expenses and are therefore added back when deriving project cash flow from net income after tax. Accordingly, the basic operating cash-flow relationship is expressed as:

$$CF_t = NIAT_t + (D_t + A_t)$$

The reported project cash flow differs from the basic operating cash flow relationship because the project model includes additional cash flow adjustments. These adjustments are incorporated in the project cash flow used for the DCF analysis (Brennan & Schwartz, 1985; Savolainen, 2016).

Real Option Valuation

To incorporate managerial flexibility under nickel price uncertainty, this study applies Real Option Valuation (ROV) using the Cox–Ross–Rubinstein (CRR) binomial lattice model. Unlike the DCF approach, which evaluates the project using predetermined cash flows, ROV incorporates the value of managerial flexibility under uncertainty.

In this study, managerial flexibility is represented by an investment deferral option, whereby the investment decision can be exercised when the underlying project value is sufficient to justify the required investment expenditure. The option value is therefore determined by comparing the underlying project value at each lattice node with the exercise price of the investment option.

The underlying project value in the initial period is denoted by S0, while the exercise price, K, represents the investment required to undertake the project on the exercise date. Under the deferred option framework, the option is exercised when the underlying project value is sufficient

to justify this investment expenditure. The underlying project value, S_0, is conceptually defined as the present value of the project's future cash flows before the investment option is exercised. This distinction is important because directly using the DCF NPV as the underlying asset value may result in double-counting of the initial investment expenditure.

The future project values are represented using a binomial lattice, in which the underlying value can move up or down at each time interval. The up and down factors are calculated as:

$$u = e^{\sigma\sqrt{\Delta t}}$$

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

Where u is the up factor, d is the down factor, σ is the volatility of the underlying variable, and Δt is the length of each time interval. The project value at each node is then calculated from the initial underlying value according to:

$$S_{t,j} = S_0 u^j d^{t-j}$$

Where $S_{t,j}$ represents the project value at time t and node j. The resulting binomial lattice structure, showing the possible upward and downward movements of the underlying project value over the evaluation period, is illustrated in Figure 2.

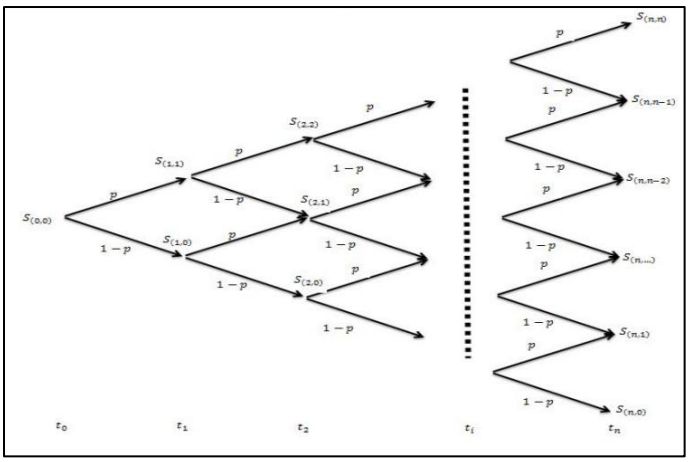

Figure 2 Cox–Ross–Rubinstein (CRR) binomial lattice framework illustrating the time-step structure, upward (u) and downward (d) movements, risk-neutral probabilities (p) and (1-p), and the evolution of the underlying project value under nickel-price uncertainty. Modified from Cox et al. (1979).

The volatility parameter σ represents the uncertainty in the underlying project value due to fluctuations in nickel prices. Historical nickel price data for the 2021–2025 period were considered as the basis for the uncertainty assessment. The available dataset provides the basis for representing nickel-price uncertainty in the CRR model.

The risk-neutral probability is calculated as:

$$p = \frac{e^{r_f \Delta t} - d}{u - d}$$

where p is the risk-neutral probability and r_f is the risk-free rate. The risk-free rate is required for risk-neutral valuation and for discounting the expected option payoff. The risk-free rate is required for risk-neutral valuation and for discounting the expected option payoff (Cox, Ross, & Rubinstein, 1979; Kelly, 1998; Alfajriyah et al., 2024).

The exercise price K represents the investment expenditure required to undertake the project. At the terminal nodes, the payoff of the investment option is:

$$V_{N,j} = \max\left(S_{N,j} - K, 0\right)$$

After the terminal payoff is determined, the option value at each preceding node is calculated using backward induction:

$$V_{t,j} = e^{-r_f \Delta t}\left[pV_{t+1,j+1} + (1-p)V_{t+1,j}\right]$$

The calculation is repeated from the terminal nodes to the initial node. The resulting option value represents the incremental value of managerial flexibility. The Expanded Net Present Value (ENPV) is then calculated as:

$$ENPV = NPV_{DCF} + ROV$$

In this formulation, ROV represents the incremental value of managerial flexibility rather than the total project value. The binomial lattice provides a structured framework for representing uncertainty, time, and decision flexibility in the valuation process (Cox et al., 1979; Trigeorgis, 1996).

Result And Discussion

The project requires an initial outflow of IDR 143.56 billion in Year 0. The original project model reports positive annual cash flows during all four operating years: IDR 61.77 billion in 2027, IDR 142.60 billion in 2028, IDR 117.38 billion in 2029, and IDR 153.69 billion in 2030. The corresponding discounted cash flows are IDR 55.23 billion, IDR 114.01 billion, IDR 83.91 billion, and IDR 98.24 billion, as shown in Table 2.

Table 2 Input parameters and assumptions used in the discounted cash flow (DCF) and real options valuation (ROV) analyses, including resource and production characteristics, economic and financial assumptions, nickel-price uncertainty, discount rates, and binomial-lattice parameters.

Component	Year 0 (2026)	Year 1 (2027)	Year 2 (2028)	Year 3 (2029)	Year 4 (2030)
Revenue	-	368.357,19	474.917,91	436.462,75	467.470,85
Royalty	-	-36.835,72	-47.491,79	-43.646,27	-46.747,08
Net Revenue	-	331.521,47	427.426,12	392.816,47	420.723,76
Operating Expenditure (OPEX)	-	-171.777,18	-167.153,90	-167.945,45	-169.031,09
Interest Expense	-	-12.290,08	-9.182,31	-6.121,54	-3.064,61

Depreciation	-	-16.681,71	-16.681,71	-16.681,71	-16.681,71
Amortization	-	-2.776,65	-2.776,65	-2.776,65	-2.776,65
Salvage Value	-	-	-	-	16.681,71
Earnings Before Tax	-	127.995,85	231.631,54	199.291,12	245.851,42
Corporate Income Tax (22%)	-	-28.159,09	-50.958,94	-43.844,05	-54.087,31
Net Income After Tax	-	99.836,76	180.672,60	155.447,08	191.764,10
Reported Project Cash Flow	-143.562,90	61.767,11	142.602,95	117.377,43	153.694,45
Component	Year 0 (2026)	Year 1 (2027)	Year 2 (2028)	Year 3 (2029)	Year 4 (2030)
Discounted Cash Flow	-143.562,90	55.229,08	114.011,72	83.910,45	98.242,67
Cumulative Discounted Cash Flow	-143.562,90	-88.333,83	25.677,90	109.588,35	207.831,02

Source: Project technical and economic documentation; nickel selling price and royalty information from applicable ESDM sources; corporate income tax based on applicable Indonesian tax regulations; historical nickel-price data from the World Bank Commodity Markets; and CRR methodology based on Cox et al. (1979).

The revenue profile shows annual revenue of IDR 368.36 billion in 2027, increasing to IDR 474.92 billion in 2028, declining to IDR 436.46 billion in 2029, and increasing again to IDR 467.47 billion in 2030. Royalty remains approximately proportional to revenue, at 10%, with a range of IDR 36.84 billion to IDR 47.49 billion. OPEX is comparatively stable, ranging from IDR 167.15 billion to IDR 171.78 billion. Interest expense declines from IDR 12.29 billion in 2027 to IDR 3.06 billion in 2030, reducing the financing burden over time.

Net income before tax is IDR 128.00 billion in 2027, IDR 231.63 billion in 2028, IDR 199.29 billion in 2029, and IDR 245.85 billion in 2030. The high 2030 value is consistent with relatively strong revenue, stable OPEX, lower interest expense, and the salvage value. However, the contribution of production volume versus nickel price to annual revenue cannot be quantitatively separated because annual production tonnage is not explicitly reported in the available documentation.

Discounted Cash Flow Analysis

The DCF NPV calculated from the complete project cash-flow series, including the initial Year 0 outflow, is IDR 207.83 billion. Because the NPV is positive, the project generates positive value relative to the 11.84% discount rate under the reported base-case assumptions. The IRR is 61%, substantially above the WACC. Given the relatively high IRR, this result should be interpreted in the context of the underlying cash-flow assumptions, production assumptions, nickel selling price, CAPEX, OPEX, tax, and financing treatment rather than as evidence that the project is intrinsically low-risk.

The discounted payback period (DPP) is 1.77 years, and the cumulative discounted cash flow becomes positive during the second operating year, indicating relatively rapid capital recovery under the reported assumptions (Shou, 2022; Savolainen, 2016).

Project-Value Evolution in the Binomial Lattice

The CRR lattice represents alternative future states of the underlying project value. An upward movement is represented by multiplication by u and a downward movement by d (Figure 3). The spread between possible project values increases as the lattice progresses through time, reflecting the accumulation of uncertainty.

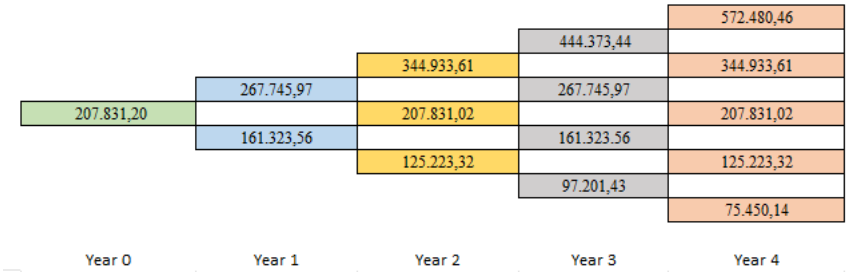

Figure 3 Project-value binomial lattice under nickel-price uncertainty, showing the evolution of possible project-value states from the initial period to the terminal period through successive upward (u) and downward (d) movements.

The lattice should be interpreted as a valuation device rather than as a prediction of a single future project value. In a non-financial mining asset, nickel price movements can affect project revenue and, therefore, project value, while physical production and reserves are governed by geological and mine-planning constraints. The present model, therefore, assumes that the principal uncertainty affecting project value is nickel price uncertainty, while production, OPEX, geology, and other sources of uncertainty are held according to the base-case project model (Cox et al., 1979; Kelly, 1998; Savolainen, 2016).

Real Option Value and Managerial Decision

The incremental real option value is IDR 113.01 billion. Under the investment-defer framework, the option value is determined by the underlying project value, exercise price, volatility, risk-free rate, and time step used in the CRR binomial lattice. These parameters determine the upward and downward movements of the project value, risk-neutral probabilities, terminal option payoffs, and the subsequent backward-induction valuation (Figure 4). The resulting option value represents the incremental economic value of managerial flexibility to defer investment under alternative future project-value states.

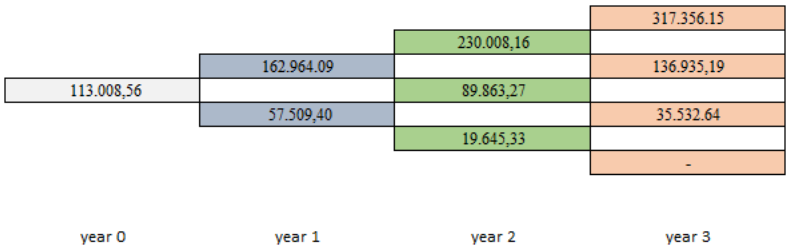

Figure 4 Backward-induction valuation of the real option, showing the recursive calculation of option values from the terminal nodes to the initial decision node using risk-neutral probabilities and risk-free discounting.

Under the investment-defer interpretation (Figure 4), the option provides managerial flexibility because the investment need not be exercised under every possible future project-value state. At each decision node, investment is exercised when the underlying project value exceeds the exercise price and generates a positive intrinsic payoff; otherwise, management retains the option to defer investment (Trigeorgis, 1996; Savolainen, 2016; Haque et al., 2014).

Comparative Analysis of Discounted Cash Flow and Real Option Valuation

The conventional DCF NPV is IDR 207.83 billion, while the ENPV after adding the incremental real option value is IDR 320.84 billion. The difference is IDR 113.01 billion, not IDR 320.84 billion. Relative to the DCF NPV, the incremental value corresponds to approximately 54.37%.

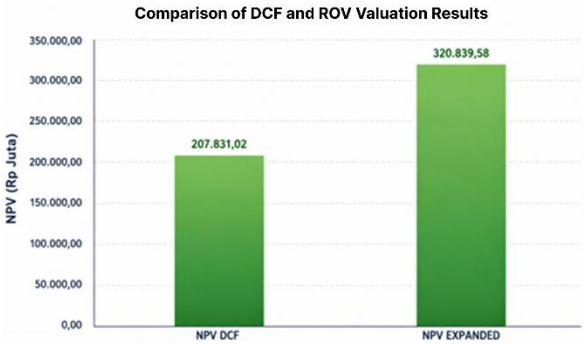

Figure 5 Comparison of DCF and Real Options Valuation (ROV) results, showing the DCF NPV, incremental real-option value, and resulting Expanded Net Present Value (ENPV).

This comparison demonstrates the economic importance of flexibility under the modeled uncertainty. The result should not be interpreted to mean that ROV universally produces a more accurate value than DCF (Figure 5). Rather, under the stated investment/defer option and model assumptions, ROV assigns additional value to the ability to respond to future project-value states. The magnitude of the 54.37% increment is therefore contingent on the volatility, risk-free rate, exercise price, underlying value construction, and time-step assumptions (Myers, 1977; Trigeorgis, 1996; Savolainen, 2016).

The interpretation of the results is consistent with the broader real-options literature in one important respect: conventional DCF and option-based valuation answer different questions. DCF provides the value of a predetermined investment plan (Figure 5), whereas real-options analysis explicitly considers the value of flexibility under uncertainty. Studies of commodity-price volatility likewise demonstrate that commodity markets can materially influence project value. The present study extends this logic to a laterite nickel mining project by quantifying the incremental value associated with an investment/deferral decision.

The reported 54.37% increase should not, however, be generalized to all nickel projects, as option value is highly dependent on volatility, investment timing, exercise cost, project life, and cash-flow assumptions. The contribution of this study is therefore best understood as a project-specific demonstration of how commodity-price uncertainty and managerial flexibility can alter investment valuation (Brennan & Schwartz, 1985; Kelly, 1998; Savolainen, 2016; Haque et al., 2014).

A sensitivity analysis was conducted to evaluate the effect of changes in nickel prices on the project's economic feasibility. Nickel price was selected as the sensitivity variable because uncertainty in nickel price represents the principal market uncertainty incorporated into the valuation framework. Three scenarios were considered: a low-price scenario with a 10% decrease from the base-case nickel price, the base case, and a high-price scenario with a 10% increase.

The DCF sensitivity results show that the project NPV decreases from IDR 207.83 billion under the base case to IDR 115.16 billion under the low-price scenario, while an increase in nickel price increases the NPV to IDR 300.47 billion under the high-price scenario (Table 3). Despite the 10% decrease in nickel price, the resulting NPV remains positive, indicating that the project remains economically feasible within the tested price range.

Table 3 Sensitivity of DCF valuation to nickel price scenarios, showing the effect of ±10% changes in the nickel price assumption on project NPV and the resulting investment feasibility.

Scenario	Nickel Price Assumption	DCF NPV (IDR billion)	Change from Base	Investment Decision
Low	−10%	115,16	−44.60%	Feasible
Base	Base case	207,83	0.00%	Feasible
High	+10%	300,47	+44.58%	Feasible

These results indicate that the base-case DCF investment conclusion is robust to the tested ±10% nickel price variation. However, the magnitude of the incremental real option value should not be assumed to remain constant across the scenarios. The incremental ROV of IDR 113.01 billion, equivalent to 54.37% of the base-case DCF NPV, represents the base-case result. Because the complete CRR input parameters are unavailable for recalculating the option lattice under alternative nickel price scenarios, the assessment of ROV and ENPV across the sensitivity scenarios is limited.

Managerial Implications and Limitations

The DCF cash-flow table also contains a component whose detailed composition is not documented. Because depreciation and amortization are non-cash accounting charges, they are added back in the calculation of project cash flow from net income after tax. In addition, the present ROV framework models nickel price uncertainty as the principal stochastic source and does not explicitly model production, OPEX, geological, or exchange-rate uncertainty. Finally, the CRR model simplifies continuous uncertainty into two-state movements at each time step. These limitations constrain the generalization of the numerical results.

The ROV result provides a complementary perspective on decision-making. Rather than treating the investment as an irreversible commitment at time zero, management can evaluate whether the expected project value justifies exercising the investment option as market information evolves. This flexibility is particularly relevant to commodity-exposed mining projects, although its quantified value remains conditional on the CRR assumptions and the quality of the historical price-volatility estimate. (Dixit & Pindyck, 1994; Trigeorgis, 1996).

A limitation of the valuation is the incomplete documentation of several inputs required to reproduce the model. These include the mineral resource and reserve parameters, average grade

and cut-off grade, annual production capacity, the complete nickel price dataset and its source and frequency, the volatility estimation procedure, the risk-free rate and tenor, WACC components, the exercise price, the time step, and the exact construction of S_0.

Conclusions

The DCF analysis indicates that the evaluated nickel mining project is economically feasible under the base-case assumptions, with an NPV of IDR 207.83 billion, an IRR of 61%, and a discounted payback period (DPP) of 1.77 years. The real options analysis indicates an incremental option value of IDR 113.01 billion associated with the modeled option to defer investment, resulting in an ENPV of IDR 320.84 billion. The incremental option value corresponds to approximately 54.37% of the base-case DCF NPV.

The sensitivity analysis further shows that the DCF-based project feasibility remains positive under the tested ±10% nickel-price scenarios, with NPVs of IDR 115.16 billion, IDR 207.83 billion, and IDR 300.47 billion for the low, base, and high scenarios, respectively. This indicates that the DCF-based investment conclusion is robust across the tested range of nickel prices.

Nevertheless, the ROV and ENPV should be interpreted as conditional on the modeled flexibility in investment timing, the assumed uncertainty in nickel prices, and the CRR parameterization. Accordingly, the results demonstrate the additional value of the modeled managerial flexibility rather than implying that real options valuation is universally superior to conventional DCF valuation.

References

Alfajriyah, A. U., Putri, E. R. M., Utomo, D. B., & Hakiki, M. T. (2024). Stock option pricing using binomial trees with implied volatility. Jurnal Matematika, Statistika dan Komputasi, 20(3), 724–742. https://doi.org/10.20956/j.v20i3.34476

Brennan, M. J., & Schwartz, E. S. (1985). Evaluating natural resource investments. The Journal of Business, 58(2), 135–157. https://doi.org/10.1086/296288

Chandra, M. (2024). Nickel price projection using multivariate regression method and investment feasibility analysis of nickel mining in Indonesia with sensitivity analysis and Monte Carlo. International Journal of Current Science Research and Review, 7(3). https://doi.org/10.47191/ijcsrr/V7-i3-34

Costa Lima, G. A., & Suslick, S. B. (2006). Estimating the volatility of mining projects considering price and operating cost uncertainties. Resources Policy, 31(2), 86–94. https://doi.org/10.1016/j.resourpol.2006.07.002

Cox, J. C., Ross, S. A., & Rubinstein, M. (1979). Option pricing: A simplified approach. Journal of Financial Economics, 7(3), 229–263. https://doi.org/10.1016/0304-405X(79)90015-1

Dixit, A. K., & Pindyck, R. S. (1994). Investment under uncertainty. Princeton University Press.

Haque, M. A., Topal, E., & Lilford, E. (2014). A numerical study for a mining project using real options valuation under commodity price uncertainty. Resources Policy, 39, 115–123. https://doi.org/10.1016/j.resourpol.2013.12.004

Hong, S., Luo, Y., Li, M., & Qin, D. (2022). Volatility research of nickel futures and spot prices based on copula-GARCH model. Frontiers in Energy Research, 10, 1011750. https://doi.org/10.3389/fenrg.2022.1011750

Kelly, S. (1998). A binomial lattice approach for valuing a mining property IPO. The Quarterly Review of Economics and Finance, 38(3), 693–709. https://doi.org/10.1016/S1062-9769(99)80097-0

Myers, S. C. (1977). Determinants of corporate borrowing. Journal of Financial Economics, 5(2),147–175. https://doi.org/10.1016/0304-405X(77)90015-0

Prinaldi, D. R., Rosana, M. F., Patonah, A., & Amiruddin, A. (2025). Petrology and geochemistry of ultramafic rock and its implication to nickel-cobalt enrichment in overlying lateritic zones at the Block X, South Sulawesi. Indonesian Journal of Economic Geology, 1(1), 33–55. https://doi.org/10.51835/ijeg.2025.1.1.488

Savolainen, J. (2016). Real options in metal mining project valuation: Review of literature. Resources Policy, 50, 49–65. https://doi.org/10.1016/j.resourpol.2016.08.007

Shou, T. (2022). A literature review on the Net Present Value (NPV) valuation method. In Proceedings of the 2022 2nd International Conference on Enterprise Management and Economic Development (ICEMED 2022) (pp. 826–830). Atlantis Press. https://doi.org/10.2991/aebmr.k.220603.135

Siña, M., & Guzmán, J. I. (2019). Real option valuation of open pit mines with two processing methods. Journal of Commodity Markets, 13, 30–39. https://doi.org/10.1016/j.jcomm.2018.05.003

Trigeorgis, L. (1996). Real options: Managerial flexibility and strategy in resource allocation. MIT Press.