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Research paper

Computational Efficiency of Latin Hypercube Sampling in Financial Risk Simulation: A Comparative Study

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Abstract

This study examines the financial risks of a condominium project in Long Xuyen, Vietnam, a promising yet uncertain real estate market. We compare the efficacy of Monte Carlo and Latin Hypercube Sampling in assessing the impact of sales strategies on financial performance, utilizing metrics such as Net Present Value (NPV) and Internal Rate of Return (IRR). Sensitivity analysis identifies key profitability drivers, focusing on initial capital and loan interest rates. The findings highlight Latin Hypercube Sampling's superior computational efficiency and stability, emphasizing the role of sales strategies in ensuring liquidity and optimizing financial outcomes. Practical recommendations include increasing contingency costs and adopting the Lotus certification building standard to empower investors in risk management and sustainable development. This research offers substantial theoretical and practical contributions, enriching financial risk analysis and delivering value to Vietnam's real estate sector.

Keywords: *Monte Carlo; Latin Hypercube; Financial Risk Analysis; Real Estate Market Vietnam; Sales Strategy; Sensitivity Analysis.*

1. Introduction

The real estate market in Vietnam has experienced substantial growth in recent years, yet it concurrently faces significant challenges associated with financial uncertainties, particularly amidst fluctuating interest rates and escalating inflationary pressures in 2025 [1], [2]. Condominium projects, which play a pivotal role in addressing housing demands in urban and provincial areas, are frequently exposed to financial risks stemming from factors such as capital costs, bank loan interest rates, and shifts in buyer sentiment. [3]. Specifically, in provincial markets like Long Xuyen, where the absorption rate of real estate products may be slower compared to major cities, effective financial risk management emerges as a critical determinant of project feasibility and performance [4]. To illustrate the context of the project in this region, Fig. 1 presents the information model of the Marina Plaza Long Xuyen project, located in Long Xuyen, An Giang, Vietnam, with a total investment of 445,748.95 million VND. The Fig. showcases the geographical location, a design model utilizing BIM (Building Information Modeling) compliant with the Lotus green building standard to reduce errors, along with the initial design and images of the completed structure, emphasizing a commitment to energy efficiency and quality of life.

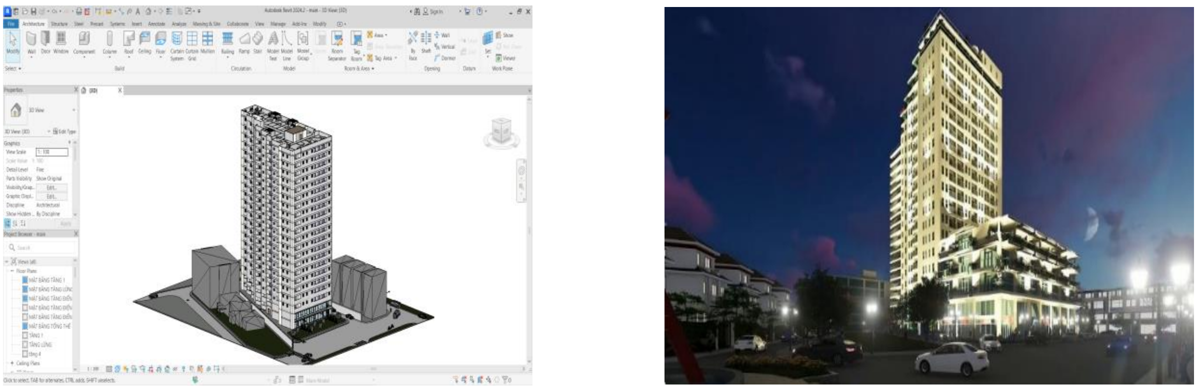


Fig. 1: Information Model of the Marina Plaza Long Xuyen project.

Note: The information model of the Marina Plaza Long Xuyen project, located in Long Xuyen, An Giang, Vietnam, has a total investment of 445,748.95 million VND. The figure illustrates the geographical location, a BIM design model compliant with the Lotus standard to reduce errors, and the initial design and the completed structure.

Drawing on the insights from Fig. 1, the Marina Plaza Long Xuyen project, a condominium development in the Mekong Delta region, not only aims to optimise financial performance but also strives to achieve the Lotus certification, focusing on enhancing energy efficiency, utilising sustainable materials, and improving resident comfort. [5]. The growing emphasis on sustainable development has gained traction, with investors and governmental bodies increasingly advocating for the adoption of green building standards to mitigate environmental impacts and elevate the quality of life. [2]. However, achieving these objectives necessitates formulating appropriate sales strategies and rigorous assessment of financial risks associated with input variables such as initial capital and interest rates. The selection of a sales strategy not only influences cash flow and profitability but also significantly impacts the long-term financial sustainability of the project. [3].

The present study compares two simulation methodologies, Monte Carlo and Latin Hypercube Sampling (Latin Hypercube Sampling), to evaluate financial risks and assess the impact of various sales strategies on the project's performance. The Monte Carlo method, renowned for its stochastic simulation capabilities, is widely employed in financial analysis; however, it typically requires many trials to achieve high accuracy, resulting in prolonged computational times. [6]. Conversely, Latin Hypercube Sampling, with its stratified random sampling technique, is anticipated to deliver superior computational efficiency and enhanced stability. [6]. The study also investigates key input factors influencing profitability, thereby elucidating the project's sensitivity to market fluctuations. [7].

The primary objective of this research is to provide a holistic framework for managing financial risks in condominium projects in Vietnam, while offering actionable recommendations to optimise economic performance and support sustainable development. [5]. By conducting a comparative evaluation of Monte Carlo and Latin Hypercube Sampling, this study not only enhances the precision of financial risk analysis but also delivers practical value for investors in making strategic decisions, particularly in an uncertain market environment with increasing demands for green building practices. [2].

2. Literature review

Financial risk analysis in real estate projects has garnered significant attention in recent studies, particularly in developing markets such as Vietnam. [8], [9]. Condominium projects often face numerous uncertainties, including interest rate fluctuations, construction costs, and capital mobilisation capacity, necessitating advanced analytical methods to support decision-making. [1], [10], [11]. In this field, the Monte Carlo method has been widely applied to simulate risk scenarios and evaluate the financial performance of investment projects. [12], [13], [14]. For instance, Monte Carlo has been used to estimate the stochastic net present value (NPV) in real estate projects. [15], [16] and to assess the risk of cost overruns [17]. However, a limitation of the Monte Carlo method lies in its requirement for many trials to achieve high accuracy, resulting in extended computation times. [7].

To address this drawback, the Latin Hypercube Sampling method has been proposed as a more efficient alternative, leveraging stratified random sampling to reduce the number of trials while maintaining accuracy. [6], [18]. Additionally, other methods, such as Quasi-Monte Carlo, have also been studied for risk analysis, but LHS remains preferred due to the efficiency of its stratified sampling technique. [19]. Furthermore, studies have indicated that combining Monte Carlo simulation with modern project management approaches, such as BIM (Building Information Modeling), can significantly enhance cost and schedule management efficiency [4] [20 – 26]. BIM has been recognised as a tool for managing the project lifecycle, from design to construction, helping to mitigate risks related to cost and time [4], [21].

From a financial perspective, indicators such as NPV and Internal Rate of Return (IRR) are commonly used to assess the investment efficiency of real estate projects [3] [27 - 34]. NPV provides insight into the present value of future cash flows, while IRR reflects the project's intrinsic profitability [28], [29]. However, studies have emphasised that the application of NPV and IRR should be complemented by sensitivity analysis to evaluate the impact of risk factors [34 - 39]. Sensitivity analysis has been employed to identify key factors affecting profitability, such as interest rates and initial investment capital [34], [37]. Additionally, using simulation techniques, such as Monte Carlo, enhances the accuracy of NPV and IRR estimates in high-risk scenarios. [3], [33].

Project risk management has also been a critical topic in recent studies. Research has underscored the importance of risk assessment in construction projects, particularly high-rise developments [1], [2], [10], [11], [40], [41]. Methods such as simulation-based risk analysis [5], [6], [18], [42], [43]Quantitative risk analysis [44] and project scheduling techniques [45], [46] Proposals have been proposed to mitigate risk impacts. Specifically, in the Vietnamese market context, studies have highlighted that risk factors such as interest rates and capital costs significantly influence the financial performance of projects. [8], [9], [47], [48]. However, there remains a lack of detailed comparative studies on sales strategies in this market, as well as evaluations of the effectiveness of Monte Carlo and Latin Hypercube methods in financial risk analysis [49], [50]. This study aims to address these gaps by providing empirical evidence on the financial performance and risks associated with two sales strategies, while comparing the effectiveness of the two simulation methods in supporting investment decision-making [51], [52].

3. Research methodology

3.1. Net present value (NPV) and Internal rate of return (IRR)

Cash flow analysis was conducted to evaluate the financial efficiency of two sales strategies for the Marina Plaza Long Xuyen project: evenly distributed revenue over time and concentrated revenue at key construction milestones. [53], [54]. Cash inflows were constructed based on revenue from sales milestones, including agreement signing, foundation completion, and apartment handover, while cash outflows encompassed costs such as land acquisition, construction, equipment, and other expenses [53]. To support cash flow management, the study integrated modern project scheduling techniques [45], [46] And applied project lifecycle management tools, such as BIM (Building Information Modeling), to enhance cost and schedule efficiency[4] [21 – 26].. BIM has been proven to be an effective tool in mitigating risks related to cost and time in construction projects [4], [16], [21].

Financial efficiency was assessed using two primary indicators: Net Present Value (NPV) and Internal Rate of Return (IRR) [27 – 34]. The formula for calculating NPV is defined as follows:

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

Where:
C_t represents the net cash flow at time t;
r is the discount rate;
t is the number of periods (measured in months);
C_0 is the initial investment cost [3], [15], [29];
NPV reflects the present value of future cash flows, with a positive value indicating that the project is likely to generate profits exceeding the discount rate [28], [29]. In this study, NPV was calculated at discount rates ranging from 0% to 100% to evaluate financial efficiency under varying levels of risk [30].
IRR is defined as the discount rate at which NPV equals zero [28 - 39], i.e., solving the equation:

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

Where:
NPV present value of project cash flows;
C_t represents the net cash flow at time t;
IRR rate of return at NPV = 0;
t is the number of periods (measured in months);
C_0 is the initial investment cost;
IRR reflects the intrinsic profitability rate of the project, with a value higher than the required discount rate indicating project feasibility [31], [32]. Additionally, the study calculated the Payback period to assess the speed of capital recovery, determined as follows:

$$\text{Payback period} = \text{Year before positive cumulative cash flow} + \frac{\text{Amount owed}}{\text{Cash flow in the first positive year}} \quad (3)$$

Where the outstanding amount is the absolute value of the last negative cumulative cash flow [27], [30]. These metrics were applied to both sales strategies, providing a basis for comparing financial efficiency and supporting investment decision-making [33], [55]. Previous studies have emphasized the importance of integrating NPV, IRR, and Payback Period in evaluating real estate investments, particularly in high-risk projects [31], [32], [35].

3.2. Monte Carlo and Latin hypercube methods

The study utilizes two simulation methods, Monte Carlo and Latin Hypercube Sampling, to analyze the financial risks of the Marina Plaza Long Xuyen project. The Monte Carlo method generates random scenarios based on the probability distributions of input variables, thereby simulating the distribution of output variables such as profit [7] [12 - 14]. The fundamental formula for the Monte Carlo method to estimate the expected value I (in this case, the expected profit of the project) is expressed as follows:

$$I \approx \frac{1}{N} \sum_{i=1}^{N} f(X_i) \quad (4)$$

Where:
I is the estimated value of the desired outcome;
N is the number of random samples taken;
$f(X_i)$ is the value of the profit function at the random sample point X_i, với X_i randomly drawn from the probability distribution of the input variables;
In this study, input variables such as bank interest rates and initial investment capital are modeled using a Triangular Distribution, rather than standard or log-normal distributions, due to the ability to specify minimum, maximum, and most likely values, making it suitable for realistic financial scenarios. This distribution is particularly well-suited to the Vietnamese real estate market, where interest rates and investment capital are influenced by credit policies and macroeconomic fluctuations, resulting in variations within defined ranges. [14]. This choice simplifies computations in Monte Carlo and Latin Hypercube Sampling (LHS) simulations while ensuring representativeness for the financial scenarios of the Marina Plaza Long Xuyen project.
Although the Monte Carlo method can simulate complex scenarios, it requires many trials to achieve high accuracy, resulting in prolonged computation times. [7]. To address this limitation, the Latin Hypercube Sampling method is employed as an alternative. [6], [18]. The Latin Hypercube Sampling (LHS) method facilitates the selection of sample values by dividing the range of factors, such as interest rates or initial investment, into equal small parts, then randomly selecting one value from each part. For example, if interest rates range from 6% to 10%, LHS can divide this into three parts (6–7.33%, 7.33–8.67%, 8.67–10%) and select one value from each part, ensuring that all value areas are considered. This approach reduces the number of computations while still providing reliable results, saving time and supporting investors in making quick decisions, particularly in complex projects like Marina Plaza Long Xuyen. The formula for generating samples is expressed as follows:

$$x_{ij} = \mathrm{F}_j^{-1}\left(\frac{s_{ij}+U_{ij}}{N}\right) \quad (5)$$

Where:
X_{ij} is the value of the j-th sample in the i-th stratum;
S_{ij} is the mean value of the i-th stratum, typically taken as i - 0.5;
U_{ij} is a random value drawn from a uniform distribution.
F_j^{-1} is the inverse cumulative distribution function of the j-th variable, transforming values from a uniform distribution to the desired distribution;
N is the number of samples. [18], [19].
Latin Hypercube Sampling ensures that samples are evenly distributed across the entire value space, reducing the number of trials required while maintaining accuracy. [6], [18]. Previous studies have demonstrated that Latin Hypercube outperforms Monte Carlo in terms of convergence speed and accuracy in project risk analysis. [6], [19], particularly in complex real estate projects [56]. The simulation results

from both methods were used to compare profit distributions, convergence rates, and risk levels of the two sales strategies, providing a basis for evaluating financial efficiency and risk. [51].

3.3. Risk and sensitivity analysis

Risk analysis was conducted using the Cumulative Distribution Function (CDF) to assess the probability of profit falling within various risk zones, based on simulation results from Monte Carlo and Latin Hypercube methods. [6], [18], [43]. The CDF formula for the profit variable (R) is expressed as follows:

$$\mathrm{CDF}(R) = \mathrm{P}(R \leq r) = \frac{1}{N}\sum_{j=1}^{N} I(R_j \leq r) \tag{6}$$

Where:
CDF(R) is the cumulative distribution function, representing the probability that the profit (R) is less than or equal to a threshold (r);
N is the number of samples (2,000 for Monte Carlo and 1,000 for Latin Hypercube);
I ($R_j \leq r$) is the indicator function, equal to 1 if the profit (R_j) at the j-th sample is less than or equal to (r), and 0 otherwise;
Σ denotes the summation, calculating the total number of times ($R_j \leq r$) from j = 1 to j = N. [5], [42].
The CDF enables the determination of risk probabilities, such as the likelihood of profit falling below a specific threshold, thereby assessing the risk level of each sales strategy. [5], [42]. This method has been effectively applied in construction projects to evaluate cost and time risks. [5], [42], [43]. Additionally, the study employed quantitative risk analysis techniques to prioritize key risk factors. [44] and integrated modern risk management methods, such as fuzzy risk analysis [47].
Sensitivity analysis was conducted to determine the impact of input variables (bank interest rates, initial investment capital) on profit, utilizing a tornado diagram. [34], [36], [37]. The sensitivity of profit (R) to the input variable (X_i) is calculated as follows:

$$\Delta R(X_i) = RX_{i\_max} - RX_{i\_min} \tag{7}$$

Where:
$\Delta R(X_i)$ is the change in profit when the variable (X_i) varies from its minimum value ($X_{i\text{-min}}$) to its maximum value ($X_{i\text{-max}}$);
$R(X_{i\text{-max}})$ is the profit when (X_i) is at its maximum value, with all other variables held constant at their baseline values;
$R(X_{i\text{-min}})$ is the profit when (X_i) is at its minimum value. [37].
The tornado diagram is constructed by ranking the variables based on their $\Delta R(X_i)$ values, facilitating the identification of the factors with the most significant impact on financial performance. [34], [38]. Previous studies have highlighted that sensitivity analysis is critical for managing financial risks, particularly in volatile markets such as Viet Nam, in real estate projects. [36], [57]. The results of the risk and sensitivity analyses were used to compare the risk levels between the two sales strategies, providing a basis for selecting the optimal strategy in the context of the Vietnamese market [49], [50], [52].

4. Results

4.1. Total project investment

The analysis of the total investment for the Marina Plaza Long Xuyen project provides a detailed overview of the cost structure, serving as the foundation for subsequent financial analyses. The total investment encompasses key cost components, including land acquisition, construction, equipment, and contingency (Table 1).

Table 1: Total Investment

No.	Cost content	Pre-tax value (million VND)	Value-added tax (million VND)	Net worth (million VND)	Proportion
I	Land purchase costs [58], [59]	68.856,48	5.987,52	74.844,00	16,79%
II	Construction costs [58], [60]	231.758,74	20.152,93	251.911,67	56,51%
III	Equipment costs [58], [60]	36.594,68	3.182,15	39.776,83	8,92%
IV	Project management costs [58], [61]	4.827,68	419,80	5.247,48	1,18%
V	Construction investment consulting costs [58], [60], [62 - 68]	11.565,45	1.005,69	12.571,14	2,82%
VI	Other costs [58], [69], [70]	4.048,52	352,04	4.400,56	0,99%
VII	Contingency costs [58]	52.437,49	4.559,78	56.997,27	12,79%
Total		410.089,03	35.659,92	445.748,95	100,00%

Note: The total investment cost for the construction of the Marina Plaza Long Xuyen project (in million VND) includes land (16.79%), construction (56.51%), equipment (8.92%), contingency (12.79%), and other expenses, totaling 445,748.95 million VND, which supports effective cost management.

This table lists the cost components before tax, value-added tax (VAT), and after tax, including costs for land acquisition, construction, equipment, contingency, investment, and construction consulting, project management, and other expenses [7]. To provide a more precise visualization of the proportion of each cost component, Fig. 2 illustrates the allocation of the total investment.

A) Total Investment (%) **B) Total Investment (Million VND)**

Fig. 2: Investment Chart.

The pie chart illustrates the percentage and after-tax values of the cost components: construction costs (the most significant proportion), land acquisition costs, contingency costs, equipment costs, investment and construction consulting costs, project management costs, and other expenses [53]. Data from Table 1 and Fig. 2 indicate that construction costs account for the highest proportion at 56.51%, equivalent to 251,911.67 million VND. In comparison, land acquisition and contingency costs represent 16.79% (74,844.00 million VND) and 12.79% (56,997.27 million VND). Other components, such as equipment costs (8.92%, 39,776.83 million VND) and consulting costs (2.82%, 12,571.14 million VND), have lower proportions. The total after-tax investment amounts to 445,748.95 million VND, reflecting the large scale of the project and the necessity for effective cost management. [10], [40].

4.2. Cash flow analysis

4.2.1. Sales strategies

Based on the analyzed cost structure, the project's cash flow evaluation compared the financial efficiency of two sales strategies: evenly distributed revenue over time and concentrated revenue at key construction milestones. The revenue for each strategy is detailed in Table 2.

Table 2: Sales Revenue of the Two Strategies

Monthly payment method			Payment method according to the construction progress		
Payment term	Payment rate	Revenue (million VND)	Payment term	Payment rate	Revenue (million VND)
Sign the agreement	10%	6.657,77	Sign the agreement	10%	4.438,51
After 1 month from the first batch	10%	20.146,40	After 1 month from the first batch	10%	13.448,69
Immediately after sending notice of completion of the foundation	10%	27.066,07	Foundation completed	10%	22.661,59
Payment after the 3rd instalment, 1 month	4%	15.026,28	Completed 1st-3rd floors	4%	13.296,64
Payment after the 4th instalment, 1 month	2%	12.465,67	Completed 4th-6th floors	4%	15.285,41
Payment after the 5th instalment, 1 month	2%	13.515,89	Completed 7th-9th floors	4%	17.318,16
Payment after the 6th instalment, 1 month	2%	14.585,91	Completed 10th-12th floors	4%	19.395,73
Payment after the 7th instalment, 1 month	2%	15.676,08	Completed 13th-15th floors	4%	21.519,04
Payment after the 8th instalment, 1 month	2%	16.786,73	Completed 16th-18th floors	4%	23.688,96
Payment after the 9th instalment, 1 month	2%	17.918,22	Completed 19th floor-ST	2%	19.804,40
Payment after the 10th instalment, 1 month	2%	19.070,91	Completed 1st-3rd floors	2%	21.040,15
Payment after the 11th instalment, 1 month	2%	20.245,14	Completed 4th-6th floors	2%	22.302,16
Payment after the 12th instalment, 1 month	2%	21.441,29	Completed 7th-9th floors	2%	23.590,95
Payment after the 13th instalment, 1 month	2%	22.659,73	Completed 10th-12th floors	2%	24.907,03
Payment after the 14th instalment, 1 month	2%	23.900,83	Completed 13th-15th floors	2%	26.250,92
Payment after the 15th instalment, 1 month	2%	9.541,53	Completed 16th-18th floors	2%	27.623,18
Payment after the 16th instalment, 1 month	2%	9.541,53	Completed 19th floor-ST	2%	29.024,35
Payment after the 17th instalment, 1 month	2%	9.541,53	Apartment handover notice	25%	123.427,10
Payment after the 18th instalment, 1 month	2%	9.541,53	Handover of apartment ownership	5%	24.685,42
Payment after the 19th instalment, 1 month	2%	9.541,53			
Payment after the 20th instalment, 1 month	2%	9.541,53			
Payment after the 21st instalment, 1 month	2%	9.541,53			
Apartment handover notice	25%	119.269,16			
Handover of apartment ownership	5%	23.853,83			

This table outlines the revenue for the two sales strategies (time-based and construction progress-based) across key project lifecycle phases, including agreement signing, foundation completion, structural construction, finishing, apartment handover, and issuance of ownership certificates. [54]. The time-based strategy distributes revenue more evenly, with 6,657.77 million VND (10%) at the agreement signing phase, 53,870.24 million VND (30%) at the foundation completion phase, 333,953.63 million VND (70%) at the finishing phase, and 453,222.79 million VND (95%) at the apartment handover phase. Conversely, the construction progress-based strategy concentrates revenue at key milestones, with 4,438.51 million VND (10%) at the agreement signing phase, 40,548.79 million VND (30%) at the foundation completion phase, 345,595.87 million VND (70%) at the finishing phase, and 469,022.97 million VND (95%) at0.0% at the apartment handover phase [53].

To better understand the cash flow differences between the two strategies, Figures 3 and 4 illustrate each strategy's cash inflows and outflows trends.

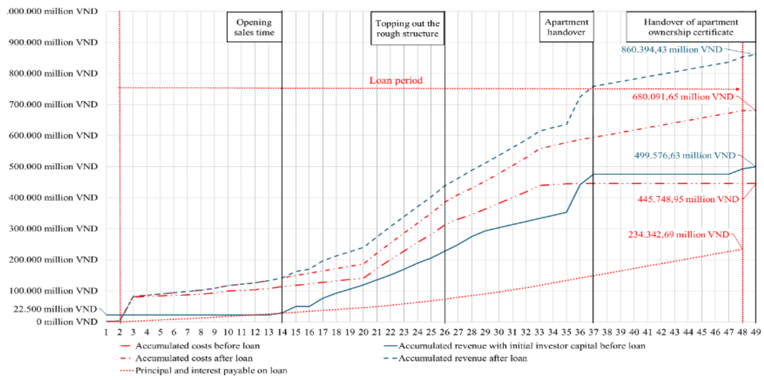


Fig. 3: Cash Flow Chart of Monthly Sales Plan.

Following this analysis, Fig. 4 provides an overview of the cash flow for the remaining strategy.

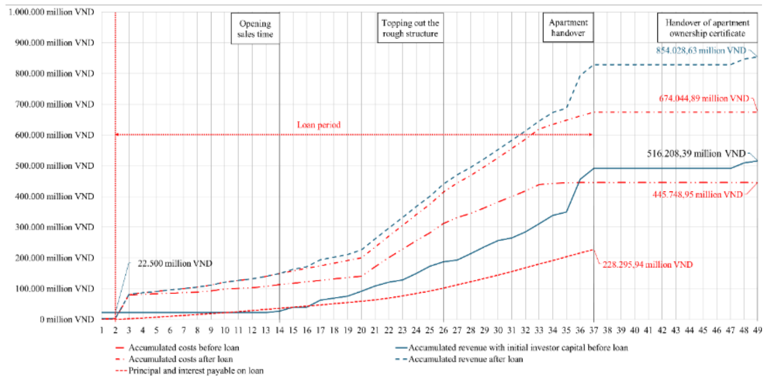


Fig. 4: Sales Plan Cash Flow Chart According to Construction Progress.

Figures 3 and 4 illustrate the cash flows of two sales strategies for a condominium project in Vietnam, corresponding to the monthly and construction progress-based strategies, respectively. These Figures include accumulated costs before and after loans, accumulated revenue after loans, and key phases such as sales launch, rough construction completion, and issuance of ownership certificates. For both strategies, accumulated costs before loans steadily increase from 0 million VND in month 1 to approximately 200,000 million VND by month 22, then stabilise, reaching 445,748.95 million VND by month 49. Regarding revenue, in Fig. 3 (monthly sales strategy), accumulated revenue after loans reaches 860,394.43 million VND by month 49. In contrast, in Fig. 4 (construction progress-based strategy), the accrued revenue after loans is 854,028.63 million VND, 6,365.80 million VND lower than Fig. 3. By month 49, the strategy in Fig. 3 achieves a profit of 180,302.78 million VND, higher than the profit of 179,983.74 million VND for the strategy in Fig. 4. Both strategies record rapid revenue increases during the sales launch and handover phases. Still, the monthly sales strategy (Fig. 3) is more effective regarding revenue and profit, particularly during the handover phase, due to a more flexible sales approach [8]. This highlights the importance of optimising sales strategies in volatile real estate markets like Vietnam. [11], [43].

Table 3: Cash Flow Summary

Criteria	Monthly payment method	Payment method according to the construction progress
Loan interest rate	8,00%	8,00%
Floating interest rate	3,00%	3,00%
Loan term	02 - 48 (47 months)	02 - 37 (36 months)
Initial owner's equity	22.500,00 million VND	22.500,00 million VND
Total pre-loan costs	445.748,95 million VND	445.748,95 million VND
Loan requirements	208.989,46 million VND	210.394,55 million VND
Total interest repayments	25.353,23 million VND	17.901,38 million VND
Total principal repayments	208.989,46 million VND	210.394,55 million VND
Total principal repayments	234.342,69 million VND	228.295,94 million VND
Total interest repayments	680.091,65 million VND	674.044,89 million VND
Total costs after the loan	860.394,43 million VND	854.028,63 million VND
Total revenue	180.302,78 million VND	179.983,74 million VND

This table presents key metrics such as loan capital requirements, total interest payments, and net revenue for the two sales strategies. [53]. The time-based strategy records a lower loan capital requirement of 208,989.46 million VND, with total interest payments of 25,353.23 million VND and net revenue of 180,302.78 million VND. In contrast, the construction progress-based strategy has a higher loan capital requirement of 210,394.55 million VND, with total interest payments of 17,901.38 million VND and net revenue of 179,983.74 million VND. This difference reflects the impact of revenue allocation on the project's liquidity and financial costs. [54], [55].

4.2.2. Financial analysis using NPV

To further evaluate the financial efficiency of the two sales strategies, an NPV analysis was conducted, with the results presented in Table 4.

Table 4: Compare NPV of the Two Sales Options

No.	Discount ratio	NPV monthly payment method (million VND)	Discount ratio	NPV payment method according to construction progress (million VND)
1	0,00%	157.802,80	0,00%	157.483,70
2	10,00%	107.608,10	10,00%	103.510,40
3	20,00%	74.905,70	20,00%	69.080,90
4	30,00%	52.677,30	30,00%	46.170,00
5	40,00%	37.019,80	40,00%	30.370,90
6	50,00%	25.650,90	50,00%	19.139,20
7	60,00%	17.177,30	60,00%	10.941,60
8	70,00%	10.716,80	70,00%	4.819,70
9	80,00%	5.692,50	80,00%	154,60
10	90,00%	1.716,30	80,30%	0,00
11	95,10%	0,00	90,00%	-2.334,50
12	100,00%	-1.716,30	100,00%	-7.665,90

This table lists the NPV values for the two strategies at discount rates ranging from 0% to 100% [29], [30]. At a 10% discount rate, the time-based strategy has an NPV of 107,608.10 million VND, significantly higher than the construction progress-based strategy, which has an NPV of 103,510.40 million VND. As the discount rate increases to 50%, the NPV for the time-based strategy decreases to 25,650.90 million VND, while the construction progress-based strategy reaches only 19,139.20 million VND. At a 100% discount rate, both strategies yield negative NPVs, at -1,716.30 million VND and -7,665.90 million VND, respectively. [28], [31], [32]. Fig. 5 depicts the NPV trends across discount rates to illustrate this difference visually.

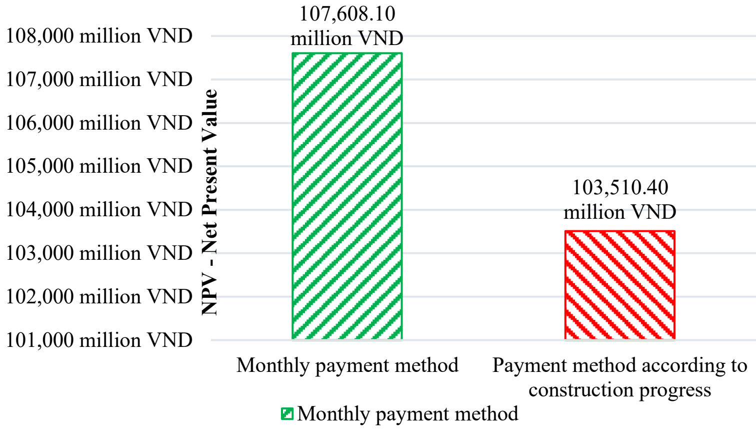


Fig. 5: NPV Chart by Discount Rate.

The monthly payment strategy demonstrates an advantage with an NPV of 107,608.10 million VND, indicating a higher present value of cash flows and a high IRR of 95.10%, reflecting strong profit potential. In contrast, the construction progress-based payment strategy, with an NPV of 103,510.40 million VND and an IRR of 80.30%, shows lower profitability. [3], [29], [33].

4.2.3. Analysis of NPV and IRR correlation

Following the NPV analysis, the correlation between NPV and IRR was examined to gain deeper insights. Fig. 6 provides a visual representation of the correlation between NPV and IRR.

Fig. 6: Correlation Chart between NPV and IRR.

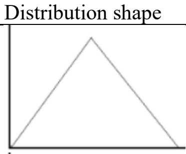
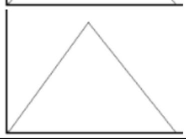
The chart for the time-based strategy shows an IRR of 95.10%, while the construction progress-based strategy records an IRR of 80.30%. At the IRR point, the NPV of both strategies equals zero. However, the time-based strategy demonstrates a significantly higher NPV at discount rates lower than the IRR. For example, at a 20% discount rate, the NPV reaches 74,905.70 million VND compared to 69,080.90 million VND for the construction progress-based strategy. [35], [36]. The chart indicates that the higher IRR of the time-based strategy reflects a superior intrinsic profitability, consistent with the prior NPV analysis. [28], [31], [32].

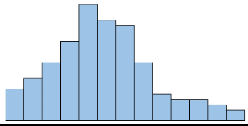
4.2.4. Comparison of Monte Carlo and Latin hypercube methods

4.2.4.1. Input variables and output distribution

The study applied Monte Carlo and Latin Hypercube simulations to evaluate the financial risks of the two sales strategies, starting with the declaration of input variables and output distributions, as presented in Table 5.

Table 5: Input Variable Declaration and Output Variable Statistics

No.	Input variables	Minimum	Likeliest	Maximum	Distribution shape
1	Bank interest rate	6%	8%	10%	
2	Initial investment capital	12.500,00	22.500,00	32.500,00	

Output variable			
3	Profit	157.802,78	

This table lists the input variables (bank interest rate, initial investment capital) with triangular distributions and the statistics of the output variable (profit) from Monte Carlo and Latin Hypercube simulations [7], [13]. The bank interest rate is assumed to fluctuate between 6% and 10%, with a most likely value of 8%, while the initial investment capital ranges from 12,500 million VND to 32,500 million VND, with a most likely value of 22,500 million VND [6], [18], [19].

4.2.4.2. Convergence speed

Next, the convergence rates of the two simulation methods were analysed to evaluate computational efficiency, with the results presented in Table 6.

Table 6: Compare the Convergence Speed of the Two Methods

Monte Carlo method	Number of tests	400	800	1200	1600	2000
	Time (seconds)	169,90	341,64	511,95	682,09	857,70
	Mean (million VND)	154.761,97	155.454,58	155.231,40	155.366,10	155.187,33
Latin Hypercube method	Number of tests	200	400	600	800	1000
	Time (seconds)	84,94	168,34	251,68	338,58	430,30
	Mean (million VND)	155.445,58	155.816,49	155.195,02	154.995,00	155.052,73

This table lists the number of trials required to achieve stability in the average profit value, with Monte Carlo requiring 2,000 trials and Latin Hypercube needing 1,000 trials [6], [7], [18], [19]. Monte Carlo achieves stability with a 1% error margin after 2,000 trials. In contrast, Latin Hypercube requires only 1,000 trials to attain the same error margin, reflecting the difference in computational efficiency between the two methods. The convergence trends are visually illustrated in Fig. 7.

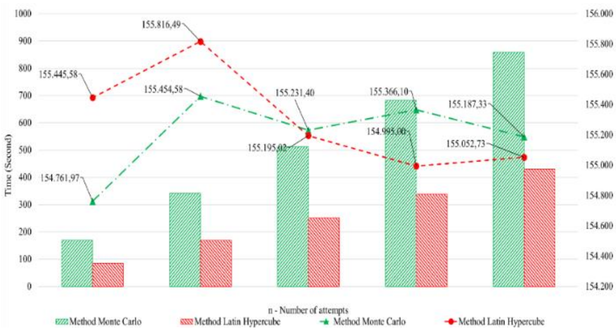


Fig. 7: Convergence Speed Comparison Chart.

The Monte Carlo and Latin Hypercube Sampling methods were compared for their efficiency and convergence speed in analysing financial risks for a condominium project in Vietnam. Monte Carlo utilised 400 to 2,000 trials, while Latin Hypercube Sampling applied 200 to 1,000 trials. Monte Carlo, based on random integration, requires a large number of trials to achieve high accuracy, with processing times ranging from 169.90 seconds (400 trials) to 857.70 seconds (2,000 trials) [7]. In contrast, Latin Hypercube Sampling, with its stratified input space strategy, significantly reduces computation time, ranging from 84.94 seconds (200 trials) to 430.30 seconds (1,000 trials) [12]. Regarding the mean value, Monte Carlo fluctuated between 154,761.97 million VND and 155,187.33 million VND. Latin Hypercube Sampling ranged from 155,445.58 million VND to 155,052.73 million VND, indicating greater stability for Latin Hypercube Sampling despite fewer trials [8]. Latin Hypercube Sampling converges faster, making it particularly suitable for volatile real estate markets like Vietnam, where computational resource optimisation is critical [43]. Therefore, Latin Hypercube Sampling outperforms Monte Carlo in efficiency and convergence speed, facilitating faster investment decision-making.

4.2.4.3. Risk analysis

Based on the comparison of convergence rates, the Latin Hypercube method is the optimal approach due to its ability to achieve stability faster with 1,000 trials compared to Monte Carlo's 2,000 trials. Consequently, Latin Hypercube was used to evaluate the financial risk levels of the two sales strategies, with the results illustrated in Fig. 8.

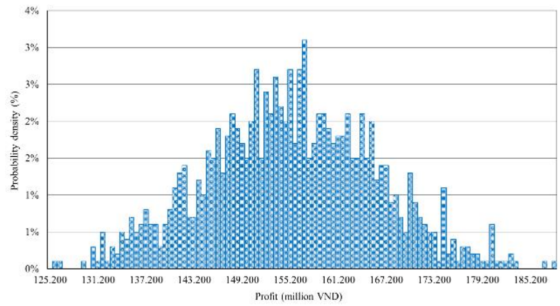


Fig. 8: Risk Analysis Chart.

Fig. 8 Risk analysis chart illustrates the profit distribution with cumulative probability for a condominium project in Vietnam, based on 1,000 trials using the Latin Hypercube Sampling method. The statistical details of this distribution are summarised in Table 7, Trial Statistics.

Table 7: Trial Statistics

Statistical	Predictive value
Trials	1.000
Base case	157.802,78 million VND
Mean	157.406,25 million VND
Median	157.576,72 million VND
Standard deviation	11.000,63 million VND
Variance	121.013.789,21 million VND
Skewness	0,0662
Kurtosis	2,8
Coeff of variation	0,0708
Minimum	123.320,84 million VND
Maximum	182.129,12 million VND
Mean Std error	347,87 million VND

Based on the data from Table 7, the profit distribution of the project ranges from 123,320.84 million VND to 182,129.12 million VND, with a mean of 157,406.25 million VND and a median of 157,576.72 million VND, indicating a relatively stable concentration around 157,500 million VND. The standard deviation of 11,000.63 million VND and a coefficient of variation of 0.0708 reflect a moderate level of dispersion. At the same time, the skewness of 0.0662 and kurtosis of 2.8 suggest a distribution that is slightly right-skewed and close to a normal distribution. The mean standard error of 347.87 million VND indicates a relatively high accuracy of the mean estimate with 1,000 trials. These findings underscore the effectiveness of the Latin Hypercube Sampling method in simulating financial risk scenarios [12], while emphasizing the need for robust risk management strategies to mitigate adverse outcomes in Vietnam's volatile real estate market [8], [43].

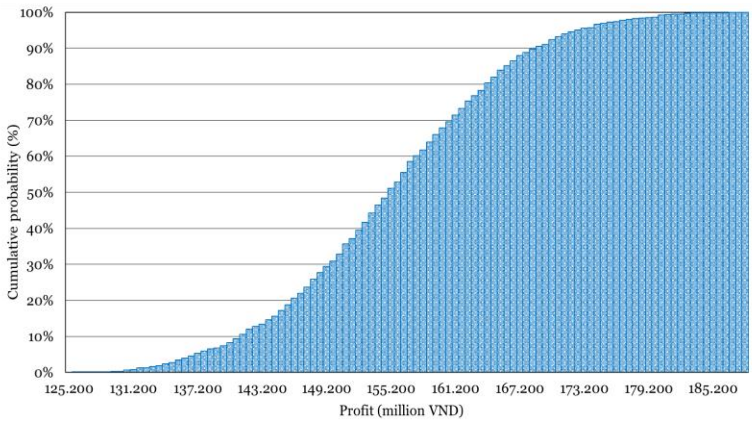


Fig. 9: Profit Distribution Chart with Cumulative Probability.

The content of the quantile chart for the profit distribution is summarised in Table 8.

Table 8: Percentiles

Percentage	Forecast value (million VND)
0%	123.320,84
10%	144.433,89
20%	147.751,45
30%	150.500,82
40%	152.719,95
50%	157.576,72
60%	159.660,43
70%	162.323,39
80%	164.420,38
90%	171.420,38
100%	182.129,12

Based on the data from Table 8, the profit distribution of the condominium project ranges from 123,320.84 million VND (0th percentile) to 182,129.12 million VND (100th percentile), with the 50th percentile (median) at 157,576.72 million VND, consistent with the mean value from prior analyses. The 20th percentile indicates a profit of 147,751.45 million VND, approximately 10,000 million VND below the median. In comparison, the 80th percentile reaches 164,420.38 million VND, about 7,000 million VND above the median, reflecting a relatively stable profit variation. Notably, the worst 20% of scenarios (below the 20th percentile) yield profits below 147,751.45 million VND, highlighting significant financial risks in adverse scenarios. These findings further confirm the effectiveness of the Latin Hypercube Sampling method in assessing financial risks. [12], while underscoring the importance of implementing risk management strategies to mitigate the impact of adverse scenarios in Vietnam's real estate market [8], [43].

4.2.4.5. Sensitivity analysis

Following the risk analysis, the impact of input variables on profit was determined, with the results illustrated in Fig. 9.

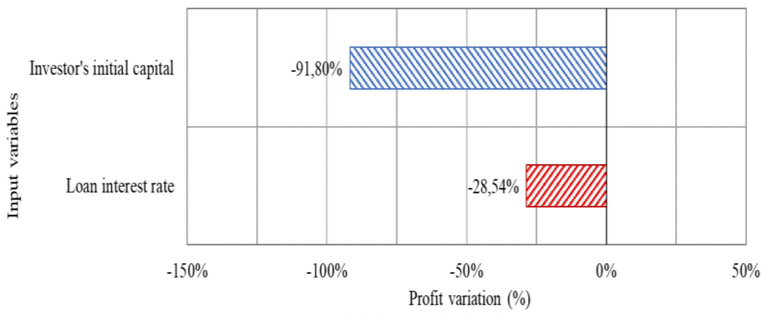


Fig. 10: Sensitivity Analysis Chart.

Fig. 9: Sensitivity analysis chart illustrates the impact of assumptions on the profit of the condominium project in Vietnam, based on sensitivity analysis. The assumptions and their effect on profit are summarised in Table 9, Sensitivity analysis.

Table 9: Sensitivity Analysis

Assumptions	Profit
Loan interest rate	-28,54%
Investor's initial capital	-91,80%

Based on the data from Table 9, the sensitivity analysis reveals that two key assumptions significantly influence the profit of the condominium project in Vietnam. The loan interest rate has a negative impact of -28.54%, indicating that an increase in the loan interest rate would substantially reduce the project's profit due to higher borrowing costs in the early stages of the project. However, the most significant factor is the investor's initial capital, with an impact of -91.80%, highlighting that profit is highly sensitive to changes in the initial capital; a reduction in this capital would lead to a sharp decline in profit, as the project heavily relies on initial funding to maintain construction progress and cover additional costs. These findings underscore the need for real estate projects in Vietnam, particularly in a volatile market, to focus on managing borrowing costs and ensuring a stable initial capital base to mitigate financial risks. [43]. Furthermore, the application of sensitivity analysis is crucial to support investors in making strategic decisions across various financial scenarios. [8], [37].

5. Discussion

The research provides a comprehensive overview of the financial efficiency and risks associated with the Marina Plaza Long Xuyên condominium project in the Vietnamese market, while highlighting the advantages of Latin Hypercube Sampling over Monte Carlo in financial risk analysis. Cash flow analysis from Fig.s 3 and 4 demonstrates that the monthly sales strategy outperforms the construction progress-based strategy in terms of revenue and profit, achieving a net profit of 180,302.78 million VND by month 49, compared to 179,983.74 million VND for the construction progress-based strategy. This finding aligns with [3], which suggests that a flexible sales strategy with evenly distributed revenue reduces liquidity pressure and enhances profitability in volatile real estate markets. However, the profit differential also indicates that in smaller provincial markets like Long Xuyên, where development may be slower, concentrating revenue at key construction milestones (as in Fig. 4) could increase financial risk due to reliance on specific time points. [4].

Profit distribution analysis from Figures 8 and 9, supported by Tables 7 and 8, shows that the project's profit ranges from 123,320.84 million VND to 182,129.12 million VND, with a mean of 157,406.25 million VND and a median of 157,576.72 million VND. Notably, the worst 20% of scenarios (below the 20th percentile) yield profits below 147,751.45 million VND, reflecting significant financial risk in adverse scenarios. This result is consistent with [43], which notes that real estate projects in emerging markets often face substantial profit declines due to interest rate fluctuations and buyer sentiment. Conversely, the best 10% of scenarios (above the 90th percentile) yield profits exceeding 171,420.38 million VND, indicating considerable profit potential under favorable market conditions. Compared to [12]. The profit distribution in this study has a lower standard deviation (11,000.63 million VND versus 25,000 million VND in [12]), attributed to using Latin Hypercube Sampling with 1,000 trials, confirming the method's stability and efficiency in reducing simulation variability.

Sensitivity analysis from Fig. 9 and Table 9 highlights the critical roles of initial investment capital and loan interest rates in influencing profit. Initial investment capital has the most substantial impact, with a sensitivity of -91.80%, indicating that reducing this capital could significantly decrease profit, as the project heavily relies on initial funding to maintain construction progress. This finding is consistent with [37], which identifies initial investment capital as the most sensitive factor in real estate projects in volatile markets. Loan interest rates, with a sensitivity of -28.54%, are also a significant factor, particularly in the context of Vietnam's volatile interest rate environment in 2025 [1]. Compared to [34]. The sensitivity to interest rates in this study is lower (28.54% versus 35% in [34]), possibly due to differences in the project's financial structure and assumptions about interest rate fluctuation ranges.

Methodologically, Latin Hypercube Sampling demonstrated superior efficiency and stability compared to Monte Carlo, with significantly reduced processing times (430.30 seconds versus 857.70 seconds for 1,000 and 2,000 trials, respectively). This supports [6], which argues that Latin Hypercube Sampling, with its stratified random sampling technique, is a more effective tool for simulating financial risk scenarios, particularly in complex real estate projects. As explained in the Research Methodology section, using a Triangular Distribution for input variables such as bank interest rates and initial investment capital simplifies simulations. Still, it may not fully capture asymmetric fluctuations in the Vietnamese real estate market, such as the impact of sudden credit policy changes or volatile buyer sentiment. Skewed distributions, such as log-normal or beta, could be explored in future research to more accurately simulate complex financial scenarios, primarily in provincial markets like Long Xuyen. [47]. Future studies should also integrate external factors, such as changes in legal policies or macroeconomic fluctuations, to enhance the reliability of simulations. [9]. Future research should expand the scope to include these factors and consider hybrid methods, such as combining Monte Carlo with fuzzy risk analysis, to improve accuracy in complex scenarios. [47].

From a practical perspective, this study underscores the importance of optimizing sales strategies and managing financial risks in real estate projects in Vietnam. With its ability to distribute revenue evenly, the monthly sales strategy improves liquidity and mitigates financial risks in adverse scenarios. Additionally, simulation tools like Latin Hypercube Sampling can assist investors in making rapid and effective strategic decisions, particularly in a volatile market with increasing demands for sustainable development. [5]. Practical recommendations include: (1) prioritizing flexible sales strategies to reduce liquidity pressure, (2) increasing contingency budgets to address adverse scenarios, and (3) effectively managing interest rates through financial instruments such as interest rate swaps.

6. Conclusion

6.1. Theoretical implications

This study contributes to the theory of financial risk management in real estate projects by comparing and demonstrating the superiority of Latin Hypercube Sampling over Monte Carlo in simulating complex financial scenarios. The findings confirm that Latin Hypercube Sampling not only reduces computation time (430.30 seconds compared to 857.70 seconds for Monte Carlo) but also provides greater stability, reinforcing the conclusions of [6]. Regarding the efficiency of Latin Hypercube Sampling in projects with high uncertainty. Furthermore, the sensitivity analysis (Fig. 9) clarifies the critical roles of initial investment capital (-91.80%) and loan interest rates (-28.54%) as key determinants of profit, adding to the theoretical framework of sensitivity analysis in financial risk management. [37]. The application of financial metrics such as NPV and IRR in the context of an emerging market like Vietnam enriches the theoretical framework for evaluating real estate investment efficiency, particularly in highly volatile markets [3], [33].

The study also extends the theory of sales strategies in real estate by demonstrating that evenly distributing revenue over time (the monthly strategy) reduces liquidity pressure and enhances profitability, particularly in smaller provincial markets like Long Xuyên. This result aligns with [3], which examines the impact of sales strategies on financial performance, while offering a novel perspective on optimizing cash flow in uncertain market conditions. This contribution clarifies the relationship between sales strategies and economic risk in condominium projects in Vietnam. [8].

6.2. Practical implications

From a practical perspective, this study offers specific solutions for real estate investors in Vietnam, particularly in the uncertain financial landscape of 2025. The adoption of the monthly sales strategy, which yields higher net profit compared to the construction progress-based strategy, demonstrates its optimality for ensuring liquidity and maximizing financial efficiency, especially in markets with slow product absorption rates like Long Xuyên [4]. Additionally, the study recommends increasing the contingency budget to 15% of the total investment to address financial risks, particularly given that the worst 20% of scenarios result in profits below 147,751.45 million VND. [43].

The sensitivity analysis underscores the necessity of managing initial investment capital and loan interest rates, which significantly impact profit (-91.80% and -28.54%, respectively). Consequently, investors should employ financial instruments such as interest rate swaps to mitigate risks from interest rate fluctuations and ensure a stable initial capital base through diversified capital mobilization strategies [1]. Integrating Latin Hypercube Sampling into the financial risk assessment process also provides practical benefits, enabling investors to quickly and accurately analyze risk scenarios, thus facilitating timely strategic decisions in a volatile market. [6].

The study further encourages the adoption of green building standards, such as Lotus certification, in condominium projects in Vietnam. This not only aligns with the trend toward sustainable development but also enhances the long-term value of projects, particularly as the government and consumers increasingly prioritize environmental standards. [5]. These recommendations provide a practical guide for investors to improve financial efficiency and mitigate risks in real estate projects in Vietnam.

6.3. Contribution

This study contributes to the field of financial risk management in real estate by providing empirical evidence on the superior efficiency of Latin Hypercube Sampling compared to Monte Carlo in simulating financial risks, adding to the body of research on simulation methods in emerging markets [6], [8]. The detailed analysis of profit distribution and sensitivity for the Marina Plaza Long Xuyên project elucidates key risk factors (initial investment capital and loan interest rates), offering a comprehensive analytical framework for condominium projects in Vietnam. The study also advances the theory of sales strategies by demonstrating the superiority of the monthly revenue distribution strategy, providing a scientific basis for investors to optimize cash flow and mitigate financial risks [3].

Furthermore, the study delivers practical value by proposing specific solutions to enhance financial efficiency and risk management, including sales strategies, interest rate management, and the application of Latin Hypercube Sampling. These contributions assist investors in making strategic decisions and lay the groundwork for future research on financial risk management in volatile real estate markets like Vietnam. Moreover, by leveraging advanced simulation methods like LHS and promoting Lotus certification, this study significantly advances sustainable development, aligning with global green building trends that emphasize energy efficiency and environmental sustainability. [5].

References

[1] Y. Liu, "Risk Analysis and Research for Construction Projects," *Advances in Economics, Management and Political Sciences*, vol. 19, no. 1, pp. 181–187, Sep. 2023, https://doi.org/10.54254/2754-1169/19/20230135.

[2] S. N. Kabilovna, "The Role of Risk Assessment in Investment Project Risk Management," *Int J Res Appl Sci Eng Technol*, vol. 10, no. 6, pp. 49–58, Jun. 2022, https://doi.org/10.22214/ijraset.2022.43925.

[3] J. J. Flaig, "Improving Project Selection Using Expected Net Present Value Analysis," *Qual Eng*, vol. 17, no. 4, pp. 535–538, Oct. 2005, https://doi.org/10.1080/08982110500250990.

[4] Y. Rui, L. Yaik-Wah, and T. C. Siang, "Construction Project Management Based on Building Information Modeling (BIM)," *Civil Engineering and Architecture*, vol. 9, no. 6, pp. 2055–2061, Oct. 2021, https://doi.org/10.13189/cea.2021.090633.

[5] L. Guan, A. Abbasi, and M. J. Ryan, "A simulation-based risk interdependency network model for project risk assessment," *Decis Support Syst*, vol. 148, p. 113602, Sep. 2021, https://doi.org/10.1016/j.dss.2021.113602.

[6] J. Sobieraj and D. Metelski, "Project Risk in the Context of Construction Schedules—Combined Monte Carlo Simulation and Time at Risk (TaR) Approach: Insights from the Fort Bema Housing Estate Complex," *Applied Sciences*, vol. 12, no. 3, p. 1044, Jan. 2022, https://doi.org/10.3390/app12031044.

[7] C. Song and R. Kawai, "Sampling and Change of Measure for Monte Carlo Integration on Simplices," *J Sci Comput*, vol. 98, no. 3, p. 64, Mar. 2024, https://doi.org/10.1007/s10915-024-02461-0.

[8] T. Thai-Phuong, “A Novel Approach to Risk Assessment and Investment Efficiency Evaluation for Commercial Mixed-Use Condominium Projects in Emerging Markets: A Case Study of Vietnam,” *Journal of Information Systems Engineering and Management*, vol. 10, no. 44s, pp. 460–476, May 2025, https://doi.org/10.52783/jisem.v10i44s.8613.
[9] M.-C. Huang, T.-J. Gong, S.-P. Sun, and P.-H. Lin, “Obstacles or catalysts? A balanced view of formal institutional risks on FDI location choice,” *Asian Business & Management*, vol. 22, no. 5, pp. 2077–2105, Nov. 2023, https://doi.org/10.1057/s41291-023-00242-5.
[10] C.-L. Lin and B.-K. Chen, “Research for Risk Management of Construction Projects in Taiwan,” *Sustainability*, vol. 13, no. 4, p. 2034, Feb. 2021, https://doi.org/10.3390/su13042034.
[11] V. Sahu and K. N. Sharma, “Study of risks in high rise building projects in India and the mitigation measures,” *Asian Journal of Civil Engineering*, vol. 24, no. 7, pp. 1957–1967, Nov. 2023, https://doi.org/10.1007/s42107-023-00615-3.
[12] J. Fabianová, J. Janeková, G. Fedorko, and V. Molnár, “A Comprehensive Methodology for Investment Project Assessment Based on Monte Carlo Simulation,” *Applied Sciences*, vol. 13, no. 10, p. 6103, May 2023, https://doi.org/10.3390/app13106103.
[13] I.-C. Yeh and C.-H. Lien, “Evaluating real estate development project with Monte Carlo-based binomial options pricing model,” *Appl Econ Lett*, vol. 27, no. 4, pp. 307–324, Feb. 2020, https://doi.org/10.1080/13504851.2019.1616049.
[14] Y. Zou, “Application of Monte Carlo model in financial field,” *Highlights in Business, Economics and Management*, vol. 10, pp. 459–463, May 2023, https://doi.org/10.54097/hbem.v10i.8139.
[15] T. Kasprowicz, A. Starczyk-Kołbyk, and R. Wójcik, “Randomized Estimation of the Net Present Value of a Residential Housing Development,” *Applied Sciences*, vol. 12, no. 1, p. 124, Dec. 2021, https://doi.org/10.3390/app12010124.
[16] T. Kasprowicz, A. Starczyk-Kołbyk, and Robert. R. Wójcik, “The randomized method of estimating the net present value of construction projects efficiency,” *International Journal of Construction Management*, vol. 23, no. 12, pp. 2126–2133, Sep. 2023, https://doi.org/10.1080/15623599.2022.2045426.
[17] Z. Bouayed, “Using monte carlo simulation to mitigate the risk of project cost overruns,” *International Journal of Safety and Security Engineering*, vol. 6, no. 2, pp. 293–300, Jun. 2016, https://doi.org/10.2495/SAFE-V6-N2-293-300.
[18] A. Senova, A. Tobisova, and R. Rozenberg, “New Approaches to Project Risk Assessment Utilizing the Monte Carlo Method,” *Sustainability*, vol. 15, no. 2, p. 1006, Jan. 2023, https://doi.org/10.3390/su15021006.
[19] R. Tamošiūnienė and T. Petravičius, “The Use of Monte Carlo Simulation Technique to Support Investment Decisions,” *Verslas: teorija ir praktika*, vol. 7, no. 2, pp. 73–80, Jun. 2006, https://doi.org/10.3846/btp.2006.09.
[20] A. Waqar *et al.*, “Modeling the Relation between Building Information Modeling and the Success of Construction Projects: A Structural-Equation-Modeling Approach,” *Applied Sciences*, vol. 13, no. 15, p. 9018, Aug. 2023, https://doi.org/10.3390/app13159018.
[21] T. Wang and H.-M. Chen, “Integration of building information modeling and project management in construction project life cycle,” *Autom Constr*, vol. 150, p. 104832, Jun. 2023, https://doi.org/10.1016/j.autcon.2023.104832.
[22] T. P. Nguyen, V.-A. Nguyen, D. D. Pham, and H. Q. Do, “Intergrating Building Information Modelling (BIM) and Tools with Green Building Certification System in Designing and Evaluating Water Efficiency of Green Building for Sustainable Buildings,” *IOP Conf Ser Mater Sci Eng*, vol. 1079, no. 3, p. 032063, Mar. 2021, https://doi.org/10.1088/1757-899X/1079/3/032063.
[23] Sunil Sharma, “Exploring the Impact of BIM on Construction Project in Reducing Life Cycle Cost,” *Journal of Information Systems Engineering and Management*, vol. 10, no. 23s, pp. 1000–1013, Mar. 2025, https://doi.org/10.52783/jisem.v10i23s.8166.
[24] M. Mayouf, J. Jones, F. Elghaish, H. Emam, E. M. A. C. Ekanayake, and I. Ashayeri, “Revolutionising the 4D BIM Process to Support Scheduling Requirements in Modular Construction,” *Sustainability (Switzerland)*, vol. 16, no. 2, 2024, https://doi.org/10.3390/su16020476.
[25] M. Parsamehr, U. S. Perera, T. C. Dodanwala, P. Perera, and R. Ruparathna, “A review of construction management challenges and BIM-based solutions: perspectives from the schedule, cost, quality, and safety management,” 2023. https://doi.org/10.1007/s42107-022-00501-4.
[26] R. M. Aziz, T. I. Nasreldin, and O. M. Hashem, “The role of BIM as a lean tool in design phase,” *Journal of Engineering and Applied Science*, vol. 71, no. 1, 2024, https://doi.org/10.1186/s44147-023-00340-3.
[27] Ardyn Sari Sinaga *et al.*, “Comparison of capital budgeting methods: NPV, IRR, PAYBACK PERIOD,” *World Journal of Advanced Research and Reviews*, vol. 19, no. 2, pp. 1078–1081, Aug. 2023, https://doi.org/10.30574/wjarr.2023.19.2.1483.
[28] J. Huang, “Comparison Between NPV and IRR: Evaluation of Investment,” *BCP Business & Management*, vol. 40, pp. 149–154, Mar. 2023, https://doi.org/10.54691/bcpbm.v40i.4373
[29] X. Chen, “Theoretical Analysis of Net Present Value,” *BCP Business & Management*, vol. 30, pp. 683–687, Oct. 2022, https://doi.org/10.54691/bcpbm.v30i.2517.
[30] Y. Zhao, “Research on the Ways to Appraise the Investment Based on NPV, Payback Period and IRR,” *Advances in Economics, Management and Political Sciences*, vol. 15, no. 1, pp. 359–366, Sep. 2023, https://doi.org/10.54254/2754-1169/15/20230947.
[31] “A Comparative Study on the Application of NPV and IRR in Financial Market Investment Decision,” *Academic Journal of Business & Management*, vol. 5, no. 4, 2023, https://doi.org/10.25236/AJBM.2023.050409.
[32] K. Zhang, “Comparative Analysis of NPV and IRR Indicators Based on Practical Applications,” *Highlights in Business, Economics and Management*, vol. 7, pp. 22–28, Apr. 2023, https://doi.org/10.54097/hbem.v7i.6815.
[33] Q. Sun, “Application Analysis of Internal Rate of Return Capital Budgeting Method in Project Investment Decision-Making,” *BCP Business & Management*, vol. 35, pp. 6–10, Dec. 2022, https://doi.org/10.54691/bcpbm.v35i.3219.
[34] S. Chen, “Net Present Value (NPV) Sensitivity Analysis: Understanding Risk in Investment Projects,” *Advances in Economics, Management and Political Sciences*, vol. 150, no. 1, pp. 186–194, Jan. 2025, https://doi.org/10.54254/2754-1169/2024.19301.
[35] C. A. Magni and A. Marchioni, “Average rates of return, working capital, and NPV-consistency in project appraisal: A sensitivity analysis approach,” *Int J Prod Econ*, vol. 229, p. 107769, Nov. 2020, https://doi.org/10.1016/j.ijpe.2020.107769.
[36] D. A. GUZHEV, “Analyzing the sensitivity of internal rate of return to the variable determination of initial investments in the life cycle to calculate the net present value of an investment project,” *Finance and Credit*, vol. 29, no. 7, pp. 1496–1513, Jul. 2023, https://doi.org/10.24891/fc.29.7.1496.
[37] P. Jovanović, “Application of sensitivity analysis in investment project evaluation under uncertainty and risk,” *International Journal of Project Management*, vol. 17, no. 4, pp. 217–222, Aug. 1999, https://doi.org/10.1016/S0263-7863(98)00035-0.
[38] G. Hazen and C. A. Magni, “Average internal rate of return for risky projects,” *Eng Econ*, vol. 66, no. 2, pp. 90–120, Apr. 2021, https://doi.org/10.1080/0013791X.2021.1894284.
[39] M. Sneps-Sneppe, “Use of criteria NPV and IRR for choosing among investment projects,” May 2023. https://doi.org/10.22616/ER-Dev.2023.22.TF146.
[40] V. Aarthipriya, G. Chitra, and J. S. Poomozhi, “Risk and its impacts on time and cost in construction projects,” *Journal of Project Management*, pp. 245–254, 2020, https://doi.org/10.5267/j.jpm.2020.6.002.
[41] W. Sulistiyowati, M. Suef, and M. L. Singgih, “Mapping Priority Improvements in Quality Improvement Projects: An Integrated Study of Quality and Risk Management,” *Journal of Posthumanism*, vol. 5, no. 5, Apr. 2025, https://doi.org/10.63332/joph.v5i5.1310.
[42] J. Deng and W. Jian, “Estimating Construction Project Duration and Costs upon Completion Using Monte Carlo Simulations and Improved Earned Value Management,” *Buildings*, vol. 12, no. 12, p. 2173, Dec. 2022, https://doi.org/10.3390/buildings12122173.
[43] A. Qazi and M. C. E. Simsekler, “Risk assessment of construction projects using Monte Carlo simulation,” *International Journal of Managing Projects in Business*, vol. 14, no. 5, pp. 1202–1218, Jul. 2021, https://doi.org/10.1108/IJMPB-03-2020-0097.
[44] F. Acebes, J. M. González-Varona, A. López-Paredes, and J. Pajares, “Beyond probability-impact matrices in project risk management: A quantitative methodology for risk prioritisation,” *Humanit Soc Sci Commun*, vol. 11, no. 1, p. 670, May 2024, https://doi.org/10.1057/s41599-024-03180-5.
[45] T. Servranckx, J. Coelho, and M. Vanhoucke, “Project management and scheduling 2022,” *Ann Oper Res*, vol. 338, no. 1, pp. 1–12, Jul. 2024, https://doi.org/10.1007/s10479-024-05971-0.

[46] A. Hassan, K. El-Rayes, and M. Attalla, “Stochastic scheduling optimization of repetitive construction projects to minimize project duration and cost,” *International Journal of Construction Management*, vol. 23, no. 9, pp. 1447–1456, Jul. 2023, https://doi.org/10.1080/15623599.2021.1975078.

[47] T. Dong, H. Li, and Z. Zhang, “The using effect of fuzzy analytic hierarchy process in project engineering risk management,” *Neural Comput Appl*, vol. 37, no. 12, pp. 7935–7945, Apr. 2025, https://doi.org/10.1007/s00521-023-09046-2.

[48] J. Cho, “Thriving in the global competitive landscape: competitive dynamics and longevity of emerging market firms,” *Asian Business & Management*, vol. 23, no. 1, pp. 82–109, Feb. 2024, https://doi.org/10.1057/s41291-023-00250-5.

[49] Wang Xiaoyang, “Research on the Importance of Project Pisk Management to Project Success,” *Journal of Information Systems Engineering and Management*, vol. 10, no. 33s, pp. 383–390, Apr. 2025, https://doi.org/10.52783/jisem.v10i33s.5542.

[50] Oleksandr Levchenko, “Mathematical Approaches to Economic Riskology in Project and Financial Management,” *Journal of Information Systems Engineering and Management*, vol. 10, no. 12s, pp. 25–35, Feb. 2025, https://doi.org/10.52783/jisem.v10i12s.1703.

[51] E. Lumnitzer, J. Fabianova, J. Janekova, A. Suhanyiova, and L. Suhanyi, “The Use of Simulations in Investment Decision-Making and Financing,” *International Journal of Simulation Modelling*, vol. 23, no. 1, pp. 113–124, Mar. 2024, https://doi.org/10.2507/IJSIMM23-1-677.

[52] Sakhawat Hussain Tanim, “Leveraging Predictive Analytics for Risk Identification and Mitigation in Project Management,” *Journal of Information Systems Engineering and Management*, vol. 10, no. 43s, pp. 1041–1052, May 2025, https://doi.org/10.52783/jisem.v10i43s.8523.

[53] D. H. Dorrah and B. McCabe, “Integrated Agent-Based Simulation and Game Theory Decision Support Framework for Cash Flow and Payment Management in Construction Projects,” *Sustainability*, vol. 16, no. 1, p. 244, Dec. 2023, https://doi.org/10.3390/su16010244.

[54] I. Primasari, “Project Investment Plan Valuation Using Discounted Cash Flow Analysis (Case Study of LLP Compression Project Investment Plan at Tango Field, Mehacca Block),” *European Journal of Business and Management Research*, vol. 7, no. 4, pp. 342–348, Aug. 2022, https://doi.org/10.24018/ejbmr.2022.7.4.1596.

[55] V. B. Nukala and S. S. Prasada Rao, “Role of debt-to-equity ratio in project investment valuation, assessing risk and return in capital markets,” *Future Business Journal*, vol. 7, no. 1, p. 13, Dec. 2021, https://doi.org/10.1186/s43093-021-00058-9.

[56] D. Gimpelevich, “Simulation-based excess return model for real estate development,” *Journal of Property Investment & Finance*, vol. 29, no. 2, pp. 115–144, Mar. 2011, https://doi.org/10.1108/14635781111112765.

[57] C. A. Magni and A. Marchioni, “Average rates of return, working capital, and NPV-consistency in project appraisal: A sensitivity analysis approach,” *Int J Prod Econ*, vol. 229, p. 107769, Nov. 2020, https://doi.org/10.1016/j.ijpe.2020.107769.

[58] Ministry of Construction, “Guidelines on certain contents for determining and managing construction investment costs (No. 11/2021/TT-BXD),” 2021.

[59] National Assembly, “Law on real estate business (No. 29/2023/QH15),” 2023.

[60] Ministry of Construction, “Announcement of construction investment capital rates and composite construction costs for structural components of projects in 2023 (No. 816/QĐ-BXD),” 2024.

[61] Ministry of Construction, “Circular on the issuance of construction norms (No. 12/2021/TT-BXD),” 2021.

[62] Ministry of Construction, “Circular on the issuance of QCVN 01:2021/BXD national technical regulation on construction planning (No. 01/2021/TT-BXD),” 2021.

[63] Ministry of Construction, “Circular on the issuance of QCVN 04:2021/BXD national technical regulation on apartment buildings (No. 03/2021/TT-BXD),” 2021.

[64] Ministry of Construction, “Circular on the issuance of QCVN 10:2024/BXD national technical regulation on construction ensuring accessibility (No. 06/2024/TT-BXD),” 2024.

[65] Ministry of Construction, “Guidelines for determining and managing costs of construction planning and urban planning (No. 20/2019/TT-BXD),” 2019.

[66] Ministry of Finance, “Regulations on the level, regime of collection, submission, management, and use of fees for appraisal of construction investment projects (No. 28/2023/TT-BTC),” 2023.

[67] Ministry of Finance, “Regulations on the level, regime of collection, submission, management, and use of fees for appraisal of environmental impact assessment reports conducted by central authorities (No. 38/2023/TT-BTC),” 2023.

[68] Government of Vietnam, “Regulations detailing certain provisions and measures for implementing the bidding law on contractor selection (No. 24/2024/NĐ-CP),” 2024.

[69] Ministry of Finance, “Regulations on the level, regime of collection, submission, management, and use of fees for appraisal and approval of fire prevention and fighting designs (No. 258/2016/TT-BTC),” 2016.

[70] Government of Vietnam, “Regulations on compulsory civil liability insurance for vehicle owners, compulsory fire and explosion insurance, and compulsory insurance in construction investment activities (No. 67/2023/NĐ-CP),” 2023.