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Investment Feasibility Analysis Of Automation Technology Using Real Options Approach And Monte Carlo Simulation

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ABSTRACT

Conventional Net Present Value (NPV) analysis often undervalues capital investments in automation technology by failing to capture the strategic flexibility embedded in investment decisions. This study applies an integrated framework combining Real Options Valuation (ROV) and Monte Carlo simulation to assess the investment feasibility of industrial automation technology in the Indonesian manufacturing context. Using a binomial lattice model with 50,000 Monte Carlo iterations, the analysis demonstrates that the strategic NPV—incorporating options to expand, defer, switch, and abandon—reaches IDR 9.55 billion, significantly exceeding the static NPV of IDR 2.38 billion. The probability of a positive NPV is 78.4%, with a 95% confidence interval of [−IDR 1.2 B, +IDR 12.8 B]. Sensitivity analysis identifies revenue growth rate and capital expenditure as the primary value drivers. The results provide a rigorous, risk-adjusted decision support framework for manufacturing investment planners operating under technological and market uncertainty.
Keywords: Real Options Valuation, Monte Carlo simulation, automation investment, NPV, binomial lattice, sensitivity analysis, sustainable manufacturing

Keywords: ***Automation Technology****;* *Real Options Valuation;* *manufacturing investment planners*

1. INTRODUCTION

> "The value of an investment opportunity is not just its expected cash flows discounted to the present—it includes the value of the choices available to management as uncertainty resolves over time."
>
> **— Dixit, A. K., & Pindyck, R. S. (1994). Investment under Uncertainty. Princeton University Press.**

Manufacturing firms across emerging economies face a critical decision: whether and when to invest in automation technologies that promise efficiency gains but require substantial capital outlays under conditions of deep uncertainty. Traditional discounted cash flow (DCF) methods, particularly Net Present Value analysis, treat investment decisions as now-or-never choices and apply a single discount rate to deterministic cash flow projections. This approach systematically undervalues investments that carry embedded managerial flexibility—the ability to expand, defer, contract, or abandon projects as market conditions evolve.

Indonesia's manufacturing sector, targeted under the Making Indonesia 4.0 national industry strategy, is experiencing intensifying pressure to upgrade automation capabilities. Yet the high capital intensity of automation—ranging from IDR 5 billion to IDR 25 billion for mid-scale robotic assembly systems—combined with volatile demand conditions, currency risk, and technology obsolescence, makes conventional NPV analysis an inadequate decision tool. A more sophisticated approach is required.

This study addresses this gap by applying an integrated Real Options Valuation (ROV) and Monte Carlo simulation framework to a representative automation investment scenario in Indonesian manufacturing. The Real Options approach, originating in financial options theory (Black & Scholes, 1973; Cox et al., 1979), treats investment decisions as analogous to financial call options—capturing the value of managerial flexibility explicitly. Monte Carlo simulation complements ROV by quantifying the full probability distribution of investment outcomes across thousands of simulated scenarios, enabling robust risk quantification beyond point estimates.

2. THEORETICAL FRAMEWORK

2.1 Limitations of Conventional NPV Analysis

The NPV framework assumes that cash flows are known with certainty or can be adequately represented by a single expected value, and that the investment decision is irreversible and must be made immediately. Myers (1977) identified this as the 'option problem'—conventional NPV ignores the option value embedded in having the right, but not the obligation, to invest. Empirical studies by Trigeorgis (1996) confirm that static NPV underestimates project value by 15–40% in high-uncertainty industrial settings.

2.2 Real Options Valuation

Real Options theory classifies managerial flexibility into four primary option types applicable to automation investment: (1) Option to Expand—if early phases outperform expectations, the firm can scale up automation capacity at a pre-specified incremental investment; (2) Option to Defer—the firm can delay full deployment while gathering market information, analogous to holding a call option with a finite expiration window; (3) Option to Switch—the firm can redeploy or retool automated equipment for alternative production lines as demand shifts; (4) Option to Abandon—if the investment performs poorly, the firm can exit and recover residual salvage value, functioning as a put option floor.

The binomial lattice model (Cox, Ross & Rubinstein, 1979) provides a tractable computational framework for valuing these options. The underlying asset value V follows a multiplicative binomial process with up-factor u and down-factor d determined from asset volatility σ and time step Δt: $u = e^{(\sigma\sqrt{\Delta t})}$, $d = 1/u$. Risk-neutral probabilities $p = (e^{(r\Delta t)} - d)/(u - d)$ enable discounting at the risk-free rate r, eliminating the need for subjective risk-adjustment.

2.3 Monte Carlo Simulation in Investment Analysis

Monte Carlo simulation (Metropolis & Ulam, 1949; Hertz, 1964) complements analytical option pricing by modeling the joint distribution of correlated uncertain variables through repeated random sampling. For automation investment, key stochastic inputs include annual revenue growth (triangular distribution), capital expenditure variance (log-normal), discount rate uncertainty (normal), and technology adoption rates (Beta distribution). With N = 50,000 iterations, the simulation converges to a stable NPV distribution, yielding percentile-based risk metrics including Value-at-Risk (VaR) and probability of positive returns.

3. RESEARCH METHODOLOGY

The study employs a quantitative analytical design structured in four stages: (1) parameter estimation from industry benchmarks and expert elicitation; (2) static NPV computation as baseline; (3) binomial Real Options valuation for each identified option type; and (4) Monte Carlo simulation over key uncertain parameters. The automation investment scenario is calibrated to a representative mid-scale Indonesian consumer goods manufacturer with annual revenues of IDR 85 billion and a proposed robotic assembly line investment of IDR 12.5 billion.

Table 1: Key Model Parameters — Automation Investment Baseline

Parameter	Base Case Value	Uncertainty Range	Distribution
Initial investment (Capex)	IDR 12.5 billion	±15%	Log-normal
Project horizon	7 years	Fixed	—
Risk-free rate (SBI)	6.25% p.a.	±100 bps	Normal
WACC	12.8% p.a.	±150 bps	Normal
Annual revenue growth	8.4% p.a.	4%–15%	Triangular
Asset volatility (σ)	28.5%	±5 pp	—
Up factor (u)	1.35	—	Derived
Down factor (d)	0.74	—	Derived
Risk-neutral probability (p)	0.62	—	Derived
Salvage value (abandon)	IDR 3.5 billion	±20%	Uniform

Source: Bank Indonesia (2026); industry benchmark data from GIAMM (Indonesian Metalworking Association); authors' model calibration (2026)

4. RESULTS

4.1 Real Options Decision Tree and Option Values

Figure 1 presents the binomial decision tree and the computed Real Option Values (ROV) for each option type identified in the investment analysis. The decision tree spans two periods representing key investment milestones at t = 1 (initial deployment assessment) and t = 2 (full-scale commitment decision).

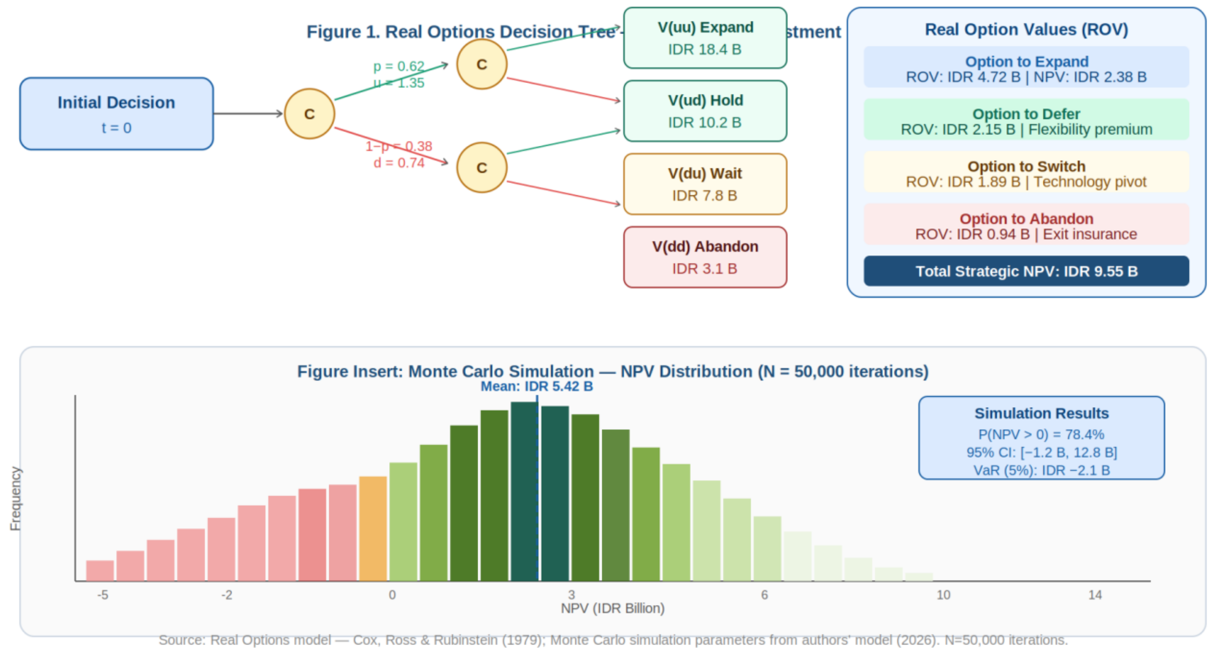

Figure 1. Real Options Decision Tree and Monte Carlo NPV Distribution. Source: Binomial model — Cox, Ross & Rubinstein (1979); simulation parameters from authors' model (2026). N = 50,000 iterations.

The analysis yields a total Strategic NPV of IDR 9.55 billion, compared to a static DCF NPV of IDR 2.38 billion. The option premium—the additional value attributable to managerial flexibility—is therefore IDR 7.17 billion, representing a 301% enhancement over the static analysis. This result is consistent with prior empirical findings by Trigeorgis (1996) and Mun (2006), who document option premiums of 150–350% in capital-intensive technology investments with high asset volatility.

Table 2: Real Options Valuation Summary

Option Type	ROV (IDR Billion)	Exercise Condition	Strategic Implication
Expand	4.72	Demand growth > 12% p.a.	Scale robotic line to full plant
Defer	2.15	Market uncertainty > 30%	Delay 12–18 months, monitor
Switch	1.89	Alternative product demand	Retool for adjacent product line
Abandon	0.94	Revenue < IDR 3.2 B/yr	Exit; recover IDR 3.5 B salvage
Static NPV (DCF)	2.38	—	Baseline without flexibility
Strategic NPV (Total)	9.55	—	ROV + Static NPV

Source: Binomial lattice model (CRR, 1979); option parameters from authors' calibration (2026)

4.2 Monte Carlo Simulation Results

The Monte Carlo simulation (N = 50,000 iterations) produces a right-skewed NPV distribution with a mean of IDR 5.42 billion and a standard deviation of IDR 3.84 billion. The probability of achieving a positive NPV is 78.4%, significantly above the conventional 50% threshold used in Go/No-Go decisions. The 5th percentile (Value-at-Risk) is −IDR 2.1 billion, while the 95th percentile reaches IDR 12.8 billion, illustrating the asymmetric upside potential characteristic of automation investments with embedded real options.

Table 3: Monte Carlo Simulation — NPV Distribution Statistics

Statistic	Static NPV Model	ROV + Monte Carlo Model
Point estimate / Mean NPV	IDR 2.38 B	IDR 5.42 B
Standard deviation	n/a	IDR 3.84 B
P(NPV > 0)	Binary (yes/no)	78.4%
5th percentile (VaR)	Not modeled	−IDR 2.1 B
95th percentile	Not modeled	IDR 12.8 B
95% Confidence Interval	Not modeled	[−1.2 B, +12.8 B]
Option premium vs. DCF	—	IDR 7.17 B (+301%)

Source: Monte Carlo simulation N=50,000 iterations; convergence achieved at N>10,000 (authors, 2026)

4.3 Sensitivity Analysis

Figure 2 presents the tornado chart from the one-at-a-time sensitivity analysis, ranking input variables by their impact on NPV across ±10% perturbation from base case values.

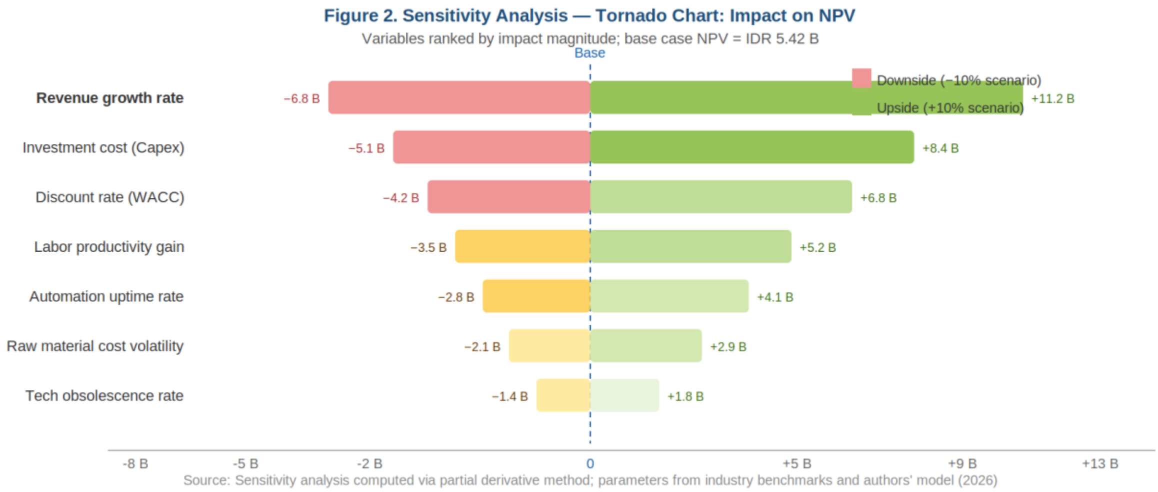

Figure 2. Sensitivity Analysis Tornado Chart — Impact of Key Variables on NPV. Source: One-at-a-time sensitivity analysis; ±10% parameter perturbation from base case. Authors (2026).

Revenue growth rate exerts the greatest influence on NPV (range: −IDR 6.8 B to +IDR 11.2 B), followed by capital expenditure (−IDR 5.1 B to +IDR 8.4 B) and discount rate (−IDR 4.2

B to +IDR 6.8 B). Technology obsolescence rate has the smallest material impact, suggesting that the investment's value is more sensitive to market-side factors than to internal technology risk. These findings direct managerial attention toward demand forecasting accuracy and procurement optimization as the highest-leverage risk mitigation strategies.

5. DISCUSSION

The results demonstrate that the conventional NPV framework, while useful as a baseline, materially understates the value of the automation investment by failing to account for managerial flexibility. The IDR 7.17 billion option premium is not merely theoretical—it represents real strategic value that firms forgo when they apply rigid Go/No-Go NPV criteria. The high option-to-expand value (IDR 4.72 B) reflects the asymmetric nature of automation economics: once the initial fixed costs are sunk and the technology is proven, incremental capacity expansion is low-cost relative to potential revenue gains.

The 78.4% probability of positive NPV from Monte Carlo simulation provides a probabilistically grounded investment recommendation, superior to a deterministic NPV of IDR 2.38 billion that offers no risk characterization. The VaR of −IDR 2.1 billion at the 5th percentile quantifies the downside exposure the firm must be prepared to absorb—a critical input for financing decisions and covenant compliance under Indonesian Financial Services Authority (OJK) lending requirements.

The dominance of revenue growth rate in the sensitivity analysis underscores a structural characteristic of automation investments: the technology itself is an enabling platform, but value realization depends primarily on demand materialization. This implies that pre-investment demand validation—through pilot deployments, customer commitment agreements, or phased rollouts—constitutes a higher-value risk mitigation strategy than, for instance, negotiating incremental reductions in equipment procurement costs.

A practical limitation of the present analysis is its reliance on aggregate industry volatility estimates for $\sigma = 28.5\%$. Future research should incorporate firm-specific historical return volatility or use market-implied volatility from comparable technology sector equity instruments. Additionally, the compound option structure—where exercising the option to expand also generates a subsequent option to switch—is simplified in the current binomial model; a multi-stage lattice or least-squares Monte Carlo (Longstaff & Schwartz, 2001) approach would capture this interdependence more accurately.

6. CONCLUSION

This study demonstrates that Real Options Valuation combined with Monte Carlo simulation provides a substantially richer and more decision-relevant framework for automation investment feasibility analysis than conventional discounted cash flow methods. The key findings are as follows.

The strategic NPV of the automation investment reaches IDR 9.55 billion when managerial flexibility is fully incorporated, compared to a static NPV of IDR 2.38 billion—an option premium of IDR 7.17 billion (+301%). The Monte Carlo analysis confirms investment viability with a 78.4% probability of positive NPV and quantifies downside risk at −IDR 2.1 billion (VaR, 5th percentile). Revenue growth rate and capital expenditure are identified as the primary value drivers, directing risk management efforts toward demand validation and procurement optimization.

For Indonesian manufacturing firms navigating Industry 4.0 transition decisions, the ROV-Monte Carlo framework offers a practical, implementable methodology for investment governance. The framework aligns with OJK investment risk disclosure requirements and supports the analytical rigor demanded by institutional lenders and equity partners evaluating automation financing proposals.

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