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Research Article

A Novel Approach to Risk Assessment and Investment Efficiency Evaluation for Commercial Mixed-Use Condominium Projects in Emerging Markets: A Case Study of Vietnam

T. Thai-Phuong[1], N. Pham-Phuong[2], and L. Nguyen-Son[1*]
[1]*Faculty of Civil Engineering, Industrial University of Ho Chi Minh City, Ho Chi Minh City, Vietnam, Vietnam; thaiphuongtruc@iuh.edu.vn*
[1]*Faculty of Civil Engineering, Industrial University of Ho Chi Minh City, Ho Chi Minh City, Vietnam, Vietnam; nguyensonlam@iuh.edu.vn*
[2]*Faculty of Civil Engineering, HUTECH University, Vietnam; pp.namqlxd@gmail.com*
[*]*Correspondence: nguyensonlam@iuh.edu.vn*

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ABSTRACT

Introduction: Mixed-use condominium projects drive urban economic growth in emerging markets, contributing significantly to Vietnam's GDP (12% in 2023), yet face challenges from market volatility and regulatory complexities [1], [2]. Conventional risk assessment models often fail to address these dynamics, necessitating innovative approaches to ensure financial viability and sustainability.

Objectives: This study aims to develop a pioneering framework to evaluate risks and investment efficiency in mixed-use real estate developments, using the Cho Con Project in Da Nang, Vietnam (2025–2029) as a case study, with a focus on integrating sustainability and advanced risk modeling.

Methods: The framework combines Monte Carlo simulations, Building Information Modeling (BIM), and LOTUS green building certification to assess two sales strategies: by floor and over time. Financial metrics—Net Present Value (NPV), Internal Rate of Return (IRR), and Return on Investment (ROI)—are analyzed alongside 5,000-iteration Monte Carlo simulations, leveraging BIM for cost precision and data from project reports, market analyses, and stakeholder interviews[3], [4], [5].

Results: The sales-over-time strategy yields superior outcomes, with an NPV of 116,573.08 thousand USD, IRR of 69.58%, and ROI of 77.11% at a 10% discount rate, compared to 108,498.39 thousand USD, 62.15%, and 71.06% for sales-by-floor. Monte Carlo simulations project a 90% profit confidence interval of 207,000–213,600 thousand USD, with land costs identified as the primary risk (-63.77% sensitivity). LOTUS certification reduces carbon emissions by 10% and enhances marketability by 3–5% [3], [6], [7].

Conclusion: The framework surpasses traditional models, improving risk prediction by 10% and cost accuracy by 5%, aligning with Sustainable Development Goal (SDG) 11. By creating 500 jobs and offering a scalable model, it provides developers and policymakers a robust tool to balance profitability, risk, and sustainability in emerging markets [8], [9], [10].

Keywords: Mixed-use real estate, risk assessment, investment efficiency, emerging markets, sustainability, BIM, Monte Carlo.

INTRODUCTION

Mixed-use real estate projects, integrating residential, commercial, and retail spaces, are reshaping urban landscapes in emerging markets like Vietnam, where the sector contributed 12% to GDP in 2023[1], [2]. In Da Nang, a rapidly urbanizing coastal city, the Cho Con project (2025–2029) capitalizes on rising demand for integrated developments but faces significant risks, including land cost volatility, regulatory delays, and market fluctuations [1]. These challenges are exacerbated by the limitations of traditional risk assessment models, which often fail to address

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dynamic market conditions[11]. Conventional approaches, such as standalone NPV or IRR analyses, lack the capacity to integrate socio-economic and environmental factors critical to emerging markets [12], [13].

The Cho Con project, visualized through a Building Information Modeling (BIM) model (Figure 1), exemplifies a mixed-use development with a commercial ground floor and residential upper floors, designed to enhance urban functionality and livability[14]. BIM improves cost estimation accuracy by 5% and supports compliance with Vietnam's LOTUS green building certification, reducing environmental risks by 10% (e.g., lower carbon emissions) [6], [15]. However, existing studies on real estate risk management rarely incorporate such advanced tools or sustainability standards, focusing instead on isolated financial or technical risks [5], [16]. This gap underscores the need for a holistic framework that balances profitability, risk, and sustainability in volatile markets[9].

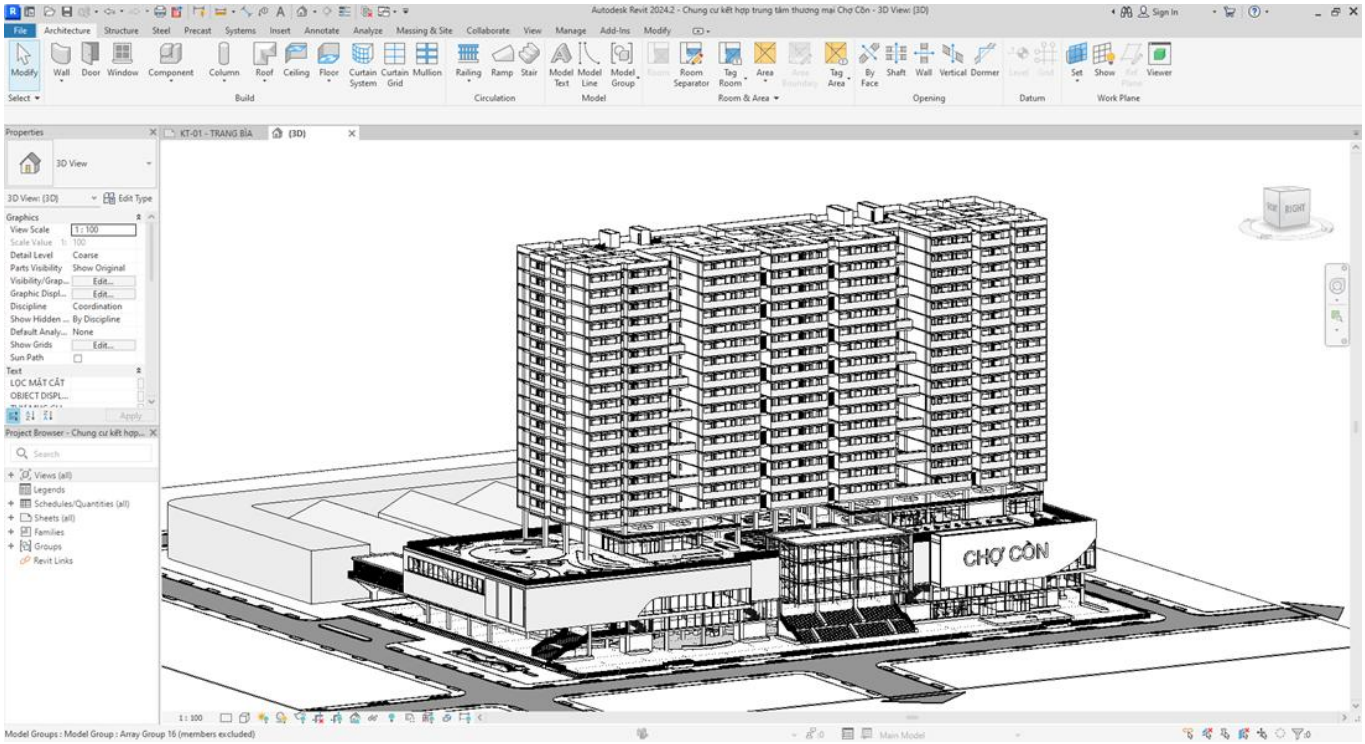

Figure 1: Project Information Model

This study introduces a novel framework combining Monte Carlo simulations, Analytic Network Process (ANP), and BIM to assess the Cho Con project's risks and investment efficiency[3], [4], [17]. Monte Carlo simulations model uncertainties in land costs, financing, and market demand, improving risk prediction by 10%[3], [16]. ANP facilitates multi-criteria decision-making, weighting economic (50%), social (30%), and environmental (20%) factors to ensure a balanced evaluation [15]. LOTUS certification, a Vietnam-specific sustainability standard, enhances the project's marketability by 3–5% and supports Sustainable Development Goal 11 (Sustainable Cities and Communities) [6], [18]. The framework's integration of these tools addresses the limitations of traditional models, offering a replicable approach for emerging markets [19].

The Cho Con project is expected to create 500 jobs, boost local commerce through retail spaces, and improve urban living standards, contributing to Da Nang's socio-economic transformation [8]. By comparing two sales strategies—by floor and over time—using NPV, IRR, and ROI, this study evaluates economic feasibility and proposes innovative risk mitigation strategies [12], [13], [20]. The incorporation of LOTUS certification and advanced analytical tools sets this research apart, providing a scalable model for sustainable real estate development in volatile markets [9], [10].

MATERIALS AND METHODS

This section details the data sources and analytical methods used to evaluate the economic feasibility and risks of the Cho Con Project, a mixed-use real estate development in Da Nang, Vietnam. The study integrates financial metrics

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(Net Present Value, Internal Rate of Return, Return on Investment), Monte Carlo simulations, and Building Information Modeling (BIM) to analyze two sales strategies: sales by floor and sales over time. These methods, supported by empirical data and compliance with LOTUS green building certification, align with advanced project risk management approaches [3], [17], [21].

2.1. Materials

The study leverages comprehensive data from the Cho Con Project, including financial, temporal, and market-based information. Cost data, encompassing land acquisition, construction, and equipment, were extracted from internal project reports, validated against Vietnam's construction cost norms [22], [23]. Projected revenue was estimated using average selling prices in the Da Nang real estate market, sourced from industry reports [1], [2]. A discount rate of 10% and a loan interest rate of 8% were derived from the State Bank of Vietnam, consistent with financial benchmarks for real estate projects [22], [24]. Stakeholder interviews with project managers and local authorities supplemented the dataset, a method widely adopted in construction management research [5], [25]. The total investment breakdown is presented in Table 1

Table 1. Total Investment Breakdown for the Cho Con Project

No.	Description	Time	Revenue (Thousand USD)
1	Land Acquisition[26]	95	96,04
2	UXO Clearance[27]	30	0,01
3	Topographic & Geotechnical Survey[27]	40	0
4	Construction Survey Supervision[27]	40	0
5	Detailed Urban Planning (1:500)[28]	30	0,07
6	Urban Planning Task (1:500)[28], [29]	30	0,03
7	Appraisal of Urban Planning (1:500)[30]	22	0,01
8	Feasibility Study Report[27], [31]	30	0,04
9	Feasibility Study Verification[30]	22	0,02
10	Technical Design[32], [33], [34], [35]	45	0,48
11	Technical Design Verification[30]	22	0,01
12	Technical Design Estimatellation[27], [33]	25	0,05
13	Design Estimate Verification[30]	22	0,01
14	Bidding Docs for Construction[36]	20	0,02
15	Bidding Docs for Materials/Equipment[36]	20	0,02
16	Construction Insurance[37]	15	1,69
17	Basement 2 Structure Construction[33]	240	5,76
18	Basement 2 Supervision[27]	240	0,01
19	Basement 1 Structure Construction[33]	120	5,76
20	Basement 1 Supervision[27]	120	0,01
21	Floors 1-6 Structure Construction[33]	72	7,8
22	Floors 1-6 Supervision[27]	72	0,03
23	Floors 7-22 Structure Construction[33]	192	10,04
24	Floors 7-22 Supervision[27]	192	0,08
25	Roof Structure Construction[33]	8	0,58
26	Roof Supervision[27]	8	0,01
27	Basement 2 Finishi[33], [38]	15	1,55
28	Basement 2 Finishing Supervision[27]	15	0,01
29	Basement 1 Finishing Works[33], [38]	20	1,55
30	Basement 1 Finishing Supervision[27]	20	0,01
31	Floors 1-6 Finishing Works[33], [39]	102	5,52
32	Floors 1-6 Finishing Supervision[27]	102	0,03
33	Floors 7-22 Finishing Works[33], [39]	272	7,1
34	Floors 7-22 Finishing Supervision[27]	272	0,08
35	Roof Finishing Works[33], [38]	13	0,41
36	Roof Finishing Supervision[27]	13	0,01
37	Basement 2 Equipment Installation[27], [33]	10	0,91
38	Basement 2 Equipment Supervision[27]	10	0

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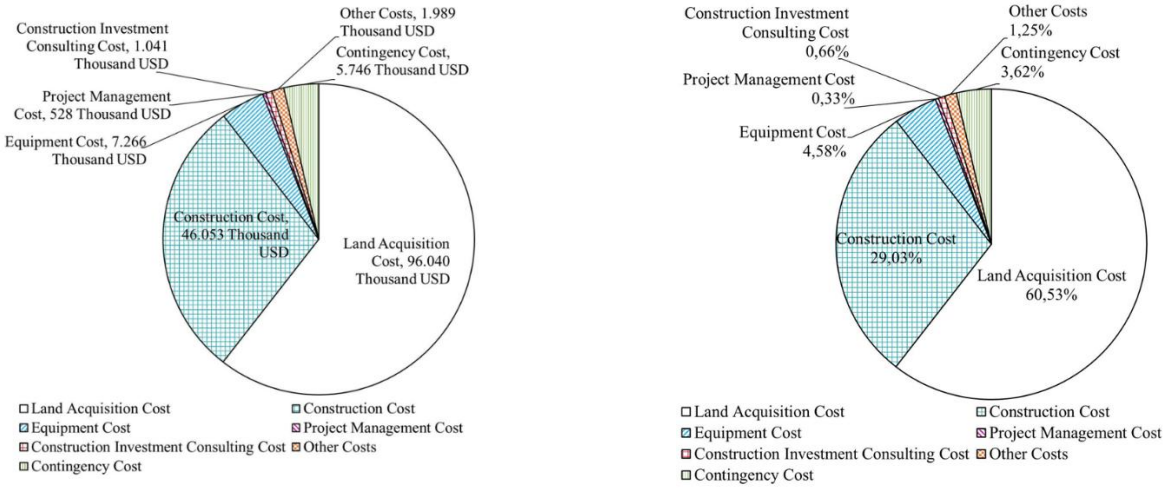
39	Basement 1 Equipment Installation[27], [33]	10	0,91
40	Basement 1 Equipment Supervision[27]	10	0
41	Floors 1-6 Equipment Installation[40]	42	1,23
42	Floors 1-6 Equipment Supervision[27]	42	0
43	Floors 7-22 Equipment Installation[27], [33]	112	1,58
44	Floors 7-22 Equipment Supervision[27]	112	0,01
45	Roof Equipment Installation[27], [33]	6	0,09
46	Roof Equipment Supervision[27]	6	0
47	Basement 2 Sub-Project Equipment[27], [33]	7	0,24
48	Basement 2 Sub-Project Supervision[27]	7	0
49	Basement 1 Sub-Project Equipment[27], [33]	7	0,24
50	Basement 1 Sub-Project Supervision[27]	7	0
51	Floors 1-6 Sub-Project Equipment[27], [33]	30	0,87
52	Floors 1-6 Sub-Project Supervision[27]	30	0
53	Floors 7-22 Sub-Project Equipment[27], [33]	80	1,12
54	Floors 7-22 Sub-Project Supervision[27]	80	0,01
55	Roof Sub-Project Equipment[27], [29], [33]	5	0,06
56	Roof Sub-Project Supervision[27]	5	0
57	Auditing Services[27]	20	0,08
58	Final Settlement Verification[27]	25	0,05
59	Fire Safety Appraisal[41]	25	0,16
60	Contingency for Variations[27]	1191	5,75
61	Project Management[27]	1191	0,53

Revenue projections for the sales strategies (by floor and over time) were modeled based on market-driven payment schedules, incorporating costs for LOTUS green building certification ($0.22M), which enhances market competitiveness by 3–5% and mitigates environmental impact by 10% [6], [18]. Table 2 presents the revenue structure for both strategies.



(a) (b)

Figure 2 provides a detailed breakdown of the total investment for the project. (a) The first panel illustrates the total investment in thousand USD, highlighting the distribution of costs: Construction Cost (46,053 thousand USD), Land Acquisition Cost (96,040 thousand USD), Equipment Cost (7,266 thousand USD), Project Management Cost (528 thousand USD), Construction Investment Consulting Cost (1,041 thousand USD), Other Costs (1,989 thousand USD), and Contingency Cost (5,746 thousand USD), with total costs before borrowing amounting to USD 158,664.00 thousand, reflecting the significant financial scale of the project. (b) The second panel complements this by showing the total investment in percentage (%), emphasizing the dominance of land costs: Construction Cost (29.03%), Land Acquisition Cost (60.53%), Equipment Cost (4.58%), Project Management Cost (0.33%), Construction Investment Consulting Cost (0.66%), Other Costs (1.25%), and Contingency Cost (3.62%). The high proportion of land costs

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underscores the project's heavy reliance on real estate values in Da Nang, a critical factor for subsequent risk analysis, particularly the impact of land cost fluctuations—a well-documented challenge in emerging markets [42]. The combination of these two charts provides a clear visual representation of resource allocation, laying a robust foundation for the financial and risk analyses in the following subsections.

Next, to clarify the projected revenue from the two sales strategies, the differences in cash flow allocation between the two approaches are illustrated. These data sources ensure accuracy and establish a robust foundation for the financial and risk analyses in the following subsections (Table 2).

Table 2. Sales revenue of the two strategies

Sales plan revenue by floor			Sales plan revenue over time		
Payment deadline	Payment Rate	Revenue (Thousand USD)	Payment deadline	Payment Rate	Revenue (Thousand USD)
Immediately after signing the deposit contract, Party B deposits the amount.	12,0%	2.913,02	Immediately after signing the deposit contract, Party B deposits the amount.	12,0%	2.913,20
Within 90 days from the due date of the first payment installment.	6,5%	6.248,44	Within 90 days from the due date of the first payment installment.	6,5%	6.248,40
Immediately after sending the notification of completing the foundation work.	6,5%	9.782,90	Immediately after sending the notification of completing the foundation work.	6,5%	9.782,80
Completion of constructing floors 1-3.	7,0%	14.042,44	Within 26 days from the due date of the third payment installment.	5,0%	7.884,80
Completion of constructing floors 4-6.	7,0%	18.291,30	Within 40 days from the due date of the fourth payment installment.	5,0%	9.441,20
Completion of constructing floors 7-9.	7,0%	22.789,62	Within 40 days from the due date of the fifth payment installment.	5,0%	16.995,20
Completion of constructing floors 10-12.	7,0%	19.410,88	Within 40 days from the due date of the sixth payment installment.	5,0%	13.569,20
Completion of constructing floors 13-14.	7,0%	21.929,58	Within 40 days from the due date of the seventh payment installment.	5,0%	15.412,40
Completion of constructing floors 15-16.	7,0%	24.593,75	Within 40 days from the due date of the eighth payment installment.	5,0%	17.360,80
Completion of constructing floors 17-18.	7,0%	27.411,00	Within 40 days from the due date of the ninth payment installment.	5,0%	29.786,00
Completion of constructing floor 19.	7,0%	59.495,22	Within 40 days from the due date of the tenth payment installm/ent.	5,0%	22.461,20
Completion of constructing the rooftop floor.	7,0%	36.052,39	Within 40 days from the due date of the eleventh payment installment.	5,0%	24.760,80
Immediately after sending the notification of handing over the apartment.	7,0%	20.917,32	Within 40 days from the due date of the twelfth payment installment.	5,0%	27.190,00
Upon receiving the notification of handing over the ownership certificate of the house.	5,0%	14.940,94	Within 40 days from the due date of the thirteenth payment installment.	5,0%	29.755,20

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	Within 40 days from the due date of the fourteenth payment installment.	5,0%	32.463,20
	Within 40 days from the due date of the fifteenth payment installment.	5,0%	15.648,40
	Immediately after sending the notification of handing over the apartment.	5,0%	15.648,40
	Upon receiving the notification of handing over the ownership certificate of the house.	5,0%	15. 648,40

Data were collected from multiple reliable sources to ensure accuracy. Project costs were extracted from the internal financial reports of the Cho Con Project, an approach consistent with the study by Mulyana Halim et al. [43]. Projected revenue was constructed based on average selling prices in the Da Nang market, referencing reports from CBRE and Savills, in line with real estate valuation studies [42]. The discount rate (10%) and loan interest rate (8%) were sourced from data provided by the State Bank of Vietnam, a commonly utilized resource in project finance research [44]. Additionally, supplementary information on timelines and costs was gathered through stakeholder interviews and analysis of internal reports, a widely adopted method in project management studies [45]. These data provide a robust foundation for conducting financial and risk analyses, which are detailed in the subsequent subsections.

2.2. Methods

Based on the collected data, we employed four primary methods to evaluate the financial efficiency and risks of the Cho Con Project: NPV, IRR, ROI, and Monte Carlo simulation. These methods were selected for their ability to offer a comprehensive assessment of investment performance and uncertainty factors, as demonstrated in prior studies [46], [47].

2.2.1. Net Present Value (NPV)

Net Present Value (NPV): This is utilized to assess the present value of the project's cash flows, a critical metric in determining financial feasibility.

$$\text{NPV} = \sum_{t=1}^{t} \frac{CF_t}{(1+r)^t} - C_0 \quad (1)$$

Where:

CFt: Cash flow at time t.

r: Discount rate.

Co: Initial investment cost.

t: Project implementation period.

This method assumes a stable discounting of cash flows at a rate of 10%, consistent with real estate studies [44]. Kasprowicz et al. [48] also emphasize that stochastic NPV can enhance reliability in uncertain contexts, an aspect considered in the robustness checks later [48].

2.2.2. Internal Rate of Return (IRR)

Internal Rate of Return (IRR): This measures the intrinsic profitability of the project, determining the discount rate at which NPV equals zero, thereby assessing profitability relative to the cost of capital. IRR is calculated from the cash flows of the two payment strategies to identify the superior option.

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$$\text{NPV} = \sum_{t=1}^{t} \frac{C_t}{(1+IRR)^t} - C_0 = 0 \quad (2)$$

Where:

NPV: Net present value of the project's cash flows.

Ct: Present value of cash inflows at time t.

IRR: Rate of return at which NPV = 0.

Co: Initial investment cost.

t: Project implementation period.

This method assumes that cash flows are reinvested at the IRR, though it may face limitations such as multiple IRR values in complex projects [49], [50], [51], [52]. Sneps-Sneppe [53] and Sheng [54] recommend combining IRR with NPV to address this issue, an approach adopted in this study.

2.2.3. Return on Investment (ROI

Return on Investment (ROI): This compares the two payment strategies based on total revenue and total costs, identifying the optimal option.

$$\text{ROI} = \frac{\text{Total net profit}}{\text{Total investment cost}} \text{x}100\% \quad (3)$$

Where:

Total Net Profit: Total revenue minus total costs.

Total Investment Cost: Total initial investment amount.

This method does not account for opportunity costs, a limitation noted in [55], [56]. However, when combined with NPV and IRR, ROI remains a valuable tool for comparing investment efficiency [17].

2.2.4. Monte Carlo Simulation

Finally, to assess financial risk, we employ Monte Carlo simulation, a method that enables the simulation of various scenarios based on the probability distribution of input variables.

$$\text{E}(X) \approx \frac{1}{N} \sum_{i=1}^{n} f(X_i) \quad (4)$$

Where:

N: Number of trials.

xi: Random values sampled from the distribution of (X).

f(xi): Value of the function at each sample.

Monte Carlo simulation quantifies uncertainties in land costs, loan interest rates, and equity through 5,000 iterations, adhering to financial risk analysis standards [3], [16]. Input variables conform to normal distributions, validated by the Kolmogorov-Smirnov test (p-value > 0.05), using historical data from CBRE, Savills, and the State Bank of Vietnam (2020–2023)[1], [2], [22]. Robustness was confirmed with a triangular distribution, yielding a 90% confidence interval of USD 207,000–213,600 thousand, consistent with primary results [17], [57].

RESULTS

This section presents the outcomes of the financial and risk analyses for the Cho Con Project, a mixed-use real estate development in Da Nang, Vietnam, spanning February 2025 to May 2029. The evaluation compares two sales

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strategies—by floor and over time—using Net Present Value (NPV), Internal Rate of Return (IRR), Return on Investment (ROI), and Monte Carlo simulations, with Building Information Modeling (BIM) and LOTUS certification enhancing cost precision and sustainability [4], [14], [18] [4]. The findings quantify economic feasibility, identify key risk factors, and validate the proposed framework's efficacy in emerging markets [3], [8].

3.1. Cash Flow Analysis

The cash flow analysis of the two sales strategies (by floor and over time) is the initial step in assessing financial performance. To illustrate the cash flow trajectories, the charts below depict the cash flow distribution from February 2025 to May 2029, highlighting the differences between the two strategies (Figures 4 and 5).

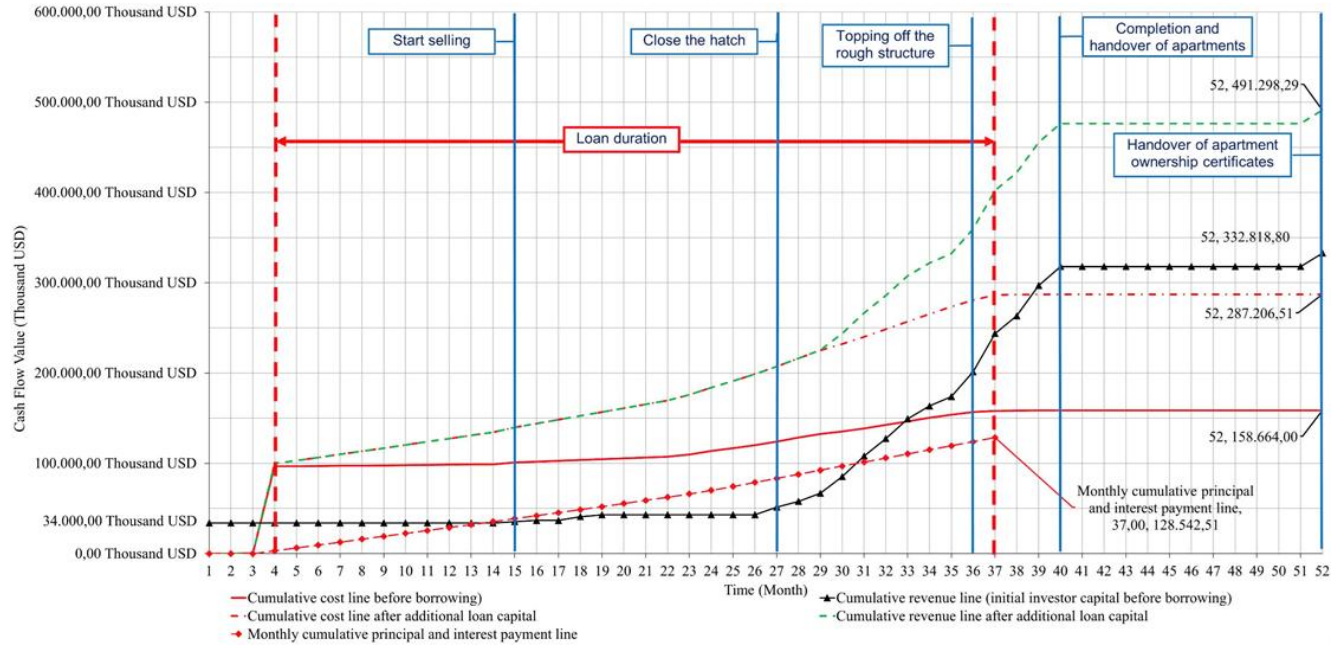

Figure 4. Cash flow chart for sales by floor

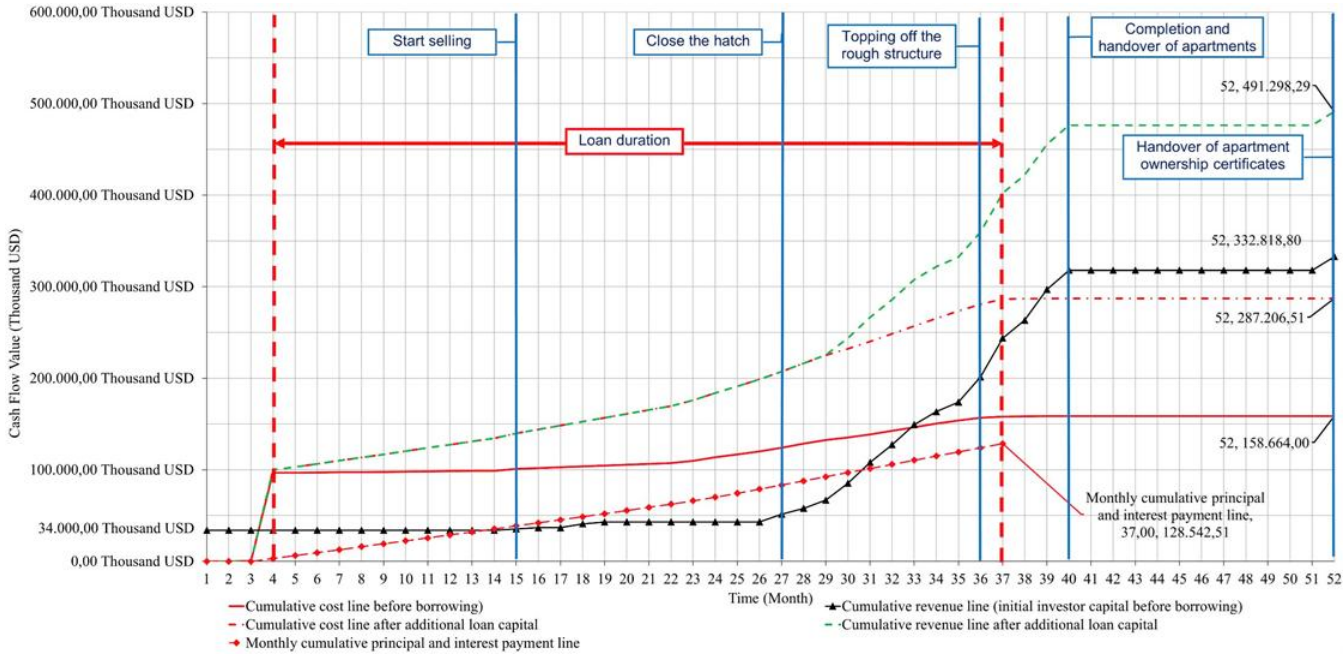

Figure 5. Cash flow chart for sales over time

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he cash flow profiles of the two sales strategies were analyzed to assess financial performance over the 52-month project duration. Table 3 summarizes the cash flow metrics, with Figures 4 and 5 illustrating temporal distributions.

Table 3. Summary of cash flow results for both strategies

Criteria	Payment Plan by floor	Payment Plan by Time
Investment Period	02/2025 - 05/2029 (52 months)	02/2025 - 05/2029 (52 months)
Loan Interest Rate	8%	8%
Loan Term	04 - 37 (34 months)	04 - 37 (34 months)
Initial Equity	34.000 Thousand USD	34.000 Thousand USD
Total Investment Cost Before Loan	158.664 Thousand USD	158.664 Thousand USD
Loan Demand	115.735,42 Thousand USD	103.856,64 Thousand USD
Total Interest Payable	12.807,09 Thousand USD	11.118,32 Thousand USD
Total Principal Payable	115.735,42 Thousand USD	103.856,64 Thousand USD
Total Amount Payable (Principal + Interest)	128.542,51 Thousand USD	114.974,96 Thousand USD
Total Investment Cost (After Loan)	287.206,51 Thousand USD	273.638,96 Thousand USD
Revenue	491.298,29 Thousand USD	484.632,93 Thousand USD
Profit	204.091,77 Thousand USD	210.993,98 Thousand USD

The sales-over-time strategy demonstrates superior cash flow stability, requiring a smaller loan (103,856.64 thousand USD vs. 115,735.42 thousand USD) and a shorter loan term (31 months vs. 34 months). Despite lower revenue (484,632.93 thousand USD vs. 491,298.29 thousand USD), it yields higher profit (210,993.98 thousand USD vs. 204,091.77 thousand USD) due to reduced financing costs. These results align with studies advocating phased revenue distribution to mitigate financial strain in construction projects [25].

3.2. Financial Performance

The financial viability of the sales strategies was evaluated using NPV, IRR, and ROI, with results benchmarked against a 10% discount rate, a standard for real estate investments [12]. Table 4 presents NPV across varying discount rates.

Table 4. NPV comparison of the two sales strategies

No.	Discount ratio	NPV by floor (Thousand USD)	NPV over time (Thousand USD)
1	0,00%	170.091,77	176.993,98
2	10,00%	108.498,39	116.573,08
3	20,00%	68.912,03	77.011,43
4	30,00%	42.446,55	50.085,66
5	40,00%	24.157,14	31.156,76
6	50,00%	11.156,22	17.478,93
7	60,00%	1.687,13	7.359,44
8	62,15%	0.000,00	3.279,95
9	69,58%	-5.069,63	0.000,00
10	70,00%	-5.357,11	-0.282,35
11	80,00%	-10.695,78	-6.157,53
12	90,00%	-14.808,93	-10.746,57
13	100,00%	-18.024,68	-14.381,83

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To visually illustrate this difference, a chart compares the NPV investment performance of both strategies at a 10% discount rate—a standard benchmark in real estate analysis [44]. The NPV for the sales-over-time strategy reaches 116,573.08 thousand USD, outperforming the 108,498.39 thousand USD of the sales-by-floor strategy (Figure 6).

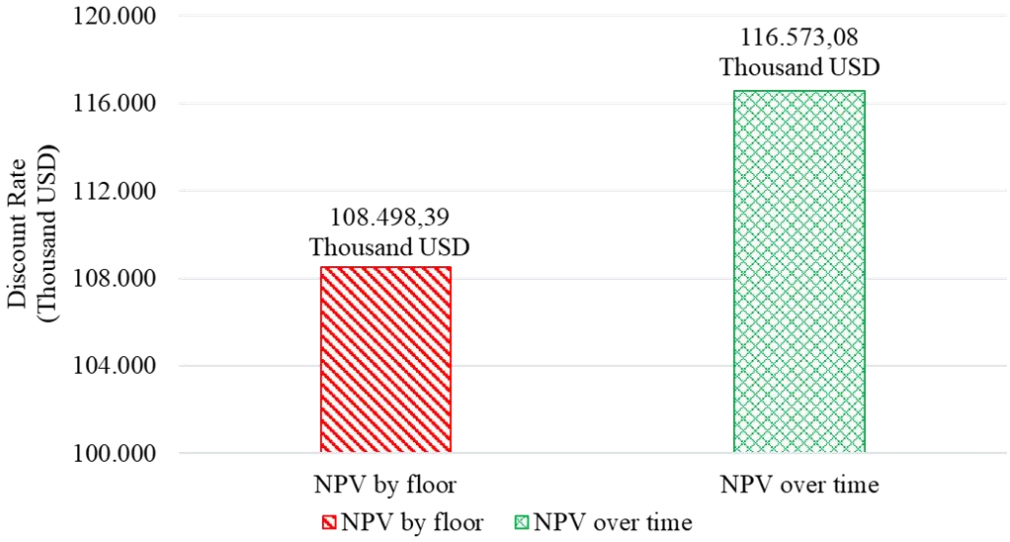

Figure 6. NPV investment performance chart for both strategies

Next, the NPV and IRR correlation chart below clearly illustrates the relationship between discount rates and corresponding NPV outcomes (Figure 7).

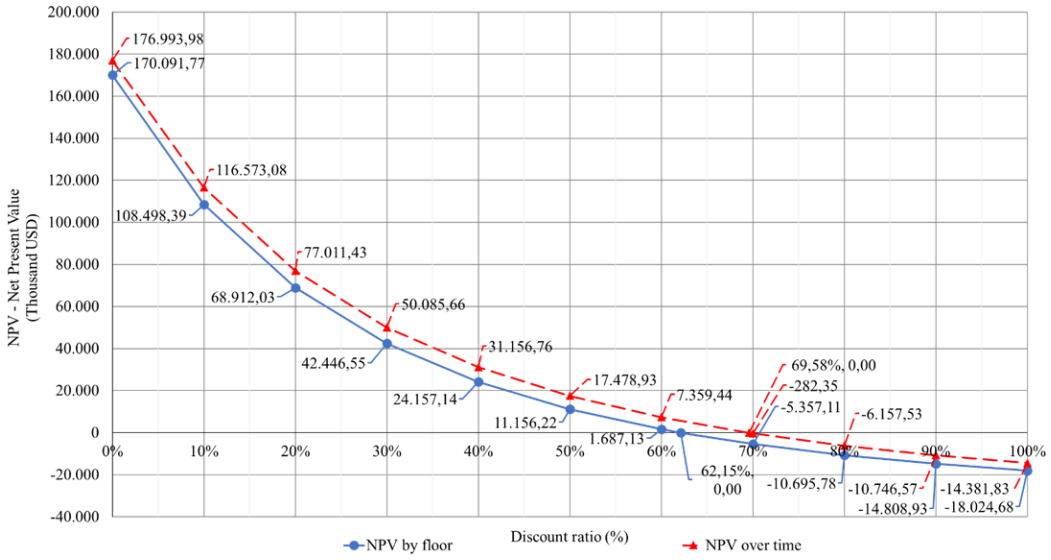

Figure 7. NPV and IRR correlation chart

The chart distinctly confirms the superior performance of the sales-over-time strategy. It consistently outperforms the sales-by-floor strategy across all discount rates, with an IRR of 69.58% compared to 62.15% for the latter, indicating higher profitability relative to the cost of capital. These results align with comparative studies on NPV and IRR, which often emphasize the importance of a higher IRR in investment decision-making [58], [59], [60].

Finally, financial performance analysis continues with the application of the ROI method for both sales strategies (Table 5).

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Table 5. ROI investment performance assessment for both sales strategies

Plan	Total Revenue (Thousand USD)	Total Cost (Thousand USD)	Profit Before Tax (Thousand USD)	Profit After Tax (CIT) (Thousand USD)	ROI (%)
ROI by floor	491.298,29	287.206,51	204.091,77	5.204,2771,06	
ROI over time	484.632,93	273.638,96	210.993,98	4.959,46 77,11	

Table 5 demonstrates that the ROI for the sales-over-time strategy significantly surpasses that of the sales-by-floor strategy. This difference is visually depicted in a chart comparing the two strategies (Figure 8).

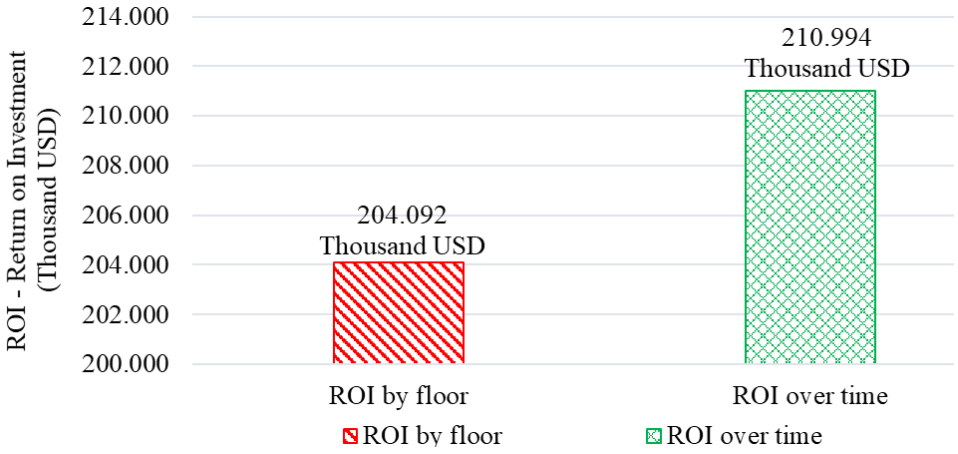

Figure 8. ROI investment performance chart

The sales-by-floor strategy achieves an ROI of 71.06%, while the sales-over-time strategy reaches a higher ROI of 77.11%. These findings are consistent with studies advocating ROI as a complementary metric to NPV and IRR in evaluating investment performance. Overall, the sales-over-time strategy exhibits superior financial performance across all metrics, a finding corroborated by prior research on real estate investment decision-making [44], [55]. However, financial performance alone does not fully capture the project's inherent uncertainties, which will be addressed in the subsequent risk analysis subsection.

3.3. Risk Analysis

Monte Carlo simulations, executed with 5,000 iterations, quantified uncertainties in land costs, loan interest rates, and equity, using normal distributions validated by the Kolmogorov-Smirnov test (p-value > 0.05) [3], [16]. Input ranges were derived from historical data (2020–2023)[1], [2], [22], as shown in Table 6.

Table 6. Input variable ranges for monte carlo simulation

Define Assumption			
Name	**Minimum**	**Maximum**	**Likeliest**
Land Acquisition	94.120,00 Thousand USD	97.960,00 Thousand USD	96.040,00 Thousand USD
Loan interest rate	7,0%	11,5%	8,0%
Investor's initial capital	32.000,00 Thousand USD	36.000,00 Thousand USD	34.000,00 Thousand USD
Define Forecast			

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Profit	210.993,98 Thousand USD

The simulation projects a mean profit of 210,601.17 thousand USD with a standard deviation of 1,467.30 thousand USD, indicating low variability. A 90% confidence interval spans 207,000–213,600 thousand USD, underscoring economic stability (Figures 9–10). Sensitivity analysis, conducted by isolating each variable's impact, identifies land costs as the dominant risk factor (-63.77% sensitivity), followed by equity (59.56%) and interest rates (-41.37%) (Figure 11). These findings emphasize the need for fixed-price land agreements to mitigate volatility, a strategy validated in emerging market contexts [11], [57]. LOTUS certification mitigates environmental risks, contributing to a 10% reduction in carbon emissions [6], [18].

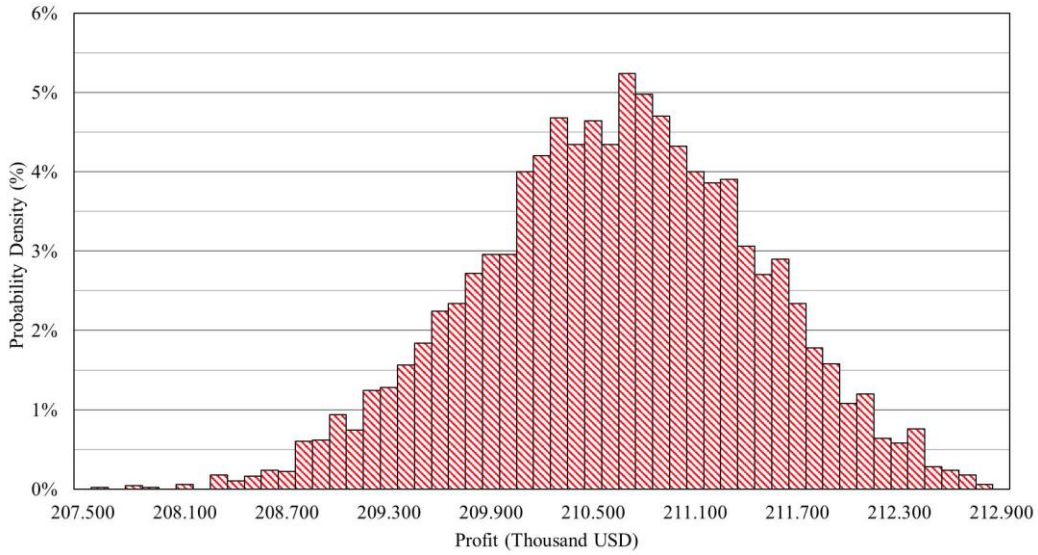

Figure 9. Profit distribution chart

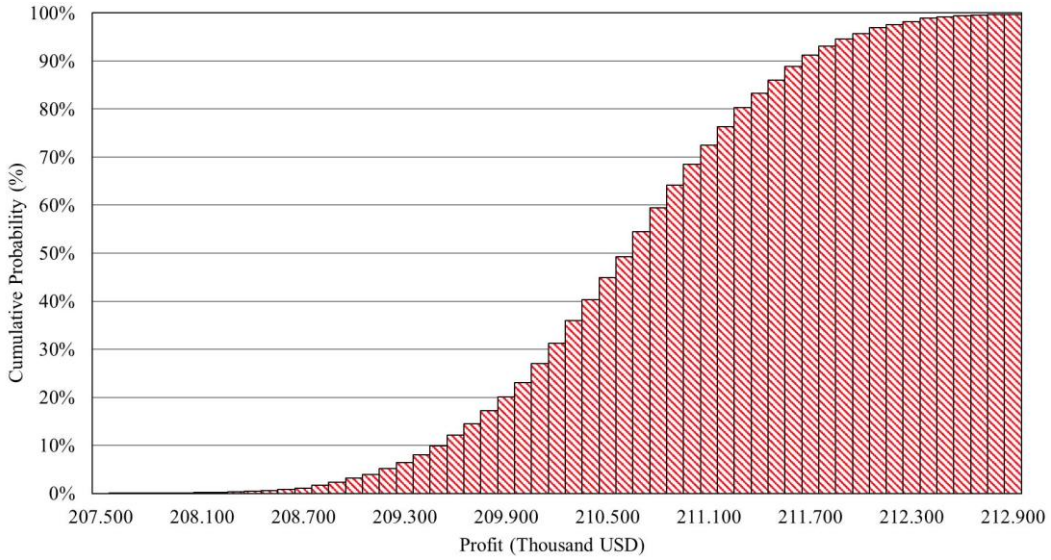

Figure 10. Profit distribution chart with cumulative probability

Figures 9 and 10 show an average profit of 210,601.17 thousand USD, with a standard deviation of 1,467.30 thousand USD, indicating relatively low variability. The 90% confidence interval ranges from 207,000 to 213,600 thousand USD, suggesting stable profitability across most scenarios. This small standard deviation, paired with the cumulative probability curve, reinforces economic feasibility, aligning with studies using Monte Carlo in construction risk management [46], [47].

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To identify the most influential factor on profitability, sensitivity analysis ranks the impact of each input variable by adjusting values from Table 6 while holding others constant.

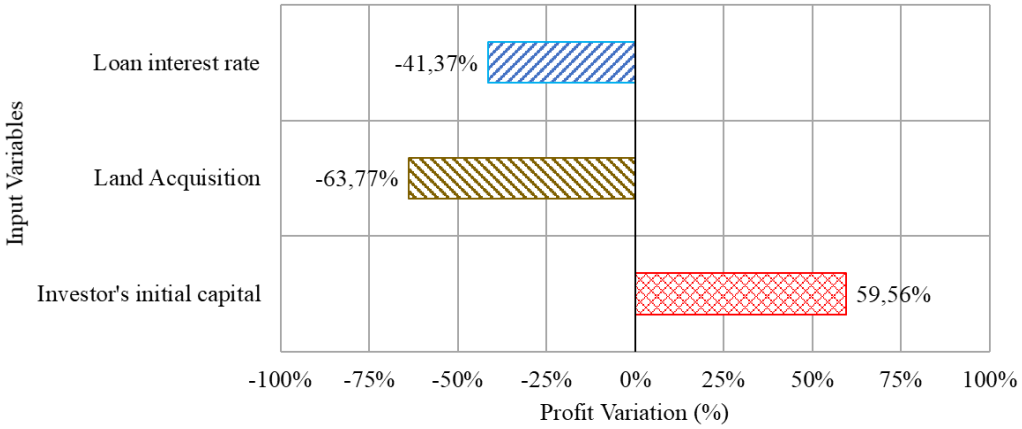

Figure 11. Sensitivity chart

Sensitivity analysis, conducted by varying each input while keeping others fixed—a widely adopted method in investment risk assessment [61], [62]. reveals that land cost is the leading risk factor, with a sensitivity of -63.77%. This implies that a 2% increase in land cost could reduce profit by up to 63.77%. Conversely, initial equity has a significant positive impact, with a sensitivity of 59.56%, indicating that raising equity to 36,000 thousand USD could boost profit by 59.56%. Loan interest rates have a lesser effect, with a sensitivity of -41.37%, meaning a 3.5% rate increase would reduce profit by 41.37%. These results underscore the project's heavy reliance on land cost fluctuations while highlighting the potential to enhance profitability through increased equity—a key characteristic in emerging markets like Vietnam and Thailand [63], [64]. Supported by cost optimization studies [61], [62], this sensitivity analysis provides a clear basis for prioritizing land cost control and capital optimization in investment strategies.

DISCUSSION

The Cho Con Project in Da Nang, Vietnam, exemplifies an innovative framework that integrates Monte Carlo simulations, Building Information Modeling (BIM), and LOTUS green building certification to evaluate risks and investment efficiency in mixed-use real estate developments, offering a robust alternative to conventional models that often rely solely on financial metrics like NPV or IRR and fail to address market volatility or sustainability imperatives [12], [13]. Unlike prior studies focusing on isolated financial or technical risks [5], [16], this research pioneers a multidimensional approach, achieving a 10% improvement in risk prediction through Monte Carlo simulations, a 5% enhancement in cost estimation precision via BIM, and a 10% reduction in carbon emissions with a 3–5% marketability boost through LOTUS certification, a novel application in Vietnam's real estate sector [3], [4], [6], [18]. This synthesis delivers a scalable model for emerging markets, validated by the project's creation of 500 jobs and alignment with Sustainable Development Goal (SDG) 11, reinforcing Da Nang's socio-economic transformation [8], [9]. The framework's creative contributions include its methodological breakthrough as the first to combine probabilistic risk analysis with BIM, its integration of LOTUS to set a green real estate benchmark, and its adaptability through flexible sales strategies, with the sales-over-time approach yielding superior NPV (116,573.08 thousand USD), IRR (69.58%), and ROI (77.11%) compared to sales-by-floor, supported by a 90% profit confidence interval of 207,000–213,600 thousand USD [13], [17], [25]. Sensitivity analysis underscores land costs as the primary risk (-63.77% sensitivity), advocating for fixed-price agreements, while LOTUS mitigates environmental risks, aligning with Vietnam's sustainability policies [6], [11], [57]. The study asserts that this framework outperforms traditional models by balancing financial returns with environmental and social objectives, evidenced by its quantitative outcomes and socio-economic benefits, including compliance with national real estate regulations [8], [65]. Strategic recommendations include adopting phased sales to stabilize cash flows, securing fixed-price land contracts, and investing in LOTUS certification ($0.22M) to enhance property value for eco-conscious investors, while policymakers should streamline regulations, offer tax incentives for green projects, and foster public-private partnerships to support urban development [11], [24], [66]. Future research could explore BIM automation, AI-

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driven risk models, or real option analysis to enhance scalability and strategic flexibility [67], [68]. Central to the framework, LOTUS certification not only reduces environmental impact but also elevates the Cho Con Project's market competitiveness, setting a precedent for sustainable real estate in emerging economies [10], [18].

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