Received: 3rd November 2025, Accepted: 13th November 2025, Published: 14th November 2025

INTERNATIONAL JOURNAL OF REAL ESTATE

IJRE

ISSN: 2476-8073

Integrating probabilistic risk analysis into property investment appraisal: evidence from Nigeria

Nnamani, Obinna Collins[1], **Onyekwelu**, Ezinne Ifeoma[1*], **Anih**, Stephen Chibuike[2], **Egbo**, Philips Nnajiofor[2], **Ajah**, Janefrances Nneka[2]

[1]Department of Estate Management, University of Nigeria, Enugu Campus, Enugu 400006, Enugu State, Nigeria
[2]Department of Estate Management, Enugu State University of Science and Technology, Agbani Campus, Agbani, 401002, Enugu State, Nigeria

*Corresponding Author: ezinne.onyekwelu@unn.edu.ng

DOI: *https://doi.org/10.5281/zenodo.17606583*

Abstract

This study examines the integration of probabilistic risk analysis into residential property investment appraisal in Nigeria; addressing the dominance of deterministic valuation techniques in emerging markets. Using a 15-year discounted cash flow (DCF) model and a case study of a six-unit block-of-flats residential property in Enugu, the research combines sensitivity analysis, scenario technique, and Hillier's standard deviation model into a unified "3S Risk Process Model." The approach quantifies investment uncertainty by generating probability distributions of returns and estimating the likelihood of achieving a target rate of return. Results identify target rate of return (TRR) and rental growth as the key determinants of investment performance, with a 61.03% probability of meeting the 10.5% TRR, indicating moderate risk exposure. The study demonstrates that probabilistic analysis provides a more rigorous and transparent framework for decision-making, offering implications for valuers, lenders, and policymakers seeking to strengthen evidence-based investment appraisal and promote resilience in Nigeria's real estate sector.

Keywords: Risks, Risk analysis, Investment appraisal, Property investment, Nigeria

Introduction

The investment environment is inherently dynamic, characterised by volatility, uncertainty, and increasing complexity. Nowhere is this more pronounced than in developing economies such as Nigeria, where macroeconomic instability, inflationary pressures, fluctuating exchange rates, and institutional weaknesses exacerbate investment risk (Nnamani, 2017). As Jovanovic (1999) observed, investors constantly confront an uncertain future, compelled to forecast outcomes under imperfect information to make rational and informed decisions. Within this context, property investment appraisal plays a pivotal role in determining the viability of real estate projects and guiding capital allocation (Baum et al., 2021; Sayce et al., 2009). However, traditional appraisal approaches adopted in Nigeria continue to rely predominantly on deterministic valuation techniques, such as the all-risks yield and single-scenario discounted cash flow (DCF) models, which implicitly assume certainty in future cash flows and discount rates (Orekan, and Bello, 2021; Nnamani, 2018).

While deterministic approaches offer simplicity, they obscure the stochastic nature of real estate variables such as rents, yields, costs, and growth rates (Park, 2025). These variables rarely evolve in a linear or predictable manner; instead, they are influenced by dynamic interactions among economic, political, and social factors (Park, 2025; Pfnür and Armonat, 2013). The consequence is a divergence between projected and actual returns, often manifesting in investment failure, project abandonment, and financial distress (Ogunba, 2004). Adjusting for risk through intuitive yield modifications, a common practice among Nigerian valuers, does little to quantify the probability or magnitude of adverse outcomes (Nnamani, 2018). This methodological inadequacy underscores the need for a paradigm shift from deterministic to probabilistic frameworks in property investment analysis (Orekan, and Bello, 2021; Adair and Hutchinson, 2005).

Probabilistic risk analysis, which explicitly models uncertainty by assigning probability distributions to key variables, has gained traction in mature real estate markets (French & Gabrielli, 2006). Techniques such as sensitivity testing, scenario modelling, and Monte Carlo simulation enable analysts to generate a spectrum of possible outcomes and evaluate their likelihoods. Yet, their adoption in Nigeria remains minimal due to limited data infrastructure, inadequate technical expertise, and the absence of locally adapted analytical tools (Abidoye and Chan, 2017; Ibiyemi

https://doi.org/10.5281/zenodo.17606583

& Tella, 2013). Consequently, investment appraisals in the country continue to lack the quantitative rigour necessary for informed risk-adjusted decision-making.

The present study addresses this methodological gap by demonstrating the integration of quantitative risk analysis techniques into residential property investment appraisal in Nigeria. Specifically, it develops and applies a unified "3S Risk Process Model," which synthesises sensitivity analysis, scenario technique, and Hillier's (1963) standard deviation probabilistic model within a 15-year discounted cash flow framework. This integrative approach represents a significant methodological innovation, as it operationalises probabilistic risk assessment in an emerging market context characterised by imperfect data and market inefficiencies. By estimating the expected Net Present Value (NPV), Internal Rate of Return (IRR), and the probability of achieving a target rate of return (TRR), the model provides a comprehensive, risk-adjusted depiction of investment performance.

The study aims, to demonstrate the application of robust quantitative risk analysis techniques in the appraisal of residential property investment, and this constitutes its central contribution. It moves beyond conventional deterministic practice to establish a replicable empirical framework capable of capturing the volatility inherent in Nigerian property markets. The approach not only quantifies uncertainty but also identifies the key drivers of investment performance, enabling practitioners to assess the likelihood of alternative outcomes.

Ultimately, this paper argues that mainstreaming probabilistic risk analysis in property investment appraisal can enhance methodological transparency, improve the predictive validity of valuation outputs, and foster investor confidence in Nigeria's real estate sector. By situating the methodological innovation within the empirical realities of the Nigerian market, the study provides a template for advancing evidence-based valuation practice in other emerging economies confronted by similar conditions of uncertainty.

Literature Review

Risk and Uncertainty in Property Investment Appraisal

Property investment decisions are inherently exposed to uncertainty and risk due to the long-term, capital-intensive, and cyclical nature of real estate markets (Ahiadu et al., 2024; Baum et al., 2021; Nnamani, 2017). Risk in property investment refers to the degree to which actual returns may deviate from expected outcomes (Hargitay & Yu, 1993). It arises when probabilities of outcomes can be assigned, whereas uncertainty denotes a state of incomplete knowledge where such probabilities cannot be reliably estimated (Kalu, 2001). This distinction is critical in investment appraisal because while risk can be quantified and managed through statistical and probabilistic models, uncertainty often requires judgmental and adaptive responses.

Conventional property appraisal techniques, such as discounted cash flow (DCF), net present value (NPV), and internal rate of return (IRR), treat risk implicitly through the adjustment of discount rates or yield parameters. However, these deterministic methods assume fixed estimates for key input variables such as rents, construction costs, and yields. This assumption masks the inherent variability of these parameters, thereby producing point estimates that may not reflect actual project outcomes (Adair and Hutchinson, 2005). As a result, traditional appraisals may underestimate potential downside risks or overstate the likelihood of achieving projected returns, particularly in volatile or data-constrained markets like Nigeria (Nnamani, 2018).

In developed economies, probabilistic techniques have been increasingly adopted to complement deterministic models by explicitly modelling uncertainty. French and Gabrielli (2006) highlight that Monte Carlo simulation, sensitivity analysis, and scenario analysis are now integral to advanced investment appraisals, allowing analysts to evaluate the distribution of possible returns rather than a single outcome. Such approaches enhance transparency and provide investors with richer information about risk-return trade-offs. Yet, their application remains limited in emerging markets, where data scarcity, technical constraints, and limited expertise persist (Ibiyemi and Tella, 2013).

https://doi.org/10.5281/zenodo.17606583

Risk Analysis Techniques in Property Investment

Risk analysis is not a substitute for standard appraisal procedures but an enhancement that quantifies variability in expected outcomes and supports more informed decision-making (Savvides, 1994). By integrating risk analysis into appraisal, investors can assess not only the expected value of returns but also the likelihood of achieving those returns. This integration serves several vital functions (Savvides, 1994):

First, risk analysis strengthens decisions on marginal projects. Projects with modest or borderline NPVs may still be accepted if probabilistic analysis shows a high probability of achieving acceptable returns. Conversely, a project with an apparently attractive NPV may be rejected if its downside risk is excessive. Second, it facilitates preliminary screening of project ideas by providing a means to assess uncertainty before incurring high feasibility study costs. Early-stage probabilistic modelling enables investors to identify projects with favourable risk-return profiles and abandon those that are too uncertain.

Third, risk analysis identifies project areas that require further investigation. By revealing which input variables contribute most to outcome variance, it guides data collection and feasibility research, reducing the cost of information gathering. Fourth, it allows projects to be reformulated to align with investor risk preferences. For instance, financing structures or lease terms can be adjusted to mitigate exposure to volatile variables such as inflation or occupancy rates.

In addition, risk analysis reduces evaluation bias by discouraging analysts from resorting to conservative assumptions to compensate for uncertainty. It also promotes the effective use of expert judgment: decision-makers can express uncertainty through probability distributions rather than single-value estimates. This participatory process bridges communication between analysts and executives, fostering shared understanding of project risk. Finally, probabilistic approaches enable post-project evaluation by comparing predicted distributions with actual outcomes, thereby improving learning and model refinement over time.

The techniques used in risk analysis can be broadly categorised into qualitative and quantitative methods, depending on the availability of data and analytical objectives (PMBOK, 2017, COSO, 2004). Qualitative techniques rely primarily on judgment, experience, and expert opinion. They are suitable for preliminary assessments or contexts with limited numerical data. Common qualitative methods include brainstorming, structured interviews, Delphi technique, and expert scoring systems. These methods facilitate the identification and ranking of key risks but provide limited insight into the magnitude or probability of potential outcomes.

By contrast, quantitative techniques employ mathematical models to estimate the likelihood and impact of risk factors. They allow investors to move from subjective impressions toward objective measurement of uncertainty. Quantitative risk analysis in property appraisal can be grouped into benchmarking, non-probabilistic, and probabilistic methods (COSO, 2004). Benchmarking involves comparing project parameters or risk indicators with industry standards or historical performance data. Non-probabilistic models, such as sensitivity and scenario analyses, examine the responsiveness of project outcomes to changes in key variables. Probabilistic models, notably Monte Carlo simulation, explicitly quantify uncertainty by assigning probability distributions to input variables and generating a range of possible outcomes (Huikku, et al., 2025; COSO, 2004).

Quantitative Risk Analysis Techniques

Among quantitative approaches, sensitivity analysis is the simplest and most widely used (Bock and Truck, 2011). It tests how changes in a single variable, such as rent or rental growth rate, target rate of return, holding period, interest rate, or exit yield affect investment viability while holding other variables constant (Wyatt, 2007). Boyd (2002) emphasizes that this technique helps identify critical variables that most influence project performance, guiding risk management priorities. However, sensitivity analysis is limited because it ignores the joint variation of multiple parameters and provides no information about probability or likelihood (Sayce et al., 2006).

Scenario analysis extends this logic by evaluating project outcomes under discrete sets of assumptions, commonly optimistic, most likely, and pessimistic scenarios (MacFarlane, 1995). It enables investors to explore how combinations of factors might influence returns and to assess resilience under extreme conditions. Despite being intuitive and easy to apply, scenario analysis

https://doi.org/10.5281/zenodo.17606583

still depends on a small number of arbitrarily defined cases and lacks the statistical rigor of probabilistic models (Sayce et al., 2006; Mietzner and Reger, 2005).

The most comprehensive approach is probabilistic analysis, which incorporates the randomness of multiple variables simultaneously. Hillier (1963) was among the first to propose a probabilistic model for deriving the standard deviation of project NPV, thereby enabling estimation of the probability of achieving a target return. Subsequent developments, such as Monte Carlo simulation, automate this process by randomly sampling from input distributions to generate thousands of potential outcomes (Pfnür and Armonat, 2013). The result is a probability distribution of NPVs or internal rates of return that provides a complete picture of project risk.

Probabilistic techniques, therefore, offer a more realistic and transparent representation of uncertainty in property investment appraisal (Nnamani, 2018). They enable decision-makers to quantify the probability of success or failure, evaluate downside risk, and compare investment projects based on both expected returns and risk dispersion. Furthermore, probabilistic outputs, such as cumulative probability curves, support communication of complex risk information in a form easily interpretable by investors and lenders.

However, despite their analytical robustness, probabilistic models remain underutilised in many developing economies. Ibiyemi and Tella (2013) attribute this to limited data availability, lack of technical expertise, and inadequate computational resources. In Nigeria, appraisers often rely on deterministic methods due to absence of reliable time-series data and industry-standard software. Consequently, investment evaluations may not fully account for risk, leading to suboptimal decisions and financial distress during market downturns (Nnamani, 2017).

The integration of probabilistic analysis into property investment appraisal thus represents both a methodological advancement and a practical necessity. By bridging the gap between deterministic and empirical approaches, it enhances the realism and reliability of investment evaluations. As real estate markets in Nigeria continue to evolve, adopting probabilistic techniques such as Monte

Carlo simulation can improve transparency, investor confidence, and the efficiency of capital allocation.

Methodology

Case study

A 6-unit, 3-bedroom residential property in New Haven, Enugu was selected as a representative buy-to-let investment. Data were collected through market surveys of comparable rents across six neighbourhoods over a 10-year period (2006–2015) and from interviews with estate surveyors.

An individual investor through an estate surveyor and valuer purchased a 6 no. 3-bedroom flat residential accommodation at New Haven at the cost of ₦30,000,000 (Thirty million naira only) for investment purpose. The property was purchased in June 2013. The tenants vacated the building by end of 2014 and refurbishment was carried out in 2015. The blocks of flat were leased January, 2016. The subsisting interest in the property is a freehold interest.

Data:

Purchase cost	₦30,000,000
Incidental cost of purchase:	
Registration (power of attorney)	₦200,000
Agency fee (5% of purchase cost)	₦1,500,000
Refurbishment cost	₦14,000,000

Property investment analysis: 15 year model

Capital outlay	₦45,700,000
Gross rental value	₦3,000,000 (₦500,000/flat)
Outgoings:	
Management	5% p.a. (Gross rental value)
Insurance	2% p.a. (Gross rental value)
Property rate	₦30,000 p.a.
Void	0%
Exit yield	6% (standard deviation 0.88%)
Rent review period	3 years (Enugu State L & T Laws 2015)
Rental growth rate	4.77% (Max) (Enugu State L & T Laws 2015)

https://doi.org/10.5281/zenodo.17606583

Target rate of return (TRR) 10.5% (Assumed)

Assumptions:

- All cash flows are assumed to be received or paid at the end of each year.
- There is 100 per cent equity in the investment.
- No major repair work is envisaged since the property was currently refurbished.

Model Framework

The analysis used a 15-year DCF model, discounting projected cash flows at a target rate of return of 10.5%. Three techniques were integrated:

- Sensitivity Analysis: Identified TRR, rental value, rental growth, and exit yield as key variables.
- Scenario Analysis: Constructed pessimistic, realistic, and optimistic cases, varying rental growth and exit yield to assess NPV under alternative futures.
- Hillier's Model: Computed standard deviation of NPV and derived probability of achieving positive NPV and meeting TRR.

Hillier (1963) demonstrates the use of standard deviation in analysing risky investments under specific assumptions, deriving formulas for investments with mutually independent and perfectly correlated cash flows. For mutually independent cash flows, the formula is:

$$\sigma^2_{NPV} = \left[\sum_{t=1}^{n} \frac{\sigma^2_{CFt}}{(1+i)^{2t}}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Also, for perfectly correlated cash flows, then the following relationship holds:

$$\left[\sum_{t=1} \frac{\sigma_{CFt}}{(1+i)^t}\right]^2$$

$$\sigma^2_{NPV} = \left[\sum^{n} \text{——}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Modifying Hillier's model for a property investment with rent reviewed every *t* years, the expected net present value of symmetrically distributed rental cash flows (CF) is expressed as:

$$NPV = -1 + \sum_{t=1}^{n} \frac{CF_1}{(1+i)^t} + \sum_{t=n+1}^{2n} \frac{CF_2}{(1+i)^t} + \sum_{t=2n+1}^{3n} \frac{CF_3}{(1+i)^t} + \ldots + \frac{EV}{(1+i)^{Rn}} \quad (3)$$

Where I = initial acquisition cost

EV= exit capital value (in Rn years time)

n = number of year between regular rent reviews

R = number of review cycles

i = discount rate

Varaince of the expected net present value

$$\sigma^2_{NPV} = \left[\sum_{t=1}^{n} \frac{\sigma_{CF1}}{(1+i)^t}\right]^2 + \left[\sum_{t=n+1}^{2n} \frac{\sigma_{CF2}}{(1+i)^t}\right]^2 + \left[\sum_{t=2n+1}^{3n} \frac{\sigma_{CF3}}{(1+i)^t}\right]^2 + \left[\frac{\sigma^2_{EV}}{(1+i)^{2Rn}}\right] \ldots\ldots(4)$$

It is assumed that rental cash flows within each cycle are perfectly correlated, while those between cycles are independent; the standard deviation equals the square root of the variance.

Standard deviation of the rental income

Future rental cash flows are projected using the rental growth rate over the investment's holding period. If the current rent is *cf* and the annual growth rate is *g%*, the rent in *t* years, *CF*, is:

$$CF = cf(1+g)t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

If the standard deviation of the rental growth rate is assessed to be σg, then the standard deviation of the rental income for each rent review cycle will be given by:

https://doi.org/10.5281/zenodo.17606583

$$\sigma_{CF} = \frac{cft\ \sigma g}{(1+g)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

To estimate the standard deviation of rental growth, the appraiser identifies maximum and minimum growth rates; their difference approximates three standard deviations, so dividing it by three gives an indirect estimate of one standard deviation.

Standard deviation of the terminal capital value

The exit capital value (EV) depends on two parameters – the projected rental cash flow at the exit period and the forecast capitalization rate (exit yield); represented as

$$EV = R/y$$

Where EV = exit capital value

R = annual rental income

y = exit capitalization rate

Both R and y contribute to the uncertainty of the capital value since they must be estimated to determine EV. R and y are independent variable and their standard deviations can be represented by the following relationships:

$$\sigma_{EV} = \left[\frac{\partial EV \sigma_R}{\partial R}\right]^2 + \left[\frac{\partial EV \sigma_Y}{\partial Y}\right]^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$\partial EV/\partial R$ denotes the rate of change of the capital value with respect to rental value (with capitalization rate held constant), and $\partial EV/\partial y$ represents the rate of change of the capital value with respect to the capitalisation rate (with rental value held constant). These first partial derivatives are formally expressed as:

$$\partial EV/\partial R = 1/y \text{ and } \partial EV/\partial y = -R/y^2$$

Therefore substituting the partial derivative in equation (7), the variance of the terminal capital value is given as:

$$\frac{1}{y}\sigma R^2 \qquad \frac{R}{y^2}\sigma Y^2$$

$$\sigma^2_{EV} = \left[\quad\right] + \left[\quad\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where σ_R = standard deviation of the rental cash flow at the exit period

σy = standard deviation of the exit yield

Standard Deviation of Internal Rate of Return (IRR)

Risk in terms of internal rate of return (IRR) is assessed using a given discount rate; the probability of NPV < 0 equals that of IRR < discount rate. By varying discount rates, a cumulative probability distribution is formed, from which the expected IRR (at 50% probability) and its standard deviation are derived.

Data analysis

Calculations produced expected NPV, probability distributions, and IRR. The standard deviation was estimated from rental growth rate variability, using maximum and minimum growth estimates to derive σg.

Results

TABLE 1. DCF appraisal to identify expected net present value

Year	(₦) Expected cash inflow (Best estimate)	Expected cash out flow (₦)	Expected Net Cash flows (₦)	Discount Factor (10.5%)	Expected Net Present Cash flows (₦)
0	-	45,700,000	-45,700,000	1	-45,700,000
1	3,000,000	240,000	2,760,000	0.9045	2,496,420
2	3,000,000	240,000	2,760,000	0.8190	2,260,440
3	3,000,000	240,000	2,760,000	0.7412	2,045,712
4	3,450,103	271,507	3,178,596	0.6707	2,131,884
5	3,450,103	271,507	3,178,596	0.6070	1,929,408
6	3,450,103	271,507	3,178,596	0.5493	1,747,003
7	3,967,737	307,742	3,659,995	0.4971	1,819,384
8	3,967,737	307,742	3,659,995	0.4499	1,646,632
9	3,967,737	307,742	3,659,995	0.4071	1,489,984
10	4,563,034	349,412	4,213,622	0.3684	1,552,298
11	4,563,034	349,412	4,213,622	0.3334	1,404,822
12	4,563,034	349,412	4,213,622	0.3017	1,271,250
13	5,247,647	397,335	4,850,312	0.2731	1,324,620
14	5,247,647	397,335	4,850,312	0.2471	1,198,512
15	5,247,647	397,335	4,850,312	0.2236	1,08,530
15	100,582,900	5,029,145	95,553,755	0.2236	21,365,820

https://doi.org/10.5281/zenodo.17606583

NPV = 1,074,737

TABLE 2. DCF appraisal to identify internal rate of return (IRR)

Year	(₦) Expected cash inflow (Best estimate)	Cash out flow (₦)	Expected net cash flows (₦)	Discount factor (12%)	Disconnected expected net present cash flows (₦)
0	-	45,700,000	-45,700,000	-	-45,700,000
1	3,000,000	240,000	2,760,000	0.8929	2,464,404
2	3,000,000	240,000	2,760,000	0.7972	2,200,272
3	3,000,000	240,000	2,760,000	0.7118	1,964,568
4	3,450,103	271,507	3,178,596	0.6355	2,019,998
5	3,450,103	271,507	3,178,596	0.5674	1,803,535
6	3,450,103	271,507	3,178,596	0.5066	1,610,277
7	3,967,737	307,742	3,659,995	0.4523	1,655,416
8	3,967,737	307,742	3,659,995	0.4039	1,478,272
9	3,967,737	307,742	3,659,995	0.3606	1,319,794
10	4,563,034	349,412	4,213,622	0.3220	1,356,786
11	4,563,034	349,412	4,213,622	0.2875	1,211,416
12	4,563,034	349,412	4,213,622	0.2567	1,081,637
13	5,247,647	397,335	4,850,312	0.2292	1,111,692
14	5,247,647	397,335	4,850,312	0.2046	992,374
15	5,247,647	397,335	4,850,312	0.1827	886,152
16	100,582,900	5,029,145	95,553,755	0.1827	17,457,671

NPV = -5,085,736

$$IRR = R_1 + (R_2 - R_1) \times \frac{NPV@R_1}{NPV@R_1 = NPV@R_2}$$

$$= 10.5 = (12 - 10.5) \times \frac{1,067,719}{}$$

1,067,719 + 5,085,736

Expected IRR = 10.76%

Sensitivity Analysis

Table 3. Sensitivity analysis

Variable	Percentage change (%)	Revised ENPV (₦)	Increase/Decrease	Percentage change	Sensitivity factor
Rental Value	+10	5,086,621	4,011,884	373	37.31
Rental Growth	+10	3,194,844	2,120,107	197	19.7
Exit Yield	+10	-868,030	-1,942,767	181	18.1
Target Rate	+10	-3,358,140	-4,432,877	413	41.3
Holding Period (30yrs)	+50	798,627	-276,110	25.69	0.5
Rental Value	-10	12,937,166	-4,011,903	373	37.3
Rental Growth	-10	-918,571	-1,993,308	185	18.5
Exit yield	-10	3,449,232	2,374,495	221	22.1
Target Rate	-10	6,141,712	5,066,975	471	47.1
Holding Period (6yrs)	-40	1,420,949	346,210	32.2	0.81

The sensitivity analysis results from table 3 show that for this particular investment, the most sensitive variable is the target rate of return (TRR), followed by the rental value. The rental growth rate and the exit yield have almost the same sensitivity factor. The holding period is not a sensitive variable as indicated by the sensitivity factor having identified the most sensitive factors. (target rate of return (TRR), rental value, rental growth rate an exit yield), further analysis on these factors will be conducted in order to establish the likelihood or variability and the range of values that could be expected for a more objective decision.

Scenario Analysis

Table 4. Scenario analysis summary using (± 10%)

	Pessimistic	Realistic	Optimistic
Changing variables	**(-10%)**	**-**	**(+10%)**
Rental value (₦)	2,700,000	3,000,000	3,300,000
Rental growth rate (%)	4.293	4.77	5.247
Exit yield (%)	6.6 (+10%)	6	5.4 (-10%)
Target rate of return (%)	11.55 (+10%)	10.5	9.45(-10%)

https://doi.org/10.5281/zenodo.17606583

NPV	**-9,931,796**	**1,074,737**	**16,517,439**

Table 5. Scenario analysis summary using (± 5%)

	Pessimistic	**Realistic**	**Optimistic**
Changing variables	**(-5%)**	**-**	**(+5%)**
Rental value (₦)	2,850,000	3,000,000	3,150,000
Rental growth rate (%)	4.5315	4.77	5.0085
Exit yield (%)	6.3 (+5%)	6	5.7 (-5%)
Target rate of return (%)	11.025 (+5%)	10.5	9.975(-5%)
NPV	**-5,893,254**	**1,074,737**	**8,175,056**

Table 6. Discrete scenario with probabilities for NPVs

Scenarios	**NPVs (N)**	**Probability**	**Weighted NPVs (NPV x probability)**
Pessimistic	-9,931,796	0.04	-397,271.84
Slightly pessimistic	-5,893,254	0.20	-1,178,650.8
Realistic	1,074,737	0.60	644,842.2
Slight optimistic	8,125,056	0.13	1,056,257.28
Optimistic	16,517,439	0.03	495,523.17
Weighted Ave. NPV (₦)	-	**1.00**	**620,799.01**

In table 6, the probability distribution of the NPVs is skewed towards pessimism since the investor would be interested in the downside risk. The result indicated that the weighted average NPV ₦620,800 is lower than the expected net present value of ₦1,074,737. Since the weighted average NPV is positive, the investor can still proceed with the investment project.

Adaptation of Hillier Model

A. Calculating Standard Deviation of the NPV

Table 7. Projection of rental value growth rate (% p.a.)

Period in years	Best estimate	Almost certain	Standard deviation
0 – 3	4.77	3.57	0.40
0 – 6	4.77	3.52	0.42
0 – 9	4.77	3.48	0.43
0 – 12	4.77	3.35	0.47
0 – 15	4.77	2.87	0.63

Table 8. Expected values of each annual cash flow with their respective standard deviations

Year	(₦) Expected cash inflow (Best estimate)	Expected cash out flow (₦)	Expected Net Cash flows (₦)	Calculated Standard Deviation (₦)
0	-	45,700,000	-45,700,000	0
1	3,000,000	240,000	2,760,000	0
2	3,000,000	240,000	2,760,000	0
3	3,000,000	240,000	2,760,000	0
4	3,450,103	271,507	3,178,596	36,407
5	3,450,103	271,507	3,178,596	36,407
6	3,450,103	271,507	3,178,596	36,407
7	3,967,737	307,742	3,659,995	88,033
8	3,967,737	307,742	3,659,995	88,033
9	3,967,737	307,742	3,659,995	88,033
10	4,563,034	349,412	4,213,622	155,643
11	4,563,034	349,412	4,213,622	155,643
12	4,563,034	349,412	4,213,622	155,643
13	5,247,647	397,335	4,850,312	261,103
14	5,247,647	397,335	4,850,312	261,103
15	5,247,647	397,335	4,850,312	261,103
15	100,582,900	5,029,145	95,553,755	16,892,254

https://doi.org/10.5281/zenodo.17606583

Using the target rate of return to discount the net cash flow, the expected net present value is calculated to be ₦1,074,737 using equation (3). The standard deviation is estimated to be ₦3,788,599 using equation (4). In dividing the expected NPV by the standard deviation, it could be seen that the NPV takes on a value of zero at 0.28 standard deviations from the mean. Using the normal tables, the area under the curve to the left-hand side of zero NPV is 38.97% of the total distribution, and hence the area to the right-hand side is 61.03%. For the investment, the result shows that there is 38.97% chance of not achieving a positive NPV. Invariably, there is 61.03% chance of achieving the target rate of return (10.5% per annum). This distribution is represented in the figure 1 below.

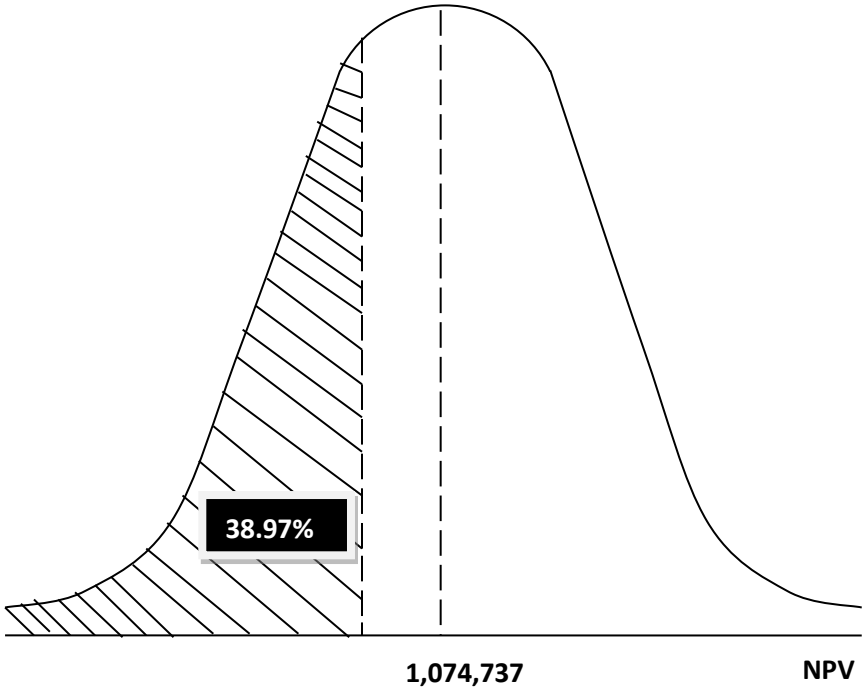

Fig 1. Probability distribution of case study property investment

B. Calculating internal rate of return (IRR) and the Standard Deviation

With the given discount rate (10.5%), the probability of NPV being less than zero is the same as the probability of the IRR being less than the selected discount rate. It has been demonstrated how for a given discount, the probability of not achieving the level of return could be calculated. In repeating the procedure for a range of values of discount rate, a cumulative probability is built as shown in table 9. The data in the table is presented in a graph shown in figure 2. The expected value of IRR is precisely the value where the cumulative probability is 50%. The standard

deviation of the IRR is derived from the graph as a cumulative probability of 15.87% which occurs 1 standard deviation below the mean of expected value. Thus, for the case study property investment, the expected IRR is 10.76%; while the standard deviation is 0.89%.

Table 9. Calculating internal rate of return (IRR) and standard deviation

Discount rate (%)	ENPV (₦) (a)	Standard deviation (b)	Z = a/b	Probability of return being less than discount rate (%)
7.0	21,052,130	6,136,506	3.45	0.0
7.5	17,603,526	5,723,427	3.07	0.1
8.0	14,377,867	5,338,038	2.69	0.4
8.5	11,359,147	4,981,009	2.28	1.1
9.0	8,532,595	4,649,499	1.84	3.3
9.5	5,884,578	4,341,270	1.36	8.7
10.0	3,402,503	4,054,830	0.84	20.1
10.5	1,074,737	3,788,599	0.28	38.6
11.0	-1,109,472	3,540,880	-0.29	61.4
11.5	-3,160,069	3,310,401	-0.95	82.9
12.0	-5,086,252	3,095,760	-1.64	95.0
12.5	-6,896,535	2,895,993	-2.38	99.0
13.0	-8,598,800	2,709,910	-3.17	100.0

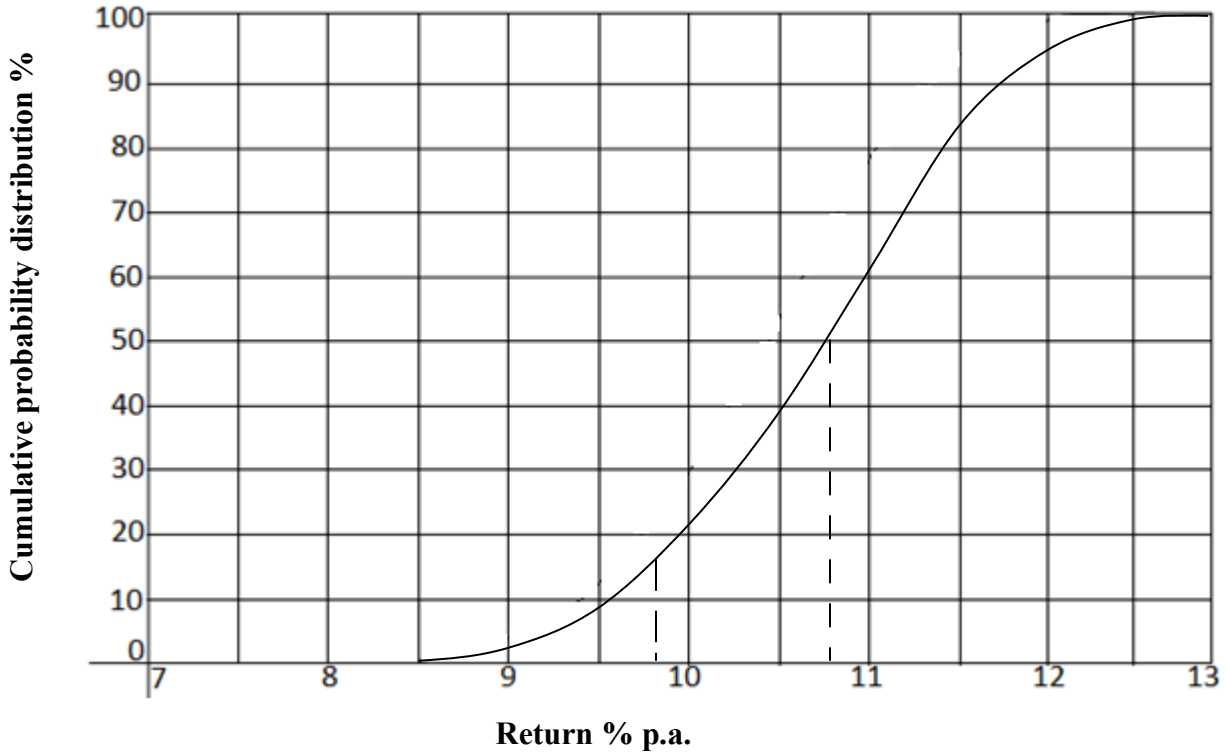

Fig 2. Cumulative probability distribution curve of case study property investment

https://doi.org/10.5281/zenodo.17606583

Summary of Results

The analysis began with a sensitivity test to identify variables that significantly influence investment returns. Target Rate of Return (TRR), rental value, rental growth, and exit yield were found to be the most sensitive, with TRR and rental growth exerting the strongest effect on Net Present Value (NPV).

Scenario analysis was then employed to examine three possible futures: pessimistic, realistic, and optimistic. Under pessimistic assumptions, the NPV turned negative, indicating potential capital loss. The realistic scenario produced an NPV of ₦1,074,737, while the optimistic scenario showed substantial capital appreciation. These results underscored the importance of incorporating multiple possible futures when appraising property investments in volatile markets.

Hillier's probabilistic model was applied to calculate the expected IRR and its variability. The expected IRR was found to be 10.76% with a standard deviation of 0.89%, implying a 61.03% probability of achieving the target return of 10.5% per annum. This probabilistic insight allows investors to make decisions with a quantified understanding of downside risk.

The combined 3S approach, sensitivity analysis, scenario technique, and standard deviation, provided a richer picture of risk exposure than traditional single-point valuation methods. It demonstrated that risk in property investment can be explicitly measured, rather than treated as an implicit yield adjustment.

This chapter advances the field of property investment appraisal by demonstrating that risk can be systematically measured and managed using a combined probabilistic framework. The proposed 3S Risk Process Model provides a practical roadmap for investors, valuers, and policymakers seeking to improve investment decision-making and reduce project failure rates in emerging real estate markets.

Discussion

The application of the integrated 3S Risk Process Model in this study provides strong empirical evidence that property investment appraisal in Nigeria can be conducted with greater

methodological rigour through explicit modelling of uncertainty. By combining sensitivity analysis, scenario technique, and Hillier's probabilistic model, the framework moves beyond the deterministic tradition that dominates Nigerian valuation practice and offers a replicable approach for quantifying investment risk. This integrated process transforms the conventional appraisal paradigm from a single-point estimate to a probabilistic depiction of returns, where each input variable contributes to an overall distribution of outcomes rather than a fixed value.

The results demonstrate that the Target Rate of Return (TRR) and rental growth rate are the most influential determinants of project viability, corroborating findings in previous international research that income dynamics are the key drivers of investment performance. More importantly, the probabilistic assessment revealed a 61.03% chance of achieving the target TRR of 10.5%, suggesting moderate but acceptable exposure to risk. This explicit probability measure introduces a decision-making advantage previously unavailable in deterministic appraisals, where risk was inferred rather than quantified. Investors can now evaluate downside risk in numerical terms and align investment decisions with their risk tolerance levels.

The practical implications of this finding are multifold. For valuers, the model provides an evidence-based structure for embedding risk measurement into appraisal reports, enhancing professional credibility and compliance with global valuation standards that increasingly demand transparency in risk disclosure. For lenders and institutional investors, the generation of probability-weighted outcomes facilitates better credit risk assessment and capital allocation decisions. Policymakers can also benefit from such analytical frameworks by understanding how market volatility influences investment feasibility and by designing fiscal and regulatory interventions that mitigate systemic uncertainty.

Beyond its empirical contributions, the 3S Model demonstrates that sophisticated quantitative techniques can be adapted to data-constrained environments like Nigeria through methodological ingenuity. The successful integration of probabilistic methods using locally sourced data dispels the notion that such techniques are infeasible in emerging markets. It underscores the transformative potential of probabilistic appraisal in promoting evidence-based valuation, improving investor confidence, and ultimately advancing the maturity of Nigeria's real estate investment market.

https://doi.org/10.5281/zenodo.17606583

Conclusion and Recommendations

This study has demonstrated that the integration of probabilistic risk analysis into property investment appraisal significantly enhances the robustness and transparency of decision-making in emerging real estate markets such as Nigeria. By uniting sensitivity analysis, scenario technique, and Hillier's standard deviation model into a single analytical framework, the 3S Risk Process Model, the study provides empirical evidence that uncertainty in investment performance can be quantified rather than merely inferred. The findings reveal that the target rate of return (TRR) and rental growth are the most critical variables influencing investment outcomes, confirming that income assumptions remain central to the viability of residential property projects. The generation of probability distributions of returns and explicit likelihood measures offers investors, valuers, and lenders a more objective basis for assessing both downside exposure and upside potential.

The study further underscores the methodological potential of adapting advanced quantitative techniques to the realities of data-constrained markets. In doing so, it provides a pathway for professional valuers to align domestic practice with international standards of risk-adjusted appraisal, while equipping policymakers with tools for evidence-based intervention. To consolidate these gains, professional bodies such as the Nigerian Institution of Estate Surveyors and Valuers (NIESV) should promote capacity building in quantitative and probabilistic techniques through continuous professional education. Developing centralized and transparent property market databases would also enhance data reliability, enabling more accurate risk modelling. Furthermore, the creation of indigenous software for risk-adjusted appraisal would make probabilistic analysis more accessible to practitioners.

Mainstreaming these innovations will not only elevate professional practice but also improve investor confidence, reduce valuation uncertainty, and contribute to the development of a resilient and evidence-driven property investment environment in Nigeria.

Although the study demonstrates the practicality of integrating probabilistic risk analysis into property investment appraisal, certain limitations must be acknowledged. The analysis was based on a single residential case study in Enugu, which, while methodologically rigorous, may not capture the full heterogeneity of Nigeria's property markets. The reliability of the probabilistic

outputs also depended on the quality and availability of market data, which remain limited due to the absence of a centralised property information system. Future research should therefore extend the application of the 3S Risk Process Model to a broader range of property types and geographical contexts to test its generalizability. Comparative studies incorporating Monte Carlo simulation, decision-tree modelling, and portfolio-level analysis could further refine the framework and establish benchmarks for probabilistic risk-adjusted appraisal in emerging markets.

References

Abidoye, R. B., & Chan, A. P. (2017). Modelling property values in Nigeria using artificial neural network. *Journal of Property Research*, 34(1), 36-53. https://doi.org/10.1080/09599916.2017.1286366

Adair, A., & Hutchinson, N. (2005). The reporting of risk in real estate appraisal property risk scoring. *Journal of Property Investment & Finance*, 23(3), 254-268. https://doi.org/10.1108/14635780510599467

Ahiadu, A. A., Abidoye, R. B., & Yiu, T. W. (2024). Decision-making amid economic uncertainty: exploring the key considerations of commercial property investors. *Buildings*, 14(10), 3315. https://doi.org/10.3390/buildings14103315

Baum, A. E., Crosby, N., & Devaney, S. (2021). *Property investment appraisal*. John Wiley & Sons.

Bock, K., & Trück, S. (2011). Assessing uncertainty and risk in public sector investment projects. *Technology and Investment*, 2(2), 105-123. https://doi.org/10.4236/ti.2011.22011.

Boyd, T. (2002). Property cash flow studies: focusing on model consistency and data accuracy. Queensland University of Technology: CRC Construction Innovation.

COSO (2004). *Enterprise risk management – integrated framework: Executive summary*. Durham: Committee of Sponsoring Organisations of the Treadway Commission (COSO).

French, N., & Gabrielli, L. (2006). Uncertainty and feasibility studies: an Italian case study. *Journal of Property Investment and Finance*, 24(1), 49-67. https://doi.org/10.1108/14635780610700732

Hargitay, S. E., & Yu, S. (1993). *Property investment decisions*. London: E & FN Spon.

Hillier, F. S. (1963). The derivation of probabilistic information for the evaluation of risky investments. *Management Science*, 9(3), 443-457. https://doi.org/10.1287/mnsc.9.3.443

Huikku, J., Karjalainen, J., & Seppälä, T. (2025). Strategic factors and the use of risk analysis techniques in strategic investment decisions. *Accounting and Business Research*, 1-29. https://doi.org/10.1080/00014788.2025.2486753

Ibiyemi, A., & Tella, E. (2013). Critical issues in economic risk consideration by commercial property investors and valuers in Nigeria. *International Journal of Emerging Science and Engineering*, 1(12), 35-43.

Jovanovic, P. (1999). Application of sensitivity analysis in investment project evaluation under uncertainty and risk. *International Journal of Project Management*, 17(4), 217-222. https://doi.org/10.1016/S0263-7863(98)00035-0

Kalu, I. U. (2001). *Property Valuation and Appraisal*. Owerri: Bon Publications.

MacFarlane, J. (1995). The use of simulation in property investment analysis. *Journal of Property Valuation and Investment*, 13(4), 25-38. https://doi.org/10.1108/14635789510099427

Mietzner, D., & Reger, G. (2005). Advantages and disadvantages of scenario approaches for strategic foresight. *Int. J. Technology Intelligence and Planning*, 1(2), 220-239.

Nnamani, O. C. (2017). Application of quantitative risk assessment techniques in property investment appraisal in Enugu Urban, Nigeria. *Journal of Land Management and Appraisal*, *5*(1), 23-41.

Nnamani, O. C. (2018). *Application of Quantitative Risk Analysis Techniques: In the Investment Appraisal of Residential Properties in Enugu Urban, Nigeria*. LAP LAMBERT Academic Publishing.

Ogunba, A. O. (2004). Globalization and risk management in development appraisal: challenges before Nigeria. *International Symposium on Globalisation and Construction*, Bangkok, Thailand.

Orekan, A. A., & Bello, K. A. (2021). A critical evaluation of conventional methods of appraisal and its materiality on the growth explicit models of valuation. *Covenant Journal of Research in the Built Environment*, 9(2), 36-47

Park, D. (2025). Basic Stochastic Framework for Designing and Understanding Real Estate Models. *International Journal of Financial Research*, 16(1), 35-49. https://doi.org/10.5430/ijfr.v16n1p35

Pfnür, A., & Armonat, S. (2013). Modelling uncertain operational cash flows of real estate investments using simulations of stochastic processes. *Journal of Property Investment & Finance*, 31(5), 481-501. https://doi.org/10.1108/JPIF-12-2012-0061

PMBOK (2017). *A Guide to the Project Management Body of Knowledge* (PMBOK® Guide). 6th ed. Project Management Institute.

Savvides, S. C. (1994). Risk analysis in investment appraisal. *Project Appraisal*, 9(1), 3-18. https://doi.org/10.1080/02688867.1994.9726923

Sayce, S., Smith, J., Cooper, R., & Venmore-Rowland, P. (2009). *Real Estate Appraisal: from value to worth*. John Wiley & Sons.

Wyatt, P. (2007). *Property valuation: In an economic context*. London: John Wiley.

https://doi.org/10.5281/zenodo.17606583