Optimal Investment Strategy Selection: Real Options Approach in Indonesia's Oilfield Drilling Services

Muhammad Reihant Muzadi[1*], Oktofa Yudha Sudrajad[2]
[1,2]Institut Teknologi Bandung
129324165@mahasiswa.itb.ac.id[1], oktofayudha@itb.ac.id[2]*

Abstract

This study develops an analytical framework to select the optimal investment strategy for an Indonesian state-owned oilfield services company, addressing CAPEX gaps and comparing static and dynamic valuation approaches under uncertainty. The study employs a case-based quantitative valuation design. Discounted Cash Flow (DCF) is used as the A case-based quantitative design uses Discounted Cash Flow (DCF) to assess project feasibility in varying demand scenarios, while Real Options Valuation (ROV), supported by Monte Carlo simulation, evaluates the value of managerial flexibility. DCF shows the project is unfeasible in low demand but viable in base and high scenarios. ROV, incorporating flexibility, provides higher investment values, turning a negative NPV in the low-demand case into a positive Total Investment Value (TIV), indicating strategic viability under uncertainty. Integrating Real Options Valuation into the firm's capital budgeting process improves investment decision making compared with relying on Discounted Cash Flow alone. The analysis focuses on a single Indonesian state-owned oilfield services company, with uncertainty primarily in market demand and volatility, limiting generalizability to other firms or environments. This study provides a decision-making framework for investment strategy selection in oilfield services by comparing DCF and ROV, showing how option value influences decisions under uncertainty through simulation-based valuation.

Keywords: *Capital Budgeting, Discounted Cash Flow, Investment Strategy, Monte Carlo Simulation, Oil and Gas Drilling Services, Real Option Valuation.*

1. INTRODUCTION

Indonesian oil and gas industry is currently driven by a national target to achieve energy security, with specific production targets set at 1 million barrels of oil per day (MMBOPD) and 12 billion standard cubic feet per day (BSCFD) by 2030. Oilfield services (OFS) company are involved in achieving energy security goal by providing technical and engineering expertise in exploration and production wells for leveraging oil & gas production. In this capital-intensive sector, the business model does not rely on selling a tangible commodity, but rather on leasing the service capacity of high-value assets, such as drilling rigs and auxiliary equipment. Consequently, the strategic valuation and timing of asset procurement are the primary determinants of a firm's competitive advantage and long-term sustainability.

While the company has demonstrated robust financial performance, it faces a significant problem. There is a persistent and widening gap between its ambitious long-term plan targets and its actual investment realization. Internal data reveals a chronic shortfall in Capital Expenditure (CAPEX) absorption, with realized investments in recent fiscal years reaching less than 10% of the targeted budget. The diagnostic analysis suggests that this investment realization gap is due to a few things: some financial limits within the company, slow-moving procurement processes, and, most importantly, the unpredictable nature of the outside market. The ups and downs in global oil prices, along with the unclear demand for drilling, make it a risky place where standard financial methods sometimes can't justify the big, permanent investments needed (Bako, 2024; Damanik, Prasetyo, Alie, & Oktaria, 2025; Firman & Khudri, 2025; Hakam & Saraswani, 2025; Ikwuo, Nwite, Nworie, & Nworie, 2025; Ilyas, Khan, Nadeem, & Suleman, 2021; Kemala & Hakam, 2025).

Accordingly, this study addresses a capital budgeting problem rather than merely an industry-specific investment issue. In highly uncertain and capital-intensive service environments, a static valuation framework may lead firms to reject projects that retain strategic value through managerial flexibility. This study therefore contributes to the capital budgeting literature by explicitly comparing Discounted Cash Flow (DCF) and Real Options Valuation (ROV) in the context of oilfield drilling services in Indonesia. It examines whether the option to expand can improve investment feasibility under uncertain well demand and identifies the strategy that produces the highest decision value for the firm. By doing so, the study not only evaluates project viability but also demonstrates how dynamic valuation can support more adaptive investment strategy selection in volatile markets.

2. LITERATURE REVIEW

Oil & Gas (O&G) drilling services, a specialized field within the upstream energy sector, focuses on constructing wellbores. O&G service (OFS) companies are typically contracted by exploration and production (E&P) to execute well plans safely, on schedule, and navigate complex subsurface geologies to access hydrocarbon reservoirs within budget (Gautam, Guria, & Rajak, 2022). The O&G industry has advanced into challenging frontiers like deep water, high-pressure/high-temperature (HPHT) environments, and unconventional shale plays, demanding technical expertise and precision engineering solutions (Ali et al., 2020).

There are two types of O&G drilling services: Rig Services and Non-Rig Services. Rig services consist of operations and technical support of drilling rig during well construction and workover/well intervention rig for well services. The primary goal of rig services is to create the wellbore safely and efficiently from the surface to the target depth (H. Wang et al., 2022). Rig services include drilling contract, which provides the rig, power systems, and its crew. Non-rig services consist of operations and technical support that does not involving rigs directly as an activity. Directional drilling (DD) and Measurement/Logging While Drilling (MWD/LWD) services are one of the important part in non-rig services, which steer the well path and gather real-time geological data (Cai et al., 2025).

Drilling fluid services also manages the mud system to maintain pressure control and wellbore stability. Casing running and cementing services are performed at the rig site to line the wellbore with steel pipe and secure it with cement, ensuring well integrity and zonal isolation (Gautam et al., 2022). Wireline services deploy tools and sensors on an electric cable for formation evaluation logging, perforation, and setting plugs. Slickline services use a non-electric solid wire for mechanical tasks like opening valves or retrieving equipment. Coiled tubing services use a continuous reel of flexible pipe to pump fluids for well cleanouts, stimulation, or milling obstructions. Well stimulation, such as hydraulic fracturing, involves pumping specialized fluids at high pressure to create or enhance flow paths in the reservoir, a large-scale operation conducted after drilling.

Business situation analysis was conducted to evaluate the strategic position of the drilling services company and identify the sources of investment uncertainty. Internally, the firm discussed on this study has a sustainable competitive advantage driven by its ownership of the largest onshore rig fleet in the region and its strategic affiliation with state owned companies, which secures a captive market and government support (Alarifi, Abdel Rahman, & Al-Ajmi, 2022). However, this is challenged by a complex external landscape characterized by rigid political mandates to meet national energy targets, economic exposure to fluctuating oil prices and production demand Afaha and Agbede (2025) and Agaton, Guno, Villanueva, and Villanueva (2020), also the urgent need to adapt to the global energy transition and technological improvements (E.-Z. Wang & Pan, 2025). While the company maintains strong operational legitimacy through adherence to legal and social standards, the rapid industry shift toward sustainability and digitalization creates significant pressure to align its capital-intensive investment strategy with these dynamic market forces.

Valuing large energy projects has traditionally relied on DCF analysis. While useful for estimating baseline profitability, this method has a major blind spot: it assumes a static future. In volatile industries like oil and gas, this rigidity often leads to undervaluing projects because it fails to account for a stakeholder's ability to adapt, such as delaying, expanding, or abandoning a project as market conditions change. To face this, ROV treats investment opportunities as strategic choices rather than fixed obligations. Empirical studies consistently show that this approach captures value that DCF misses. Tang, Zhou, Chen, Wang, and Cao (2017) used Real Options Analysis (ROA) to determine the optimal timing for overseas oil investments, and Giriarso and Hakam (2025) applied it to assess technology options in the geothermal sector.

Similarly, research by Oliveira, Couto, and Pimentel (2021) on infrastructure projects confirmed that valuing the option to expand significantly enhances a project's feasibility compared to static metrics. Methodologically, the field is moving toward hybrid approaches that combine discrete models with probability simulations. Chen, Wang, and Ye (2016) and Zheng, Wang, and Zhao (2025) successfully paired Binomial Lattices with Monte Carlo simulations to handle complex uncertainties in renewable energy. Building on this established foundation, this study applies these proven methodologies to the specific challenge of investing in drilling service fleets.

Although prior studies have shown that real options analysis is valuable in infrastructure, renewable energy, and upstream energy investments, evidence remains limited in oilfield drilling services, particularly in Indonesia's service-based oil and gas segment. This gap is important because drilling services investments are characterized by high irreversibility, contract-based revenue, and volatile demand. Under such conditions, a valuation approach that captures managerial flexibility may provide a more relevant basis for capital budgeting decisions than a static discounted cash flow model. Building on this argument, this study proposes the following hypotheses.

H_1: Real Options Valuation provides a higher and more decision-relevant investment value than Discounted Cash Flow under uncertainty.

H_2: The option to expand increases total investment value and can change an initially negative static investment decision into a positive strategic investment decision.

Table 1. Previous research of real options valuation

No	References	Industry	Country	ROV Model	Research Scenario & Options Analysis
1	Agaton et al. (2020)	Renewable Energy	Philippines	Discrete	Investment in WtE technology as a landfill alternative; comparison between deferring the investment or continuing to use landfill.
2	Balliauw (2021)	Transportation	Not specified	Dynamic Programming	Port capacity expansion under uncertainty.
3	Chen et al. (2016)	Carbon Capture	China	Stochastic	Coal plant retrofitting investment for Carbon Capture & Storage.
4	Giriarso and Hakam (2025)	Renewable Energy	Indonesia	Binomial Lattice	Geothermal investment feasibility considering technology selection and carbon credit.
5	Gustino, Hakam, and Prasetio (2025)	Refinery & Petrochemical	Indonesia	Binomial Lattice	Immediate construction vs. a two-year deferral for an integrated refinery.
6	Hakam and Saraswani (2025)	Carbon Capture	Indonesia	Binomial Lattice	Carbon Capture & Storage investment in Indonesia's reservoir under energy transition & government incentives.
7	Hwang and Kim (2025)	Renewable Energy	Korea	Stochastic	Floating hydropower investment under market and policy uncertainty in Korea.
8	Kim, Park, and Kim (2017)	Renewable Energy	Indonesia	Binomial Lattice	Hydropower plant expansion in Indonesia.

9	Lazo, Baute, and Watts (2025)	Renewable Energy	Not specified	Binomial Lattice	Optimal timing for converting agricultural land to a solar PV plant.
10	Moon and Lee (2025)	Renewable Energy	Not specified	Quadrinomial Lattice	Investment in a natural hydrogen project with/without subsidy.
11	Oliveira et al. (2021)	Infrastructure	Portugal	Binomial Lattice	Expansion in Ponta Delgada Airport for tourism improvement.
12	Or, Bilgin, Akcay, Dikmen, and Birgonul (2024)	Renewable Energy	Turkey	Least-Square Monte Carlo	Investment feasibility of photovoltaic.
13	Tang et al. (2017)	Oil & Gas	Kazakhstan	Binomial Lattice	Investment opportunity analysis in China’s overseas project.
14	Tautorat, Iversen, Schmidt, and Steffen (2025)	Chemical	Switzerland	Dynamic Programming	Decarbonization investment pathways for a representative chemical plant.
15	Yue and Ying (2021)	Transportation	Not specified	Black–Scholes; Binomial Lattice	Investment in new desulfurization equipment; comparison of short-term and long-term valuation.
16	Zheng et al. (2025)	Renewable Energy	China	Least-Square Monte Carlo	Investment feasibility of offshore photovoltaic.

Conceptual framework of this study is built based on the previous research done in analysing investment strategy and decision-making using ROA. This study establishes a framework grounded in the recognition that traditional valuation methods often fail to capture the strategic value of flexibility in high-risk environments. By integrating traditional valuation theory with Real Options Theory, the framework addresses the critical interplay between market uncertainty and investment irreversibility, which serves as the foundation for valuing managerial adaptability.

The methodological process advances sequentially from a static DCF baseline to Monte Carlo simulations, which quantify the volatility required to populate the Real Options Analysis (ROA) models. This comprehensive approach not only calculates the expanded value of the project but also synthesizes these findings into a strategic narrative, allowing management to weigh the downside risks against the upside potential of adaptive investment decisions.

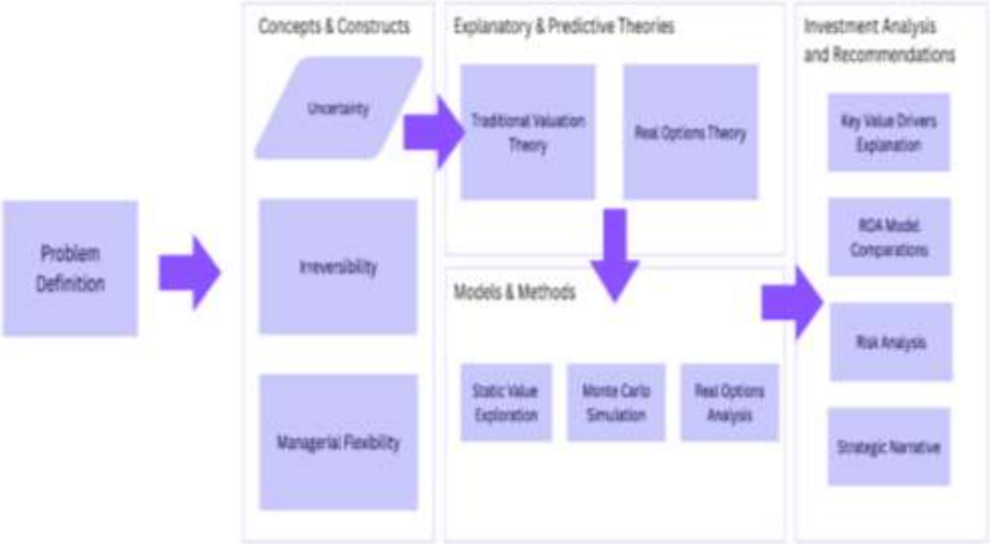

Figure 1. Conceptual framework

3. METHODOLOGY

This study uses a sequential valuation design. First, Discounted Cash Flow (DCF) is employed to estimate the project's baseline feasibility under low, base, and high demand scenarios. Second, Monte Carlo simulation is used to estimate the volatility of annual well demand, which serves as a key input for real options pricing. Third, Real Options Valuation (ROV) is applied through the Binomial Lattice Model and the Black–Scholes Model to quantify the value of managerial flexibility, especially the option to expand. In this study, Monte Carlo simulation is not used as a stand-alone decision model, but as a tool to generate the uncertainty parameter required for the real options analysis. The role of Monte Carlo simulation in this study is limited but important. It is used to model possible future paths of well demand and to estimate project volatility. That volatility is then incorporated into the real options models. This approach helps avoid relying on a single deterministic demand forecast and makes the valuation more consistent with the uncertain nature of drilling service demand.

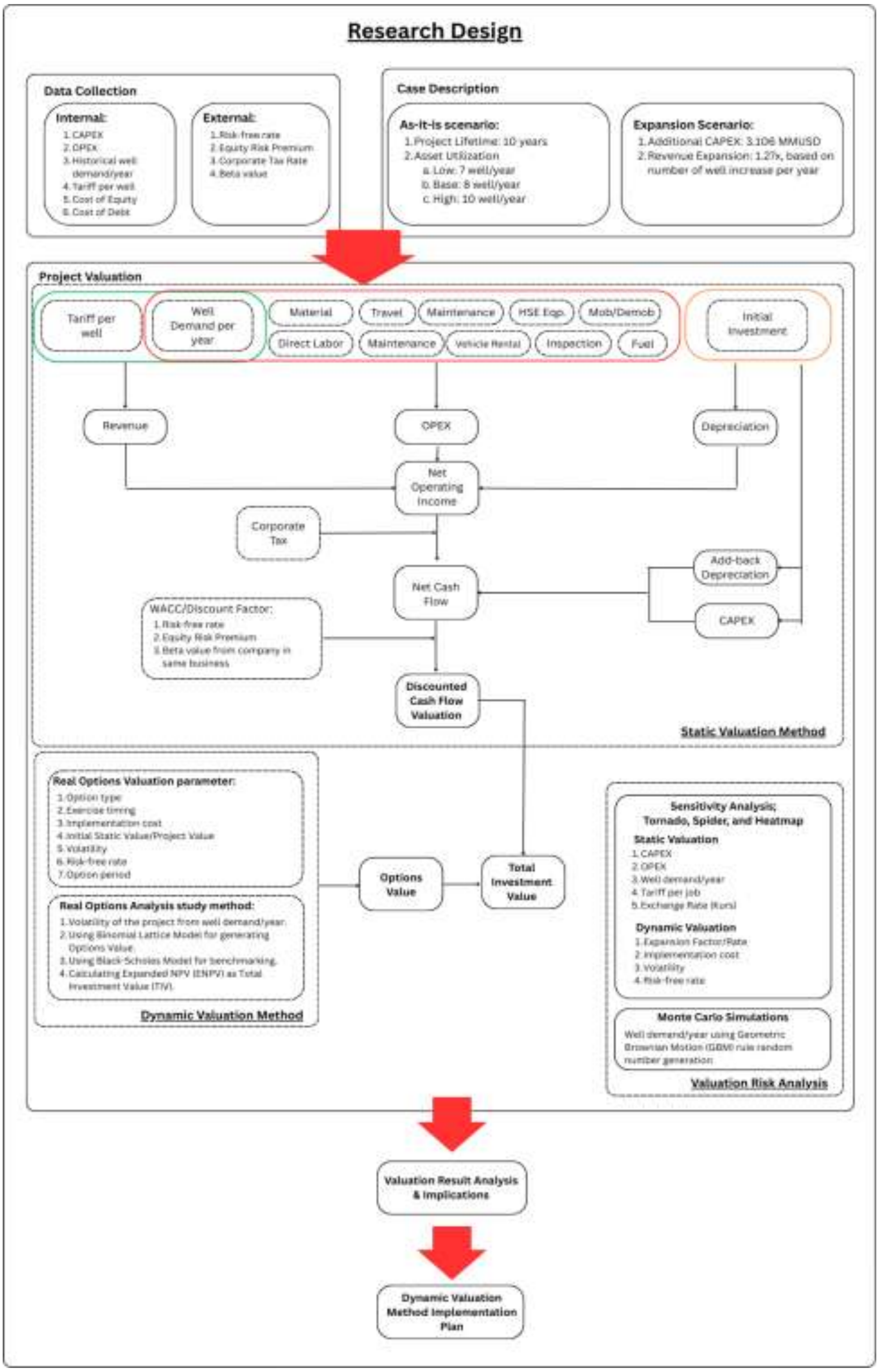

Figure 2. Research design of the study

The core analysis employs a multi-stage quantitative approach by using DCF analysis to establish a baseline value, and ROA to measure the strategic value of managerial flexibility. DCF analysis are conducted with the following steps. Where CF_t denotes as a cash flow in the period t, r represents discount factor/hurdle rate and I represent Initial Investment. Investment acceptance occurs when the NPV is positive. The discount factor/hurdle rate used are the Weighted Average Cost of Capital (WACC) of the drilling services companies.

$$NPV = \sum\nolimits_{t=0}^{n} \frac{CF_t}{(1-r)^t} - I \qquad (1)$$

Generating WACC was done by calculated by multiplying the cost of each capital component (debt and equity) by its proportional weight in the company's total capital structure, and then summing the results. WACC calculation is expressed with the equation below, where E is Company's Equity, D is Company's Debt, R_e is Company's Cost of Equity, R_d is Company's Cost of Debt, V is Total Value of the Firm, and T_c is Corporate Tax Rate. The Cost of Equity is calculated using the Capital Asset Pricing Model (CAPM). Cost of Debt and Cost of Equity are calculated using the Capital Asset Pricing Model (CAPM) expressed as below, where R_f is Risk-Free Rate, β is a mease of the project's/company's volatility relative to the overall market, and R_m is Expected Market Return.

$$WACC = \left(\frac{E}{V}\right) R_e + \left(\frac{D}{V}\right) R_d (1 - T_c) \qquad (2)$$

$$R_d = \frac{Interest\ Expense}{Average\ Interest - Bearing\ Debt} \qquad (3)$$

$$R_e = R_f + \beta(R_m - R_f) \qquad (4)$$

The research concludes by translating these quantitative results into practical recommendations for investment strategy. Recognizing the high uncertainty inherent in drilling operations, the study then advances to Monte Carlo Simulations to stress-test the project's financial resilience. By running 1,000 iterations based on the Geometric Brownian Motion (GBM) rule for annual well demand, this step quantifies the project's volatility (σ). Instead of relying on a single forecast, this stochastic approach generates a distribution of possible outcomes, providing a robust measure of risk that feeds directly into the option pricing models. For well demand generation, GBM follows the formula as expressed below, where dS_t^{well} is the well demand at *t* time, μ is the yearly drift rate, σ is the yearly volatility of the well demand/year, and dW_t is the increment of a standard Wiener process.

$$dS_t^{well} = \mu S_t^{well} dt + \sigma S_t^{well} dW_t \qquad (5)$$

Following the GBM rule, historical well demand/year are converted into lognormal value to determine the mean log return which serves as the fundamental input for generating random future demand paths in the Monte Carlo simulation, then continued by generating μ and σ using the following expression, where dS_{t+1}^{well} is the well demand at *t+1* time and $\bar{r}$ is mean log return of the well demand.

$$\mu = \frac{1}{n} \sum_{t=1}^{n} \ln\left(\frac{dS_{t+1}^{well}}{dS_t^{well}}\right) \qquad (6)$$

$$\sigma = \sqrt{\frac{1}{n-1} \sum_{t=1}^{n} \left(\ln\left(\frac{dS_{t+1}^{well}}{dS_t^{well}}\right) - \bar{r}\right)^2} \qquad (7)$$

To generate the random well count for Monte Carlo Simulation in discrete-time simulations, Or et al. (2024) and Balliauw (2021) use the following equation as a random number generation baseline for well demand/year, where S_t is the well count on the year t, and Z is a Standard Normal Random Variable that changes every time when simulation happens. The simulation employs GBM to model future well demand because its mathematical structure ensures non-negative outcomes, aligning with the physical reality that job counts cannot fall below zero. Furthermore, GBM accurately captures the compounding σ and μ by modelling changes as percentage returns rather than fixed increments, a method rigorously supported in Real Options literature for quantifying uncertain project parameters.

$$S_{t+1} = S_t \times e^{\left(\mu - \frac{1}{2}\sigma^2\right)\Delta t + \sigma\sqrt{\Delta t}Z} \tag{8}$$

Two ROA methods are used in this project as a comparison, the Binomial Tree Model and Black-Scholes Model.

3.1 Binomial Tree Model

Binomial Tree Model is an option valuation method that maps out potential future value paths in a step-by-step, discrete manner (Yue & Ying, 2021). Binomial Tree Model simulating the present value of the project of the underlying asset with certain time step, defined as Δt, by dividing the total period of the option in years (T) and number of discrete time steps in the tree (n) as expressed below.

$$\Delta t = \frac{T}{n} \tag{9}$$

The fluctuating movements are represented by the factors *u* and *d*. Both of the factor's generation are calculated using the expression below, Where *u* is the up-factor of the Binomial Tree Model and σ is the annual uncertainty of the project's value.

$$u = e^{\sigma\sqrt{\Delta t}} \tag{10}$$

$$d = \frac{1}{u} \tag{11}$$

The first-time step of the Binomial Tree Model contains two decision result possibilities defined with a node that shows the value of the investment project at the end of the period, either it goes up (S_0u) or down (S_0d), then the number increase of the nodes is following the binomial expansion with the probability as expressed in the formula below.

$$S_{next} = S_{current} \times u \text{ or } S_{next} = S_{current} \times d \tag{12}$$

$$p = \frac{e^{r_f \Delta t} - d}{u - d} \tag{13}$$

The valuation of Binomial Tree Model starts from the last period of the project then working backward to the first period of the project. For the final nodes, the value is expressed with the formula below, Where $V_{Year\ n}$ is the option value at the last period of the project, $S_{Year\ Last}$ is the project value at the last period of the project, and *X* is the cost (or cash received) to exercise an option (Exercise Price).

$$V_{Year\ Last} = max(S_{Year\ Last}, X) \tag{14}$$

$$V_{Current} = \left[p \times V_{up} + (1 - p) \times V_{down}\right] \times e^{-r_f \Delta t} \tag{15}$$

3.2 Black-Scholes Model

Black-Scholes Model is a mathematical formula used to find the theoretical price of financial options. In context of Real Options Analysis, Black-Scholes Model is adapted to evaluate investment projects by treating them as a type of "call option" (Yue & Ying, 2021). The formula for Black-Scholes Model is analogous to an Option to Defer an investment as expressed below, where *C* is a Call Option Value generated (the value of project's strategic flexibility), S_o is the Static NPV of the project, *X* is the Exercise Price, *T* is the period of deferring the investment (Time to Expiration), σ is the uncertainty of the project's cash flow, $N(d_1)$ and $N(d_2)$ are standard normal cumulative distribution functions.

$$C = S_0N(d_1) - Xe^{-rT}N(d_2) \tag{16}$$

The two models follow the same rule for the investment decision based on the options value generated compared with the static value at the period of options generated Yue and Ying (2021) as shown on the Table 1.

Table 2. Decision rule under real options valuation

Deterministic Valuation	**Investment Value after Real Options Valuation**	**Decision**
NPV < 0	TIV > 0	Executing the options to expand the investment
NPV < 0	TIV ≤ 0	Abandon the investment
NPV ≥ 0	TIV ≥ NPV	Executing the options to continue the investment
NPV ≥ 0	TIV < NPV	Executing the options to defer the investment

4. RESULT AND DISCUSSIONS

The project chosen as a study case is investing in 1 (one) non-rig drilling fleet, with the lifetime duration is 10 years and the project duration is set based on the typical contract duration in the client's field (5 years). The scenario considers the fluctuations in well demand/year in client's field. The study evaluates three scenarios derived based on the number of the well demand/year in the client field (Low, Base, and High case). Revenue structure in this project is built from two sources, namely Material Charge and Services Charge. Revenues are in MMUSD/well done in a job. Capital expenditures in this project are packaged within one set of equipment on one procurement process. The CAPEX on this project are tangible costs and will be depreciated. The CAPEX incurred in the first year of the project is USD 9.67 MMUSD in 2026 with the breakdown shown on the

Table

Table 3. Revenue structure breakdown of the project chosen

Charge Type	**Price (MMUSD/well)**
Material	0.346
Service	0.060
Total	0.406

Table 4. Capital expenditure breakdown of the project chosen

Equipment	**Price (MMUSD)**
Main Equipment	6.58
Auxiliary Equipment	1.20
Prime Mover Truck	0.65
Down Hole Tools	0.06
Treating Iron	1.07
Fleet Software	0.07
Total	9.67

OPEX on the project selected are divided into two types of cost, namely fixed cost that incurred per year, and variable cost that vary according to the annual number of jobs per year. OPEX are escalated per year based on the inflation per year. Details of the OPEX breakdown are shown below.

Table 5. Operational expenditure drawdown of the project chosen

Operation Expenditure	**Fixed Costs (MMUSD/year)**	**Variable Costs (MMUSD/year)**
Material	-	0.5070
Direct Labor	0.033	0.045
Employee Travel	-	0.001
Health & Safety Equipment	0.007	-
Maintenance	0.068	-
Inspection & Certification	0.011	-
Mobilization & Demobilization	-	0.161
Fuel	-	0.034
Vehicle Rental	0.040	-
Percentage (%)	17.60%	82.40%
Total (MMUSD/year)	0.160	0.751
Grand Total (MMUSD/year)		0.911

The fleet job profile on this project is determined based on the number of wells serviced as one job and charged based on the price agreement in the provision contract between the client and contractor. The total job needed for the fleet on the client's oil/gas field is divided by another drilling services' fleet on the same field, resulting in the number of jobs potentially secured within one year. The assumed job secured for the 2026 onwards are generated based on the percentile of the total jobs realized between 2022 – 2026. The percentile of the well/year then used as a Low, Base, and High scenario based on the 10%, 50%, and 90% percentile, respectively as shown in

Table

Table 6. Historical well/year realization and forecast from 2022 - 2026

Year	**2022**	**2023**	**2024**	**2025**	**2026**	**Total**
Realized well/year	31	25	25	44	34	159

Table 7. Percentile breakdown of well/year for fleet utilization

Scenario	**Percentile**	**Percentile of well from 2022 – 2026**	**Total fleet on the field**	**Number of well/year, rounded up**
Low	10%	25 wells	4 fleets	7 wells/year
Base	50%	31 wells	4 fleets	8 wells/year
High	90%	40 wells	4 fleets	10 wells/year

WACC calculation used are derived from the inputs from risk-free rate (R_f), Equity Risk Premium Damodaran (2026), Corporate Tax Rate (T_c), β, and Cost of Capital of the OFS company discussed. Summary of the WACC calculation is shown in Table . Interest Expense and Average Debt are taken from the annual report of the OFS company discussed. WACC used on this study are 9.30%.

Table 8. WACC calculation

No.	**Parameter**	**Value**	**Description & Formula**
1	Risk-Free Rate (R_f)	6.18%	Derived from yield of the 10-year Indonesian government bond, Source: Damodaran (2026)
2	Equity Risk Premium	6.87%	Additional return required for market risk, Source: Damodaran (2026)
3	Corporate Tax Rate (T_c)	22%	Source: Damodaran (2026)

4	Beta	0.673	Based on the average β of OFS firm in Indonesia
5	Cost of Debt (R_d)	7.36%	Interest Expense: 10.13 MMUSD (from discussed OFS company's annual report) Average Debt: 137.72 MMUSD (from discussed OFS company's annual report Using Equation (3)
6	Cost of Equity (R_e)	10.80%	Using Equation (4)
7	WACC	9.30%	OFS company's E/V ratio = 70.41% OFS company's D/V ratio = 29.59% Proceed using Equation (2)

The volatility calculation was done by gathering the yearly historical and forecasted job drilling fleet from 2022 to 2026 as shown in Table 9. Using equations [6] and (7), the yearly drift rate and volatility are 0.023 and 0.3786.

Table 9. Yearly well demand drift and volatility calculation

Time	**Well Demand/year**	$\mathbf{ln}\left(\frac{dS_{t+1}^{well}}{dS_t^{well}}\right)$	$\left(dS_t^{well} - \bar{r}\right)^2$
2022	31		
2023	25	-0.215	0.057
2024	25	0	0.001
2025	44	0.565	0.294
2026	34	-0.258	0.079

After the inputs needed for DCF analysis are calculated, valuation of the project based on the three different scenarios are summarized in Table 2. As shown on the table, NPV on the low case resulting in negative value. In static valuation rule, discounted NPV below zero are not viable as an investment option.

Table 2 Discounted cash flow valuation summary

Scenario	**Low**	**Base**	**High**
Net Present Value (USD)	(713,435.38)	680,892.67	3,469,548.78
Internal Return of Rate (%)	7.68	11.41	18.50
Discounted Payback Period (years)	>10	8.65	5.93
Net Profit Margin (%)	-0.43	6.64	15.48

The result of the DCF analysis is further evaluated using the ROV. Real option analysis was conducted to evaluate the potential benefits of expanding the project or divesting the project, taking account the project's value expansion by two times for the next 5 year in the Year 6 to Year 10 if it is expanded. For Binomial Lattice Model, the 5-year period is set to match the project's duration and contract after renewal for the expansion. The time step of 1 year is set for annual assessment, resulting in a lattice framework divided into 5 steps following the option period. The Python programming language was used to generate the Options Value discussed.

For this study, the options discussed are the option to expand the investment project. The investment scenario option evaluation is set at the end of the contract period to determine whether the investment expansion until the end of the useful life is positive to the project's value. As an input for the valuation, the expansion factor of the valuation is set on 127% (1.27x) based on the value increase when the amount of well job done per year is substantially increased. The 5-year period is aimed to observe the investment feasibility based on the market condition after the contract ended.

With Δt of 1 year, the analysis was done in annual period, resulting in a binomial lattice framework branching into 5 steps following to the option period. The analysis incorporates key input parameters such as the NPV of the project and the implementation cost for expanding the project.

For the initial valuation, the core mathematical requirement of the Binomial and Black-Scholes models is that the underlying asset must follow a Geometric Brownian Motion (GBM), which assumes asset values cannot be negative Giriarso and Hakam (2025) and Or et al. (2024), this principle is violated when the Net Present Value (NPV) is negative, as applying the multiplicative up-factor (u) to a negative NPV results in an even larger negative number, signifying that favourable market conditions worsen the project's financial outlook. To resolve this, ROV mandates that the volatility must be applied only to the Asset Value presented as a GPV for determining the Static Value (S_0). This value is inherently positive and represents the intrinsic worth of the asset before the initial investment is factored in. The CAPEX is thus correctly identified as the fixed Strike Price of the option, and the NPV is recognized as merely the net payoff. By building the stochastic tree based on the GPV, the model maintains theoretical integrity, allowing it to accurately calculate the value of managerial flexibility required to overcome a negative Static NPV and justify a go or no-go investment decision (Chen et al., 2016; Kim et al., 2017).

Summarized result of the ROA are shown in Table . For the low base, the TIV is USD 123,721.09 elevating the project's NPV from USD (713,435.38). For the base case, the TIV is USD 1,817,808.47 elevating the project's NPV from USD 680,892.67. Similarly, for the high case, the TIV is USD 5,205,983.21 elevating the project's NPV from USD 3,469,548.78. Derived from the decision rule of real options valuation in Table , low case scenario meets the criteria of NPV < 0 and TIV ≥ 0, and for the base case and high case meets the criteria of NPV > 0 and TIV > NPV. As a result, based on the decision rule criteria, the Options to Expand can be executed on all scenarios provided.

The DCF results provide the first-stage investment decision because they reflect the project's baseline feasibility without managerial flexibility. Under this static rule, the low scenario leads to a No-Go decision because the NPV is negative (USD -713,435.38), indicating that the project is unable to recover its initial investment at the required rate of return. In contrast, the base and high scenarios lead to Go decisions because both produce positive NPVs of USD 680,892.67 and USD 3,469,548.78, respectively. These positive values indicate that the expected operating cash inflows are sufficient to cover the investment cost and create additional value. Therefore, under DCF, the decision is highly dependent on the demand scenario and does not yet consider the strategic value of future managerial actions.

Table 11. Real options analysis (binomial lattice model) summary

Scenario	NPV (USD)	Options Value (USD)	Total Investment Value (USD)
Low	(713,435.38)	837,156.47	123,721.09
Base	680,892.67	1,136,916	1,817,808.47
High	3,469,548.78	1,736,434.43	5,205,983.21

					49,886,024
				31,110,035	
			18,251,871		18,251,871
		9,446,350		9,446,350	
	3,416,158		3,416,158		3,416,158
(713,435)		(713,435)		(713,435)	
	(3,541,461)		(3,541,461)		(3,541,461)
		(5,478,148)		(5,478,148)	
			(6,804,429)		(6,804,429)
				(7,712,692)	
					(8,334,689)
2026	2027	2028	2029	2030	2031

Figure 2. Binomial tree model for low case

					59,143,326
				37,449,615	
			22,593,340		22,593,340
		12,419,472		12,419,472	
	5,452,210		5,452,210		5,452,210
680,893		680,893		680,893	
	(2,586,598)		(2,586,598)		(2,586,598)
		(4,824,239)		(4,824,239)	
			(6,356,620)		(6,356,620)
				(7,406,024)	
					(8,124,676)
2026	2027	2028	2029	2030	2031

Figure 4. Binomial tree model for base case

					77,657,928
				50,128,776	
			31,276,276		31,276,276
		18,365,716		18,365,716	
	9,524,314		9,524,314		9,524,314
3,469,549		3,469,549		3,469,549	
	(676,872)		(676,872)		(676,872)
		(3,516,442)		(3,516,442)	
			(5,461,001)		(5,461,001)
				(6,792,686)	
					(7,704,651)
2026	2027	2028	2029	2030	2031

Figure 5. Binomial tree model for high case

With Black-Scholes Model, the inputs used are the same as on the Binomial Lattice Model. With equation (16), the TIV generated for the low case is USD 130,603.50 elevating the project's NPV from USD (713,435). For the base case, the TIV is USD 1,795,803.16 elevating the project's NPV from USD 680,893.00. Similarly, for the high case, the TIV is USD 5,179,829.49 elevating the project's NPV from USD 3,469,549.00.

Table 12. Real options analysis (black-scholes model) summary

Scenario	NPV (USD)	Options Value (USD)	Total Investment Value (USD)
Low	(713,435.38)	844,038.88	130,603.50
Base	680,892.67	1,114,910.49	1,795,803.16
High	3,469,548.78	1,710,280.71	5,179,829.49

The TIV generated from both of Binomial Lattice Model and Black-Scholes has a small margin difference with the difference of TIV from the result of Binomial Lattice in Low, Base, and High scenario are 5.56%, 1.21%, and 0.50%. The generation of TIV estimates derived from the Binomial Lattice Model and the Black-Scholes Model simultaneously provides rigorous validation for the robustness of the valuation. In the context of real options analysis, utilizing complementary mathematical frameworks to arrive at similar valuations serves as a critical cross-verification of the results, confirming that the outputs are not artifacts of a specific model's computational logic. Giriarso and Hakam (2025) demonstrated in their feasibility study of geothermal investments that comparable value estimates from both Black-Scholes and Binomial Lattice models reinforce the reliability of the Expanded Net Present Value (ENPV) and the underlying volatility assumptions (Bazyar & Abbasi, 2025). Furthermore, the alignment of these results suggests that the premium for early exercise, which is captured by the Binomial model but not the Black-Scholes, is negligible in this specific context.

Sensitivity analysis was conducted using Tornado Diagram by applying the ± 10% variation to each variable, since the scenario selection are based on one parameter, the sensitivity analysis is applicable on each scenario. Based on the tornado chart provided on Giriarso and Hakam (2025), "Tarif per job" held as a most influential parameter affecting the project's net value, followed by the number of well demand/year as the second impactful parameter to the project. It aligns with the project's dependency to the tariff's pricing and well demand in the client's oilfield, making the project's financial performance highly sensitive to the fluctuation of the job demand and pricing. CAPEX, "Kurs" (exchange rate) and OPEX also affect the project's financial performance on the significant margin.

Sensitivity analysis of TIV from the ROV Analysis was conducted with the different parameter evaluation. Based on the graph shown on Figure , the Expansion Factor is the most influential parameter affecting the project's option value, followed by the expansion cost of the project based on the option discussed. It aligns with the sensitivity analysis of NPV since the expansion factor is determined by the increase of job/well done.

The investment decision becomes more nuanced when evaluated using ROV. In the low scenario, the project changes from No-Go under DCF to conditional Go under ROV because the option to expand generates sufficient strategic value to turn the negative NPV into a positive TIV. This means that, although the project is not attractive as a fixed one-stage investment, it becomes acceptable when management retains the flexibility to expand after observing more favorable market conditions. In the base and high scenarios, the decision remains Go, but for a stronger reason: the projects are not only feasible in their static form, but also gain additional value from flexibility, as reflected by TIV values that exceed their respective NPVs. Thus, ROV does not merely confirm feasibility; it explains why managerial flexibility strengthens the investment case and can overturn a rejection decision in the low-demand scenario.

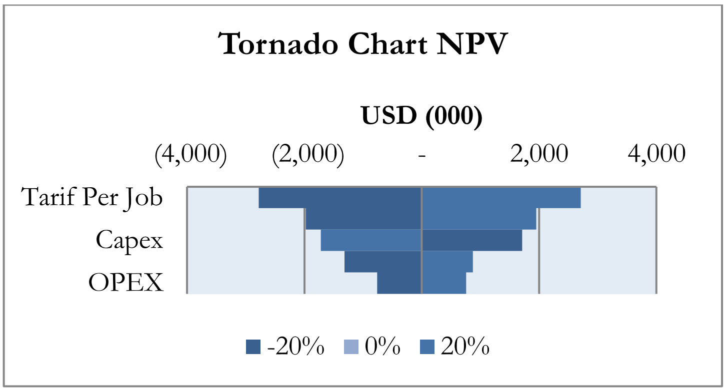

Figure 6. Sensitivity analysis of NPV

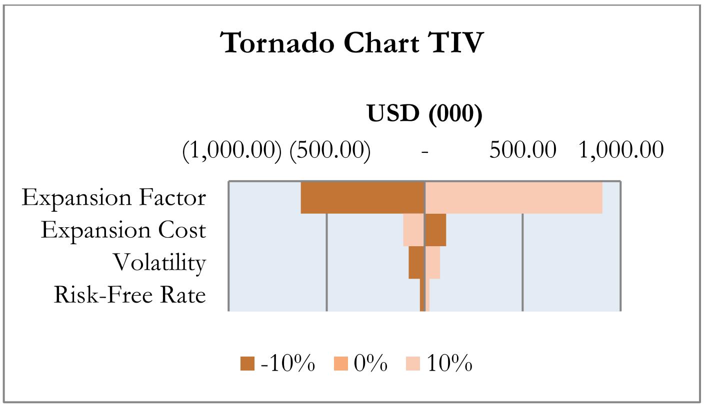

Figure 7. Sensitivity analysis of TIV

Monte Carlo simulation further refines the interpretation of these decisions by showing that a positive TIV does not eliminate downside risk. The probability of negative TIV remains 38.60% in the low scenario, 27.60% in the base scenario, and 21.00% in the high scenario. This indicates that the low scenario should not be interpreted as an unconditional Go, but rather as a strategic Go with higher risk exposure, appropriate only if management has sufficient risk tolerance and the capability to monitor demand signals before exercising the expansion option. By comparison, the base and high scenarios support a more confident Go decision because both their static and strategic values are positive, while their downside probabilities are materially lower..

Table 3 Monte carlo simulation summary

Scenario	**Low**	**Base**	**High**
Total Investment Value (USD)	123,721.09	1,795,803.16	5,179,829.49
Cumulative Negative TIV Probability (%)	38.60	27.60	21.00

Table 4 Monte Carlo simulation result

Low Case			**Base Case**			**High Case**		
Bin	***Frequency***	***Cumulative***	***Bin***	***Frequency***	***Cumulative***	***Bin***	***Frequency***	***Cumulative***
(13,602,018)	1	0.10%	(11,907,931)	6	0.60%	(11,264,904)	15	1.50%
(9,882,786)	10	1.10%	(7,657,379)	43	4.90%	(6,305,927)	39	5.40%
(8,023,169)	69	8.00%	(5,532,104)	78	12.70%	(3,826,439)	58	11.20%
(4,303,937)	128	20.80%	(3,406,828)	149	27.60%	(1,346,950)	98	21.00%
(2,444,320)	178	38.60%	843,724	140	41.60%	1,132,538	95	30.50%
1,274,912	164	55.00%	2,969,000	140	55.60%	3,612,026	139	44.40%
3,134,528	141	69.10%	5,094,275	96	65.20%	6,091,515	109	55.30%
6,853,761	111	80.20%	9,344,827	110	76.20%	8,571,003	95	64.80%
8,713,377	57	85.90%	11,470,103	85	84.70%	11,050,492	81	72.90%
12,432,610	48	90.70%	13,595,378	51	89.80%	13,529,980	71	80.00%
14,292,226	33	94.00%	15,720,654	34	93.20%	18,488,957	44	84.40%
18,011,459	16	95.60%	19,971,206	22	95.40%	20,968,445	31	87.50%
19,871,075	15	97.10%	22,096,482	18	97.20%	23,447,934	38	91.30%
23,590,308	9	98.00%	24,221,757	5	97.70%	25,927,422	24	93.70%
25,449,924	7	98.70%	28,472,309	5	98.20%	28,406,911	14	95.10%
29,169,157	2	98.90%	30,597,585	6	98.80%	30,886,399	16	96.70%
31,028,773	3	99.20%	32,722,861	2	99.00%	33,365,887	11	97.80%
34,748,006	2	99.40%	34,848,136	4	99.40%	35,845,376	6	98.40%
36,607,622	4	99.80%	39,098,688	3	99.70%	38,324,864	7	99.10%
40,326,855	1	99.90%	47,599,791	2	99.90%	43,283,841	2	99.30%
More	1	100.00%	More	1	100.00%	45,763,330	3	99.60%
						48,242,818	1	99.70%
						50,722,306	1	99.80%
						63,119,748	1	99.90%
						More	1	100.00%

Based on the valuation results using NPV, the Low scenario yields an NPV below zero. When interpreted as a static value, the project is not feasible to execute. However, the ROV analysis demonstrates that by accounting for the probability of expansion value through additional CAPEX in Year 5, the TIV exceeds zero. This indicates that the expansion factor by spending the additional cost with market and demand volatility inherent in the project can generate greater value if an expansion is executed during the project evaluation year.

The stochastic analysis using Monte Carlo Simulations and the sensitivity analysis for TIV indicate that the probability of a negative TIV is driven by the sensitivity of the expansion factor, which is derived from the estimated changes in annual well demand based on the GBM rule. To mitigate risks associated with fluctuations in annual well demand, the firm must evaluate the risk factors influencing demand volume by identifying risk indicators, particularly during the investment approval phase and extending through the contract approval process with clients.

Consequently, in the Low scenario, an investment incorporating the Option to Expand in Year 5 may be strategically pursued, if the firm possesses a sufficiently aggressive risk appetite. For the Base and High scenarios, immediate investment is justified, as both the static value (NPV) and strategic value (TIV) yield positive results, regardless of whether the project is executed in its initial scope or if expansion is undertaken in Year 5, subject to favorable market conditions.

5. CONCLUSIONS

5.1 Conclusion

The primary source of uncertainty for OFS company’s investment performance was identified as the fluctuation in well demand per year, calculated with a volatility of 37.86%. This volatility significantly impacts the project's revenue stream, rendering traditional static forecasting insufficient for capturing the true risk-reward profile of the investment.

The DCF results show that project feasibility is highly scenario dependent. The base and high scenarios yield positive NPVs of approximately USD 0.68 million and USD 3.47 million, respectively, while the low scenario yields a negative NPV of approximately USD (0.71) million. If management relies on DCF alone, the low scenario leads to project rejection.

The ROV results show that managerial flexibility adds measurable value to the project. By incorporating the option to expand in Year 5, the TIV becomes positive across all scenarios, including the low case. The similarity of the Binomial and Black-Scholes outputs further supports the robustness of this conclusion.

The comprehensive valuation justifies a "Go" decision for the investment. The project is robustly feasible in Base and High scenarios. In the Low scenario, it remains strategically viable due to the option value, provided that the discussed OFS company maintains the readiness to execute expansion if market signals improve.

Practical Implications for managers in oilfield drilling services, the findings indicate that capital budgeting should distinguish between baseline feasibility and strategic flexibility. DCF remains useful for initial screening, but ROV is more informative when demand is volatile, investment is irreversible, and management retains the ability to expand later. This logic may also apply to other capital-intensive service industries such as mining services, marine logistics, heavy equipment leasing, power infrastructure services, and industrial contracting.

5.2 Research Limitations

Black-Scholes This study has several limitations. First, the analysis is based on a single Indonesian state-owned oilfield services (OFS) company and one investment case (a single non-rig drilling fleet), which limits generalizability to other asset types, contracting regimes, and private contractors. Second, uncertainty is modeled primarily through annual well demand using a Geometric Brownian Motion (GBM) process calibrated from a relatively short historical window (2022-2026) and 1,000 Monte Carlo paths; this may not fully capture structural breaks, policy shocks, or fat-tailed outcomes typical in oil and gas cycles. Third, key commercial and operational drivers such as tariff renegotiation, exchange-rate exposure, procurement lead time, and contract execution risk are treated as deterministic inputs or sensitivity shocks rather than jointly stochastic and correlated, which can understate downside risk. Finally, the expansion factor (1.27x) and expansion cost reflect case-specific assumptions; different scaling realities could materially change the option value and the preferred strategy.

5.3 Suggestions and Directions for Future Research

Future research can strengthen and extend this framework in several directions. First, researchers can model multi-factor uncertainty by jointly simulating well demand, service tariffs/day-rates, OPEX inflation, CAPEX, exchange rates, and oil prices with empirically calibrated correlations, then valuing flexibility using methods such as Least-Squares Monte Carlo or dynamic programming. Second, studies can evaluate a richer set of managerial options (defer, stage, contract, switch, abandon, and portfolio rebalancing) and compare optimal policies across asset classes (rig and non-rig) and multi-field portfolios. Third, extending the dataset (longer demand histories and multiple client fields) and testing alternative stochastic processes (e.g., mean-reversion and regime-switching) would improve robustness. Finally, ex-post validation using realized project outcomes and decision records would help quantify how real options adoption changes capital budgeting quality and CAPEX absorption in practice.

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AUTHOR CONTRIBUTIONS

The authors contributed equally to the research process. MRM was responsible for the conceptualization, methodology development, data collection, formal analysis, interpretation of findings, manuscript preparation, and final revision. OYS assisted with methodology refinement, data analysis, and manuscript revisions. Both authors collaborated on the integration of Real Options Valuation (ROV) with the firm's capital budgeting process and contributed to the interpretation of the results and recommendations for investment strategy.

REFERENCES

Afaha, J. S., & Agbede, S. A. (2025). Energy consumption, prices and economic growth in Nigeria: Autoregressive distributed lag model analysis. *Annals of Management and Organization Research, 6*(4), 385-404. doi:https://doi.org/10.35912/amor.v6i4.2191

Agaton, C. B., Guno, C. S., Villanueva, R. O., & Villanueva, R. O. (2020). Economic analysis of waste-to-energy investment in the Philippines: A real options approach. *Applied Energy, 275*, 115265. doi:https://doi.org/10.1016/j.apenergy.2020.115265

Alarifi, S., Abdel Rahman, S., & Al-Ajmi, M. (2022). Feasibility study formulation for the applicability of rigless temporary ESPs. *Journal of Petroleum Exploration and Production Technology, 12*(9), 2493-2509. doi:https://doi.org/10.1007/s13202-022-01499-w

Ali, M., Jarni, H. H., Aftab, A., Ismail, A. R., Saady, N. M. C., Sahito, M. F., Sarmadivaleh, M. (2020). Nanomaterial-based drilling fluids for exploitation of unconventional reservoirs: a review. *Energies, 13*(13), 3417. doi:https://doi.org/10.3390/en13133417

Bako, P. M. (2024). Audit committee attributes, audit quality and performance of oil and gas companies. *International Journal of Financial, Accounting, and Management, 5*(4), 525-536. doi:https://doi.org/10.35912/ijfam.v5i4.1634

Balliauw, M. (2021). Time to build: A real options analysis of port capacity expansion investments under uncertainty. *Research in Transportation Economics, 90*, 100929. doi:https://doi.org/10.1016/j.retrec.2020.100929

Bazyar, A., & Abbasi, M. (2025). Optimum estimation and forecasting of gasoline consumption in Iran's national oil refining and distribution company. *International Journal of Financial, Accounting, and Management, 6*(4), 509-524. doi:https://doi.org/10.35912/ijfam.v6i4.2492

Cai, Z.-W., Zhao, R.-L., Huang, Z.-M., Qiao, Y.-P., Yue, Q.-Y., Li, C.-L., Wen, H. (2025). Research on the Development Trends of Measurement While Drilling (MWD) Technology in Oil and Gas Drilling. *Petroleum Science*. doi:https://doi.org/10.1016/j.petsci.2025.12.013

Chen, H., Wang, C., & Ye, M. (2016). An uncertainty analysis of subsidy for carbon capture and storage (CCS) retrofitting investment in China's coal power plants using a real-options approach. *Journal of Cleaner Production, 137*, 200-212. doi:https://doi.org/10.1016/j.jclepro.2016.07.074

Damanik, S. D., Prasetyo, G., Alie, M. S., & Oktaria, E. T. (2025). MSME Financial Management: Cash Flow Management Strategies to Enhance Business Sustainability. *Jurnal Relevansi: Ekonomi, Manajemen dan Bisnis, 9*(1), 115-125. doi:https://doi.org/10.61401/relevansi.v9i1.271

Damodaran, A. (2026). Country Default Spreads and Risk Premiums. Retrieved from https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html

Firman, M. S. K., & Khudri, T. M. Y. (2025). Analysis of the internal control system in gas stations. *International Journal of Financial, Accounting, and Management, 6*(4), 477-493. doi:https://doi.org/10.35912/ijfam.v6i4.2186

Gautam, S., Guria, C., & Rajak, V. K. (2022). A state of the art review on the performance of high-pressure and high-temperature drilling fluids: Towards understanding the structure-property relationship of drilling fluid additives. *Journal of Petroleum Science and Engineering, 213*, 110318. doi:https://doi.org/10.1016/j.petrol.2022.110318

Giriarso, J. P., & Hakam, D. F. (2025). Real options valuation for geothermal investments considering technology selection and carbon credit: A feasibility study in Indonesia. *Sustainable Energy Technologies and Assessments, 83*, 104557. doi:https://doi.org/10.1016/j.seta.2025.104557

Gustino, R., Hakam, D. F., & Prasetio, E. A. (2025). Real options valuation for refinery and petrochemical investments: A feasibility study in Indonesia. *Energy Reports, 13*, 1321-1331. doi:https://doi.org/10.1016/j.egyr.2025.01.007

Hakam, D. F., & Saraswani, R. (2025). Sustainable Carbon Capture and Storage (CCS) Investments in Oil and Gas: Real Options Analysis Under Energy Transition and Government Incentives. *Greenhouse Gases: Science and Technology*, e2389. doi:https://doi.org/10.1002/ghg.2389

Hwang, S., & Kim, M.-K. (2025). Comprehensive techno-economic analysis of a floating offshore wind farm based on real options approach in the Korean power market. *Energy, 335*, 138114. doi:https://doi.org/10.1016/j.energy.2025.138114

Ikwuo, A. K., Nwite, I. M., Nworie, G. O., & Nworie, F. N. (2025). Shareholder value diminution through long-term debts: Evidence from the Nigerian oil industry. *Annals of Management and Organization Research, 6*(3), 271-285. doi:https://doi.org/10.35912/amor.v6i3.2628

Ilyas, M., Khan, A., Nadeem, M., & Suleman, M. T. (2021). Economic policy uncertainty, oil price shocks and corporate investment: Evidence from the oil industry. *Energy Economics, 97*, 105193. doi:https://doi.org/10.1016/j.eneco.2021.105193

Kemala, P. N., & Hakam, D. F. (2025). Optimizing final investment decision with real options valuation: A case study of offshore natural gas development project in Indonesia. *Energy, 316*, 134363. doi:https://doi.org/10.1016/j.energy.2025.134363

Kim, K., Park, H., & Kim, H. (2017). Real options analysis for renewable energy investment decisions in developing countries. *Renewable and Sustainable Energy Reviews, 75*, 918-926. doi:https://doi.org/10.1016/j.rser.2016.11.073

Lazo, J., Baute, E. T., & Watts, D. (2025). Real option approach to solar PV investment amid uncertainties and land opportunity costs. *Sustainable Futures, 10*, 101031. doi:https://doi.org/10.1016/j.sftr.2025.101031

Moon, S., & Lee, D.-J. (2025). Optimal investment strategy for natural hydrogen exploration and production considering dual price uncertainties: A real options approach. *Resources Policy, 109*, 105697. doi:https://doi.org/10.1016/j.resourpol.2025.105697

Oliveira, A., Couto, G., & Pimentel, P. (2021). Uncertainty and flexibility in infrastructure investments: Application of real options analysis to the Ponta Delgada airport expansion.

Research in Transportation Economics, 90, 100845. doi:https://doi.org/10.1016/j.retrec.2020.100845

Or, B., Bilgin, G., Akcay, E. C., Dikmen, I., & Birgonul, M. T. (2024). Real options valuation of photovoltaic investments: A case from Turkey. *Renewable and Sustainable Energy Reviews, 192*, 114200. doi:https://doi.org/10.1016/j.rser.2023.114200

Tang, B.-J., Zhou, H.-L., Chen, H., Wang, K., & Cao, H. (2017). Investment opportunity in China's overseas oil project: An empirical analysis based on real option approach. *Energy Policy, 105*, 17-26. doi:https://doi.org/10.1016/j.enpol.2017.02.023

Tautorat, P., Iversen, J., Schmidt, T. S., & Steffen, B. (2025). Real options analysis of decarbonization investments in the chemical industry. *Applied Energy, 397*, 126238. doi:https://doi.org/10.1016/j.apenergy.2025.126238

Wang, E.-Z., & Pan, T. (2025). Does ISO 50001 adoption reduce manufacturing energy intensity? Micro-evidence from China. *Economic Analysis and Policy, 86*, 653-672. doi:https://doi.org/10.1016/j.eap.2025.03.050

Wang, H., Huang, H., Bi, W., Ji, G., Zhou, B., & Zhuo, L. (2022). Deep and ultra-deep oil and gas well drilling technologies: Progress and prospect. *Natural Gas Industry B, 9*(2), 141-157. doi:https://doi.org/10.1016/j.ngib.2021.08.019

Yue, Y., & Ying, Y. (2021). Real option analysis for emission reduction investment under the sulfur emission control. *Sustainable Energy Technologies and Assessments, 45*, 101055. doi:https://doi.org/10.1016/j.seta.2021.101055

Zheng, H., Wang, X., & Zhao, X. (2025). Investment feasibility of offshore photovoltaics under multiple uncertainties: A real options approach. *Journal of Cleaner Production, 532*, 146949. doi:https://doi.org/10.1016/j.jclepro.2025.146949