A simulation-based binomial model for building development appraisal

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Abstract

Purpose - Building developments are often capital intensive, have a long payback period and many associated risks and uncertainties. This makes investments in building projects to be a big challenge. This study aims to develop a computerized simulation-based binomial mode! (CSBBM) for building investment appraisal with a view to improving the economic sustainability of proposed building projects.

Desigti/methodology/approach - Mathematical equations and algorithms were developed based on the binomial method (KM) of real options analysis and then implemented on a computer system. A hybrid algorithm that integrates Monte Carlo simulation (MCS) and BM was also developed. A real-life project was used to test the mode!. Sensitivity analysis was also conducted to explore the influence of input variables on development option value **(IX)**V).

Findings - The test result shows that the model developed provides a better estimate of the value of an investment when compared with traditional net present value technique, which underestimate the value. Moreover, inflation rate (i) and rental value (Ri) are the must sensitive variables for DOV. An increase in i and Ri by just 5% causes a corresponding increase in DOV by 202% and 132%, respectively. While the least sensitive variable is the discount rate (r), as an increase in r by 5% causes a corresponding decrease in DOV by just 9%. The CSBBM is capable of determining the optimal time of development of buildings with an accuracy of 80.77%.

Practical implications - The hybrid model produces higher DOV than that of only the BM because MCS considers randomness in uncontrollable variables. Thus, building investment decision-makers should always use MCS to complement the BM in an investment analysis.

Originality/value - There is limited evidence on the use of this kind of hybrid model for determining DOV in practice.

Keywords Sustainable construction, Construction management, Building investment, Binomial method, Development option, Monte Carlo simulation

Paper type Research paper

1. Introduction

Capital investments in buildings are often considered to be high-risk especially when considering the challenges of estimation and measurement of the numerous uncertainties encountered over a

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building's lifecycle. Over the lifecycle of a building, cash flows in the form of costs and benefits are expected. Buildings require maintenance, repair and replacements at different phases over their lifecycle (Salvado *et al.*, 2021). So, investment in the right building project that generate potential benefits higher than initial and future costs will bring success and growth to the project. On the contrary, investment into non-profitable building projects can lead to the failure of the project. According to Ellingham and Fawcett (2006), a construction project capital investment that is insufficient in taking account of potential benefits is inefficient thereby making it an under-investment. Also, a construction project that is heavily invested for small future benefits is inefficient which makes it an over-investment. They noted that avoiding both cases makes an investment in a building project to be economically sustainable.

Over the years, building developments especially in Nigeria have increased drastically. Unfortunately, at the same time, many of these projects have to be abandoned and some are undergoing evaluation for a possible phase out due to negative economic impact (Sattarnusart, 2012). This shows that poor planning and bad investment decisions could cause significant economic losses in building projects. Therefore, inefficient investment decisions could be catastrophic especially in a period of global economic recession. So, it is now more important to justify not only the initial capital investments needed in a building development project but also all other subsequent costs over a building's lifecycle (Flanagan and Jewell, 2005; Salvado *et al.*, 2020). As building development projects have profound consequences, they should be thoroughly considered, planned and executed. Then, therefore, a comprehensive evaluation of building development projects is crucial to achieving economic sustainability (Kelly and Hunter, 2009). However, building investment decision-makers are faced with the challenges of uncertainty and complexity, making the process more tedious and time-consuming (Salvado *et al.*, 2018; Goh and Sun, 2016; Boussabaine and Kirkham, 2004).

Building investment decision-makers are faced with a big challenge in determining the viability of building projects and analyzing the best time to invest. Investment analysts undertake crucial investment decisions such as whether to develop, postpone or even abandon a building project. To ensure sustainable building development, it is essential to efficiently evaluate a building project and determine the optimal time of investment. However, the available traditional building investment appraisal tools are often unreliable. The techniques mostly used in building investment appraisal are the discounted cash flow (DCF) techniques such as the net present value (NPV) method, internal rate of return (IRR), profitability index (PI) and payback period (PP). According to Akkoyun (2012), Kishk *et al.* (2003) and Boussabaine and Kirkham (2004), the most popular and generally accepted method for investment appraisal is the NPV method. Sattarnusart (2012) added that NPV method is mostly used, as it offers a clear criteria and quantitative information to investment analysts.

Unfortunately, the traditional DCF methods do not take account of the volatility in costs and benefits over the lifecycle of a building project. Also, the DCF techniques do not take account of managerial flexibility – the flexibility to change decisions as more and certain information becomes available in the future (Peters, 2016; Ellingham and Fawcett, 2006). According to Fawcett (2011), the major drawback of the DCF techniques is the assumption that future decisions are fixed at the beginning and it ignores the flexibility in decision-making during the course of the investment. With the DCF methods, decisions have to be made now or never while in reality investments in building projects could be made now or postponed to a better time in the future. With managerial flexibility, decisions made today can be revised by future decision-makers in response to unexpected circumstances. As building projects move through each stage, new risks are encountered and new information revealed. This future information allows a developer to adjust the course of a project to stem losses or to capitalize on gains (Sattarnusart, 2012). The current economic downturn in

Nigeria gives instances where the progress of building projects have to be altered based on new information and risk. For example, building projects in the planning stage have been put on hold and building projects in the construction stage have been abandoned due to the current economic downturn. In view of the limitations of traditional DCF techniques, there is a need to explore other techniques so that, both flexibility in decision-making and volatility in future cash flows can be addressed.

Peters (2016) and Mun (2006) posited that real options (RO) approach takes account of volatility and managerial flexibility but different methods have their strengths and weaknesses. Katerina (2015) also stated that the best way to value a development project is through RO valuation theory. RO is a means to structure and value flexible strategies in investment decisions and provide solutions for handling uncertainties (Katerina, 2015; Peters, 2016). In the language of RO theory, the owners have options that allow them to respond in different ways, depending on the outcome of future events that are presently uncertain (Mun, 2006; Ellingham and Fawcett, 2006). There are numerous methods used for real options analysis (ROA). The binomial method (BM) and the Black-Scholes method (BSM) are the major methods used for ROA while other methods are either simulation-based methods or an extension of BM or BSM (Lawal, 2020). The BSM is a continuous mathematical model, while the BM is discrete and graphical making it easier to interpret. Implementation of both methods is complex and computer implementation greatly simplifies the process and improves both accuracy and robustness.

This study uses the advantages of BM to develop an innovative simulation-based model that can be used for the evaluation of building investments with a view to encapsulating both managerial flexibility and cash flow volatility thereby ensuring economically sustainable decisions.

2. Literature review

2.1 Traditional whole-life costing techniques

The traditional whole-life costing (WLC) techniques are investment appraisal techniques used for evaluating long-term investment opportunities. According to Shapiro *et al.* (2013), in practice, the most widely accepted method of investment evaluation is the DCF technique. Pandey (2005) stated that the most useful DCF techniques are the NPV method, IRR, savings to investment ratio (SIR) and benefit to cost ratio (BCR). However, according to Ibrahim (2019), not all of these techniques find usability in the construction industry. Dale (1993) identified the most commonly used investment appraisal techniques in the building sector as PB, NPV and IRR. Other researchers (Boussabaine and Kirkham, 2004; Kishk *et al.*, 2003; Flanagan and Jewell, 2005) agree that the NPV method, PI, IRR and equivalent annual cost (EAC) are the most commonly used techniques in the building sector. Ibrahim (2019) concluded that NPV and EAC methods are mostly used in the evaluation of mutually exclusive projects while IRR is mostly used in the screening or ranking of competing projects. However, according to Kwabena *et al.* (2018a), the DCF method has been criticized by many leading authors including Dixit and Pindyck (1994), Dixit and Pindyck (1995), Hayes and Abernathy (1980), Hodder and Riggs (1985) and Myers (1984). Kwabena *et al.* (2018a) encapsulated that ignoring changes in input variables due to uncertainties or the use DCF techniques in evaluating future opportunities from flexibility will lead to serious inaccuracies.

2.2 Development option

Ellingham and Fawcett (2006) stated that development option (DO) comes into being when a developer has a development opportunity. Thus, DO is the right owned by a prospective

investor to develop a piece of land. The option holder holds an option of either to develop or to defer the option to a later date. The developer can postpone development until when conditions are favorable within the option's validity period. They emphasized that efficient building investment decisions could be made with the options approach which leads to more cost-effective and sustainable decisions and ensures achieving economic sustainability by minimizing the risk of under or over-investment. Sustainable building development aims at maximizing future benefits in relation to the resources used over the lifecycle of a building (Fawcett *et al.*, 2012a).

According to Peters (2016), DO is equal to an American call option on the gross present value of the completed project's operating cash flows and the exercise price is equivalent to the investment cost of the project. Peters (2016) added that deferral options are suitable for proprietary investments and valuable in real estate development due to high uncertainty, long-term investment horizon and limited competition.

Over the lifecycle of a building project, uncertainties and risks may arise due to unfavorable changes in economic conditions. In view of this, building investment decision-makers require strategies that can deal with these uncertainties better. According to Kwabena *et al.* (2018a), managing uncertainties in development projects require managerial flexibilities. Myers (1984) termed managerial flexibilities or strategies as options. Lucius (2001) categorized options to include option to defer, option to expand, option to stage, option to abandon, temporary shutdown options and compound options.

2.3 Real options

ROA originated from financial options and gained popularity after the development of the Black-Scholes option-pricing model (Kwabena *et al.*, 2018a). The term "real option" was introduced by Myers in 1977. Copeland and Antikarov (2001) refer that an option holder has the right but not the obligation to exercise an option until its expiration date. Therefore, RO is the right but not the obligation to undertake certain business initiatives, such as developing, deferring, abandoning, expanding, staging or contracting a capital investment project. A similar logic is applicable to building projects where a developer has the right but not the obligation to commence development or defer development until such a time imposed by either planning permission or contractual obligations (Kwabena *et al.*, 2018a). Therefore, there is embedded flexibility in building designs.

However, Ibrahim (2019) stated that the current WLC tools used in building development appraisal are not capable enough to evaluate the adequacy and value of embedded flexibility in building designs. He further stressed the need for development of special models using ROA which can adequately value the embedded flexibility in building designs. According to Kwabena *et al.* (2018a), Titman (1985) was the first to apply RO theory to a practical real estate case study. Chiang *et al.* (2006) used ROA to identify embedded options in land development and stressed that DCF techniques are not capable of evaluating ROs. Shen and Pretorius (2013) developed a model for real estate development. Kwabena *et al.* (2018a) used ROA to value staging options embedded in residential projects and compared the results with that of DCF technique. Kwabena *et al.* (2018b) used ROA to determine the economic value of a switching output flexibility embedded in residential property investment.

According to Peters (2016), the common types of real options are the option to defer, the option to expand or contract and the option to abandon or switch. Peters (2016) presented several approaches to ROA stating that each approach contains several methods that address RO problems in a different way. According to Peters (2016), the fundamental methods for ROA are BSM and BM. He added that other methods are either an extension of these two or simulation-based models.

2.4 Lifecycle options

The options approach to WLC was proposed by Ellingham and Fawcett (2006). The approach adopted the term "lifecycle options" (LCO) which provides the basis for a new generation WLC. The principle behind LCO is that rather than making decisions today when there is high uncertainty, it would be better if decisions are made in the future when more information becomes available. Fawcett *et al.* (2012b) defined LCO as a design feature that is incorporated in the initial design and construction of a building, which allows for alternative courses of action to be followed in the future. LCOs are an instance of the more general concept of "real options" (Fawcett *et al.*, 2012b), for which there is a large body of theory and experience in other application areas (Mun, 2006). LCO is based on a direct analogy with financial options (Ellingham and Fawcett, 2006).

Ellingham and Fawcett (2006) pointed out that many LCOs exist but are unrecognized. A building owner holds many options which include the option to sell, option to develop, option to improve, option to refurbish, etc. These are the rights that come with the ownership of the building. Table 1 shows the types of LCOs as adopted from Lawal and Ibrahim (2018).

Therefore, a LCO is a design feature which if acquired in initial building design, provides alternative courses of action to be followed in the future. LCO includes development option, abandonment option, expansion option, option to switch use, option for new technology, reconfiguration and refurbishment options, contraction option, option to suspend project and option to switch projects.

2.5 Call and put options

According to Peters (2016) and Ellingham and Fawcett (2006), there are two basic forms of financial options – call and put options. A call option gives the option holder the right (but not the obligation) to buy a stock or purchase an underlying asset at a particular price within a specified period of time (Peters, 2016; Arnold, 2014). While a put option gives the option holder the right (but not the obligation) to sell a stock or an underlying asset at a particular price within a specified period of time (Peters, 2016; Arnold, 2014). Liu (2014)

Lifecycle options	Description
Development/ Deferral Option	The option to invest in a development opportunity or to postpone development to a later date. The investor has the option to develop or to "wait and see"
Expansion/Upgrade Option	The option to expand a building
Abandonment Option	The option to exit a project to realize an abandonment value. It is the flexibility to abandon a project in the presence of negative results
Switching Use Option	The option to change the use of a building from one to the other during the occupancy stage of a building
Option for New Technology	Option to adapt to change in technology
Reconfiguration Option	The option to reconfigure a building to meet current needs
Refurbishment Option	The option to refurbish a building to bring it up to user's requirements
Contraction Option	The option to reduce the scale of a project when conditions become unfavorable
Option to Suspend Project	The option to suspend a project when it is unfavorable to continue and when conditions are expected to get better in a short period
Option to Switch Projects	The option to switch resources from one project to another

Table 1. Types of lifecycle options (Lawal and Ibrahim, 2018)

added that a call option gives an owner the right to procure an asset at a given price in the future, while a put option gives the owner the right to sell an asset at a given price in the future. A call option is valuable if the exercise price is below the current price of the underlying asset whereas a put option is valuable if the strike price is above the current price of the underlying security (Arnold, 2014). Generally, an option is said to be similar to a call option if an investment can be made to take advantage of an opportunity whereas an option is said to be similar to a put option if cash inflow can be received from selling an opportunity at a specified price (Arnold, 2014). A call option requires investment to be made and for a put option, cash inflow is received. Therefore, a put option can be viewed as the opposite of a call option.

Peters (2016), pointed out another difference in options terminology which is between an American and a European option. For American option, the option holder has the right to exercise the option at any time during its life. However, for European option, the option holder has the right to exercise an option only at the end of its life. Arnold (2014) added that the exercise of an option prior to maturity can occur if the option is an American option whereas a European option can only be exercised at maturity.

Acquired options are options that are acquired by some deliberate effort (Peters, 2016). They are options that are created (e.g. development option). By just acquiring a plot of land, one has created a development option. On the other hand, embedded options are options that come automatically with the ownership of an asset (Peters, 2016). According to Peters (2016), options can be created or destroyed. Therefore, acquired options are deliberately created while embedded options come with the ownership of an asset.

2.6 Binomial method

The BM was first proposed by Cox *et al.* (1979). The BM provides a general numerical method for options evaluation (Peters, 2016). So, using the Cox-Ross-Rubinstein Method (CRRM), a binomial tree can be developed showing probable future values. Also, the discounted weighted average of all the values on the binomial tree can be obtained.

According to Mun (2002), the BM is suitable for representing uncertainty that increases over time and has the advantage of being easy to build and understand. He added that although, the BM is sometimes computationally stressful, but it can be implemented on a spreadsheet package. He further stressed that BM is very flexible, in that, it can be tweaked easily to accommodate most types of option problems. Also, according to Mun (2002), although both BM and BSM are proven to provide reliable results, BSM has limitations of being very difficult to derive and highly specific in nature. Tweaking BSM equation requires facility with sophisticated stochastic mathematics (Mun, 2010). Mun (2002), pointed out that BM is easy to implement and explain because it requires no more than simple algebra. Therefore, BM is a discrete and graphical mathematical model which is easier to interpret.

2.7 Monte Carlo simulation

MCS is a widely recognized tool that was introduced in capital budgeting problems by Hertz (1968). MCS can generate all possible combinations of inputs and therefore, it can generate the entire distribution of the possible outcomes (Brealey *et al.*, 2006). Moreover, MCS assists investment analysts to be more rational and consistent in their decisions and to gain greater understanding of the risk factors in a development project (Loizou and French, 2012). Hoesli *et al.* (2006) and Atherton *et al.* (2008) used MCS to capture uncertainties in valuation which uses a range of values. Atherton *et al.* (2008) evaluated real estate development case study and suggested that improvements can be made when range of values are used in evaluating the value of development projects.

3. Methodology

This study developed a simulation-based binomial model for building development appraisal with a view to improving the economic sustainability of proposed building projects. Mathematical equations were developed based on the BM of ROA which was first developed by Cox *et al.* (1979). According to Peters (2016) and Katerina (2015), ROA takes account of the value of uncertainty in investment decisions and provides solutions for handling these uncertainties. Cox *et al.* (1979) proposed the binomial option pricing model as an alternative to the BSM. He (2007) depicted that one of the criticisms of ROA comes from practitioners who often find it difficult to understand and implement due to the complex mathematics involved. Peters (2016) added that these practitioners prefer to stick to the traditional valuation methods because of their simplicity. According to Mun (2002), the BM has high modeling flexibility as it can be tweaked easily to accommodate most types of option problems. Although the BM is sometimes computationally stressful, it can be implemented on a spreadsheet package which is suitable for representing uncertainty that increases over time making it easier to build, explain, understand and implement (Ashuri *et al.*, 2012; Mun, 2002). The BSM has limitations of being very difficult to derive and highly specific in nature as tweaking the BSM equation requires facility with sophisticated stochastic mathematics (Mun, 2002; Mun, 2010), but both BSM and BM are proven to provide reliable results (Mun, 2002). Mun (2002), pointed out that the BM is easy to implement and explain because it requires no more than simple algebra. As both BM and BSM are proven to provide reliable results, the BM is better for ease of exposition and understanding. Therefore, this work adopted the BM.

The mathematical equations where derived in line with ISO 15686–5 (Life-cycle costing) cost breakdown structure and forms the basis for generating a flowchart algorithm to represent the computational process. A basic flowchart was used to develop an algorithm that integrates MCS and BM. The hybrid algorithm was then implemented on excel spreadsheet software. The combination has the advantages of generating the entire distribution of all possible outcomes as suggested by Brealey *et al.* (2006) and enables investment analysts to gain greater understanding of the risk factors in a development project for better investment appraisal (Loizou and French, 2012).

To ascertain the robustness and reliability of the model, a proposed building development project located at Kaduna State, Nigeria was used to test the model. The proposed project was used to test both the binomial model and the hybrid model. In addition, sensitivity analysis (SA) was also conducted to explore the influence of input variables on DOV.

4. Results and discussion

4.1 Model design and development

The model was designed based on the BM of ROA and in line with ISO 15686–5 (Life-cycle costing) cost breakdown structure. The BM was tweaked to accommodate the development option. In addition, a hybrid model was developed which integrates the BM and MCS.

4.1.1 Future value. The BM provides a general numerical method for options evaluation (Peters, 2016). The probable future values on the binomial tree can be obtained using the Cox *et al.* (1979) formula in equation (1):

$$S_n = S_0 \times U^{N_u - N_d} \tag{1}$$

where; S_n = present value of project's or investment's cashflow at nth period, S_0 = value at step 0, U = upward ratio = $\frac{1}{d}$, (where d = download ratio), N_u = number of upticks, N_d = number of downtricks.

Figure 1 shows a five-step recombining binomial tree showing Steps (y) and States (n) as modified and used in this work. Steps y represents the change in time on the binomial tree. The vertical dotted lines from 0 to 5 represent the steps (Step 0, Step 1, Step 2, etc.). States *n* represent the number of nodes on each step. States (n) are represented numerically with numbers from top to bottom up to the last node on each step. All nodes on the binomial tree are represented as S (y, n). The highlighted node S (4, 2) represents the node on Step 4 and State 2. This applies to every node on the binomial tree. The initial value in year 0 is $S_0 = S(0, 1)$.

Using the CRRM, a five step recombining binomial tree can be presented in Figure 2 using equation (1):

Using equation (1), Figure 2 was developed starting from year 0 up to year 5. For each node, the number of upticks and downticks are counted from year 0 to that node and imputed in equation (1) to get the value at that node. This applies to all nodes on the binomial tree. However, as $u = \frac{1}{d}$ (Ellingham and Fawcett, 2006). Therefore, $u = d^{-1} = (d\hat{} -1)$. Then, $d = \frac{1}{u} = u^{-1} = (u\hat{}-1)$.

Hence, substituting the values of d, in Figure 2, yields Figure 3 below:

Figure 3 is the outcome of substituting $d = (u\hat{} -1)$ in Figure 2 at each node on the binomial tree. This was carried out to further simplify the binomial tree. However, $u = (1 + \delta)$ (Ellingham and Fawcett, 2006). Where δ is the volatility. Also, substituting $u = (1 + \delta)$ in Figure 3 above yields Figure 4 below:

To further expand the binomial tree, u was replaced with $(1 + \delta)$ at each node on the binomial tree as seen in Figure 4. Using equation (1), the binomial tree can be constructed. However, counting Nu (number of upticks) and Nd (number of downticks) could be tedious and time-consuming especially in binomial trees with higher number of steps. Therefore, a simplified formula was derived to make it easier. So, equation [2] was developed for computing FVs on a binomial tree (Lawal, 2020).

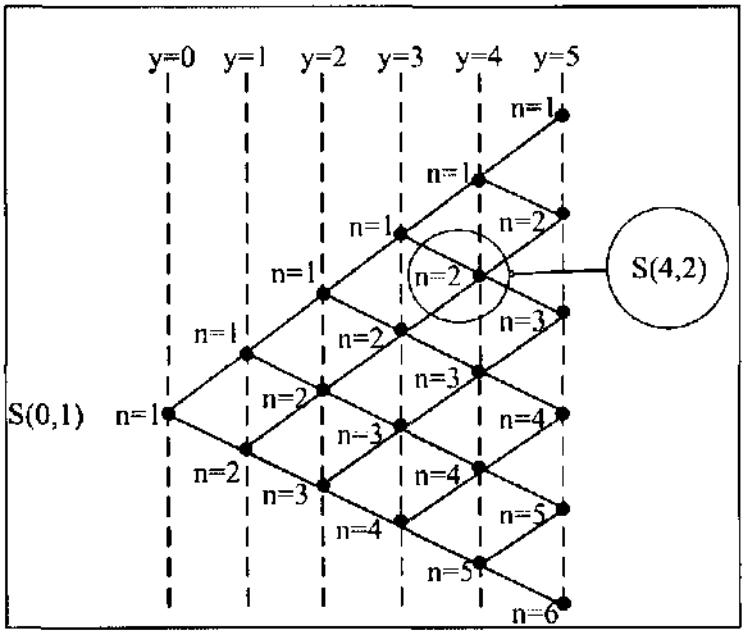


Figure 1.
A five-step recombining binomial tree showing steps (y) and states (n)

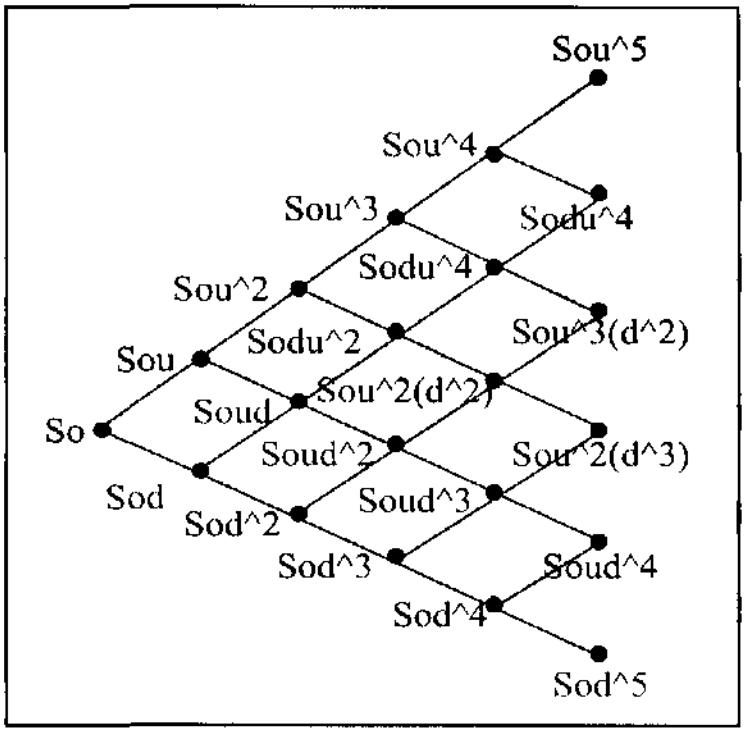


Figure 2.
A five-step recombining binomial Lattice using CRRM

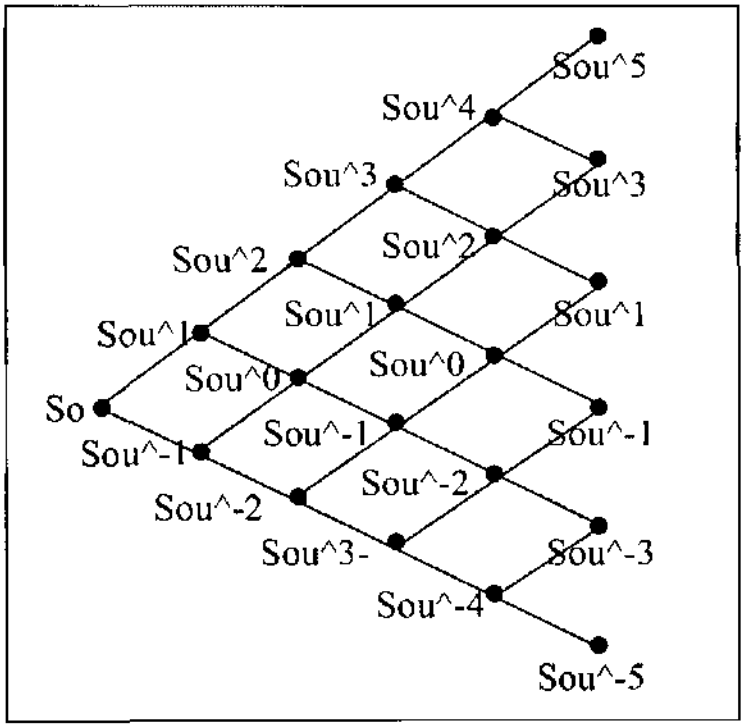


Figure 3.
A five-step recombining binomial lattice with ratios expressed in terms of upward ratio

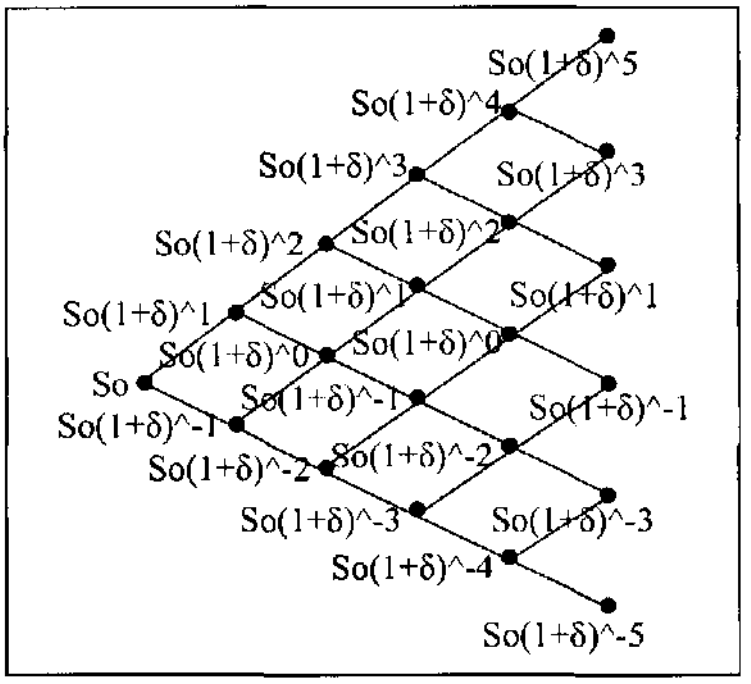


Figure 4.
A five-step recombining binomial Lattice with ratios expressed in terms of volatility

$$FV_{(y,n)} = V_0 \times (1 + \delta)^{y\ (2n-2)} \tag{2}$$

where $FV_{(y,n)}$ = future value; V_0 = value at step 0; y = step; n = state; δ = volatility. Here, Vo = So from Figures 1–4. With equation (2), the value at any node on the binomial tree can be obtained without relying on the number of upticks and downticks.

4.1.2 Present value. A binomial tree can be discounted back to the present to obtain the PV. Equations (3) and (4) (Ellingham and Fawcett, 2006) were modified to arrive at equation (5) for calculating the discounted weighted average of all entries on a binomial tree:

$$V = v + \left[P_u \times \frac{V_u}{(1+r)}\right] + \left[P_d \times \frac{V_d}{(1+r)}\right] \tag{3}$$

$$P_u + P_d = 1 \tag{4}$$

where; V = cumulative value at the node being studied, v = the entry at the node being studied, V_u = cumulative value at the upward parent node, V_d = cumulative value at the downward parent node, P_u = upward probability, P_d = downward probability, r = discount rate:

$$PV_{(y,n)} = V_{(y,n)} + \left[P_u \times \frac{V_{((y+1),n)}}{(1+r)}\right] + \left[P_d \times \frac{V_{(y+1),(n+1)}}{(1+r)}\right] \tag{5}$$

where $PV_{(y,n)}$ = PV at the node being studied, $V_{(y,n)}$ = the entry/value at node (y, n), P_u = upward probability, P_d = downward probability, r = discount rate.

Equation (5) was modified to suit Figure 4 as used in this paper.

4.1.3 NPV of development. In a building's lifecycle perspective, equations (6), (7), (8) and (9) were formulated in line with ISO 15686–5 (Life-cycle Costing).

$$LCCD = I_C + \sum O_C + \sum M_C + T_C \tag{6}$$

$$DVc = I_C = C_C + N_C \tag{7}$$

$$LCCD = DVc + \sum O_C + \sum M_C + T_C \tag{8}$$

And, Net NPVd can be:

$$NPVd_{(y,n)} = LCBD_{(y,n)} - LCCD \tag{9}$$

where:

LCCD = Lifecycle Cost of Development;
LCBD = Lifecycle Benefit of Development;
DVc = Development Cost;
NPVd = Net Present Value of development;
I_C = Initial cost;
C_C = Construction cost;
N_C = Non construction costs;
O_C = Operating cost;
M_C = Maintenance cost; and
T_C = Terminal cost.

4.1.4 Development value

$$DVv_{(y,n)} = Max\left[LCBD_{(y,n)} - LCCD, \quad 0\right] \tag{10}$$

Equation (10) shows DVv as the difference between all benefits and all costs over the lifecycle of a building. When the difference is negative, it is rounded back to zero which means that the project is not viable. Substituting equation (9) in equation (10) yields equation (11):

$$DVv_{(y,n)} = Max\left[NPVd_{(y,n)}, \quad 0\right] \tag{11}$$

4.1.5 Option value. Let, $Vd_{(y,n)}$ be the cumulative weighted average of all entries on the development value tree and $DOV_{(y,n)}$ be development option value. Equation (5) is used to obtain the cumulative weighted average of all entries on the development value (DVv) tree. Thus;

$$Vd_{(y,n)} = V_{(y,n)} + \left[P_u \times \frac{V_{((y+1),n)}}{(1+r)}\right] + \left[P_d \times \frac{V_{(y+1),(n+1)}}{(1+r)}\right] \tag{12}$$

The value of the option to develop is the maximum between DVv at the present and the value to defer development ($Vd_{(y,n)}$) to the future. Thus, equation (13) can be represented as follows:

$$DOV_{(y,n)} = Max\left[DVv_{(y,n)},\ Vd_{(y,n)}\right] \quad (13)$$

4.1.6 Model algorithm. Assuming there is a building development option with expiry time T. A developer could decide to invest (develop) today or defer development to another time within the option's validity period. The option holder could wait for the best time to invest/develop in the future when more information about the project is available. This model determines the optimal time of investment in a building project when the option to defer development exists.

Table 2 contains the list of symbols and abbreviations and their meanings as used in formulating the algorithm.

The algorithm is formulated into modules to make it more comprehensive. Figure 5 represents the algorithm for Determining DOV. The modules are presented in Figures A1 to A8. in the Appendix.

Figure 5 shows the algorithm for determining DOV. It starts by calling for input of economic data and then computation of development cost, salvage value, discount rate, upward and downward values and the number of steps. The PVs of maintenance and operating costs are then computed using modules Mc and Oc, respectively. The algorithm then calculates the LCCD and computes LCBD using module LCBD. Afterward, it develops and displays the binomial tree of PVs of LCBD using module PLCBD. The binomial trees of NPVd and DVv are then developed and displayed using modules NPVd and DVv, respectively. A binomial tree showing decisions over the analysis period is also generated and displayed using module De. Finally, the DOV is calculated at every year over the option validity period using module DOV.

4.1.7 Simulation design. Determining the expected value of DO in a general case is very useful in the investment decision-making process. To find the expected value, MCS was used to generate all possible values by changing the uncontrollable variables randomly. Combining simulation with the BM allows investment analysts to make appropriate decisions. Therefore a hybrid model was developed by integrating the BM and MCS. The objective of the simulation is to find the expected value and all possible values of development option.

The design of the simulation follows the following steps:

- Use the base values in the binomial model for development option.
- Randomly select values for rental value (Ri), volatility (δ), borrowing rate (b) and inflation rate (i).
- Calculate DOV.
- Repeat until 10,000 iterations are reached.
- Use the values to produce a frequency curve.
- Identify the most likely value.

Table 2.
List of symbols/ abbreviations used in formulating the algorithm

Abbreviation	Meaning	Abbreviation	Meaning
PV	Present value	d	Downward value
DVc	Development cost	y	Steps
Mc	Maintenance cost	LCBD	Lifecycle benefit of development
Oc	Operating cost	LCCD	Lifecycle cost of development
Sv	Salvage value	PLCBD	Present value of LCBD
r	Discount rate	T	Analysis period
u	Upward value	NPVd	NPV of development

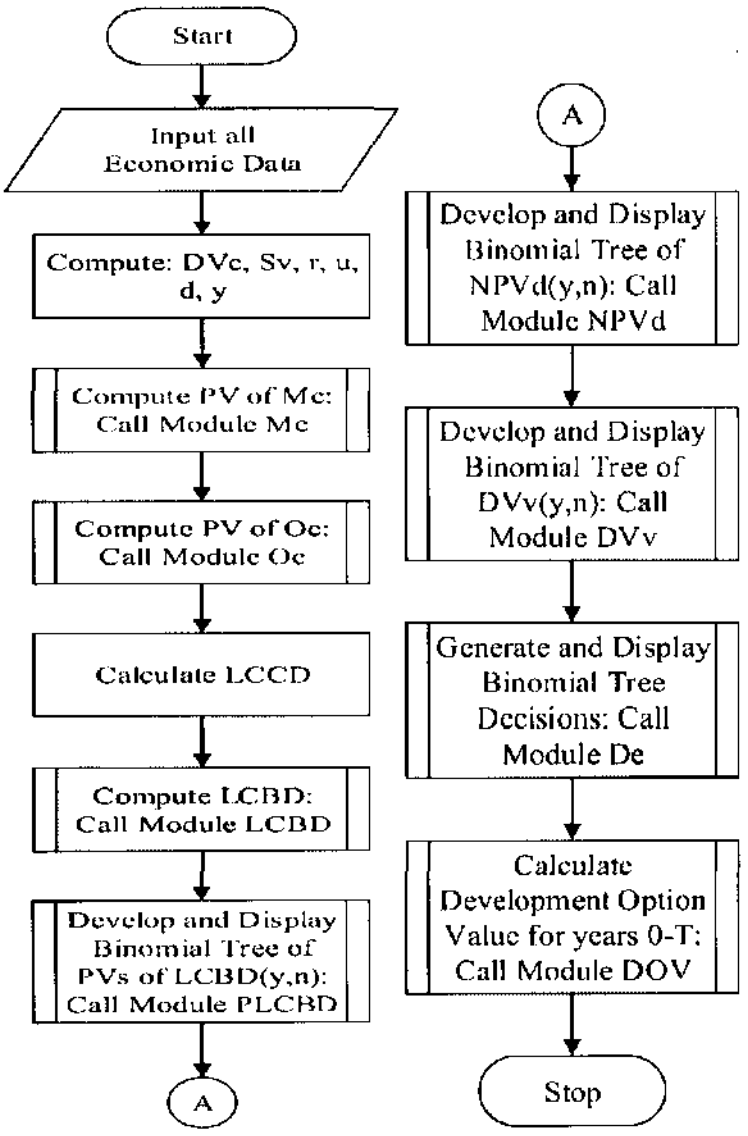


Figure 5.
Algorithm for determining building development option value

The procedure for running the simulation can be described by the algorithm in Figure 6. The algorithm in Figure 6 shows the hybrid which integrates the BM and MCS.

Figure 6 is the flow chart for DOV simulation which represents the hybrid algorithm that integrates the BM with MCS. The algorithm starts by calling for economic data input. It also calls for input of range of values for rental income (Ri), volatility (δ), inflation rate (i) and borrowing rate (b). The range of values gives a maximum and minimum possible values. The algorithm then randomly selects the values for Ri, δ, i and b. Using this input, the algorithm uses the binomial model to compute the DOV. This circle is repeated until different combinations of Ri, δ, i and b have been randomly selected for up to 10,000 iterations. Here, the simulation stops and result is obtained in form of a frequency curve and a table showing the statistical measurement of the simulation.

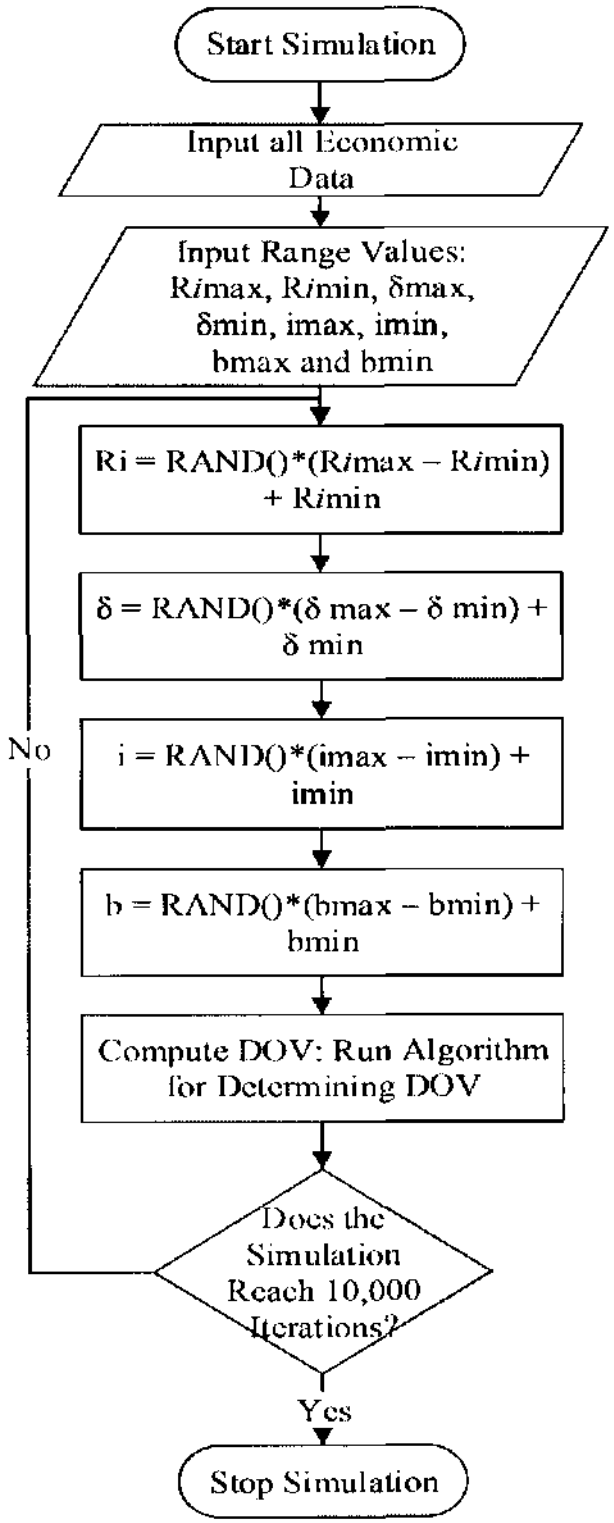


Figure 6.
Flow chart for DOV simulation representing the hybrid algorithm

4.3 Model evaluation and testing

To test the reliability and validity of the model, a practical case was used. The developed model is for building development appraisal and hence a proposed building development project was used. The proposed project is located at Unguwan Kaji, Kaduna State, Nigeria. The developer plans to construct a commercial-residential building which will be rented out. The project has an approximate area of land being 1,207.8 m^2 and an overall building area of 529.60 m^2. Data was obtained from different sources. Global variables such as the inflation rate, borrowing rate and volatility were obtained from the Central Bank of Nigeria, National Bureau of Statistics and Debt management office. Cost variables such as the construction cost, maintenance cost, operating cost, rental value and terminal cost among others were obtained from quantity surveying firms and estate and facilities management firms. The following data was obtained and used as the input parameters in the model.

Figure 7 shows the result from the NPV tree from year 0 to 10. From the results, the BM suggests that the owner should go ahead with the proposed development. The DOV is around ₦1.9M, which is higher than zero meaning that development at the present is viable. Other nodes on the NPV tree show the probable NPVs at each node. The value of development in year 10 is the weighted average of all entries on the NPV tree discounted back to year 0 from year 10. This also applies to any year on the binomial tree whereby the weighted average of all the entries are discounted back from that year back to year 0 to obtain the DOV at that year. Table 3 shows the DOV from year 0 to year 30.

As can be seen from Table 3, the binomial model suggests that development at the present is very valuable. However, it also shows that deferring development by one year is

	0	1	2	3	4	5	6	7	8	9	10
1	1,857,529	8,207,966	15,282,354	23,163,222	31,942,509	41,722,634	52,617,694	64,754,790	78,275,516	93,337,604	110,116,770
2		0	1,857,529	8,207,966	15,282,354	23,163,222	31,942,509	41,722,634	52,617,694	64,754,790	78,275,516
3			0	0	1,857,529	8,207,966	15,282,354	23,163,222	31,942,509	41,722,634	52,617,694
4				0	0	0	1,857,529	8,207,966	15,282,354	23,163,222	31,942,509
5					0	0	0	0	1,857,529	8,207,966	15,282,354
6						0	0	0	0	0	1,857,529
7							0	0	0	0	0
8								0	0	0	0
9									0	0	0
10										0	0
11											0

Figure 7.
Result from NPV Tree from year 0 to 10

Year	DOV (Millions ₦)	Year	DOV (Millions ₦)	Year	DOV (Millions ₦)
0	1.9				
1	4.1	11	10.7	21	15.1
2	4.7	12	11.1	22	15.4
3	5.9	13	11.7	23	15.9
4	6.4	14	12.0	24	16.2
5	7.3	15	12.6	25	16.6
6	7.8	16	12.9	26	16.9
7	8.6	17	13.5	27	17.4
8	9.0	18	13.8	28	17.7
9	9.7	19	14.3	29	18.1
10	10.1	20	14.6	30	18.4

Table 3.
Development option value

twice more valuable than development at the present. Then the value of deferring development keeps on increasing with time. The best decision is therefore to defer the development until a future date when the project will be re-evaluated in the light of reliable and certain information. This scenario has been noted by Ellingham and Fawcett (2006) and Sattarnusart (2012).

Figure 8 is a snapshot showing decisions over 30 year analysis period. The cells in green represent the decision to develop in which case the project is viable. The cells in yellow represent the decision to "wait and see" in which case the project is unprofitable. Then the cells in red represent the decision to abandon in which case the project is unprofitable and at the end of the option validity period.

The result from the BM was compared with that of the traditional NPV method. All costs and benefits over 30 years analysis period, were discounted to their PVs to obtain the NPV of the cashflow. Equation [4.1] is the NPV formula (Ellingham and Fawcett, 2006) where; V_0, V_1, V_2, ...V_n = cashflows, r = discount rate, n = number of periods.

$$\mathbf{NPV} = \mathbf{V_0} + \frac{\mathbf{V_1}}{(\mathbf{1}+\mathbf{r})} + \frac{\mathbf{V_2}}{(\mathbf{1}+\mathbf{r})^2} + \ldots\ldots\ldots\ldots\ldots\ldots \frac{\mathbf{V_n}}{(\mathbf{1}+\mathbf{r})^n} \qquad [4.1]$$

All recurrent costs and benefits were computed using the NPV formula. The costs were calculated as lifecycle cost of development (LCCD) and the expected benefits were calculated as lifecycle benefit of development (LCBD). Table 4 shows the traditional NPV computation.

Where; Cc-construction cost, Nc-nonconstruction cost, Oc-operating cost, Mc-maintenance cost, BE-expected benefit, RV-residual value and Tc-terminal cost.

Table 4 shows the traditional NPV computation of the proposed building project. It shows the PVs of the lifecycle costs and benefits over 30 years analysis period. The figures in red are the PVs of the cash outflows while those in green are the PVs of cash inflows. Therefore, using the traditional NPV method, the NPV of the project is −2.02M. This implies that the project is unprofitable and development should not proceed. When compared with

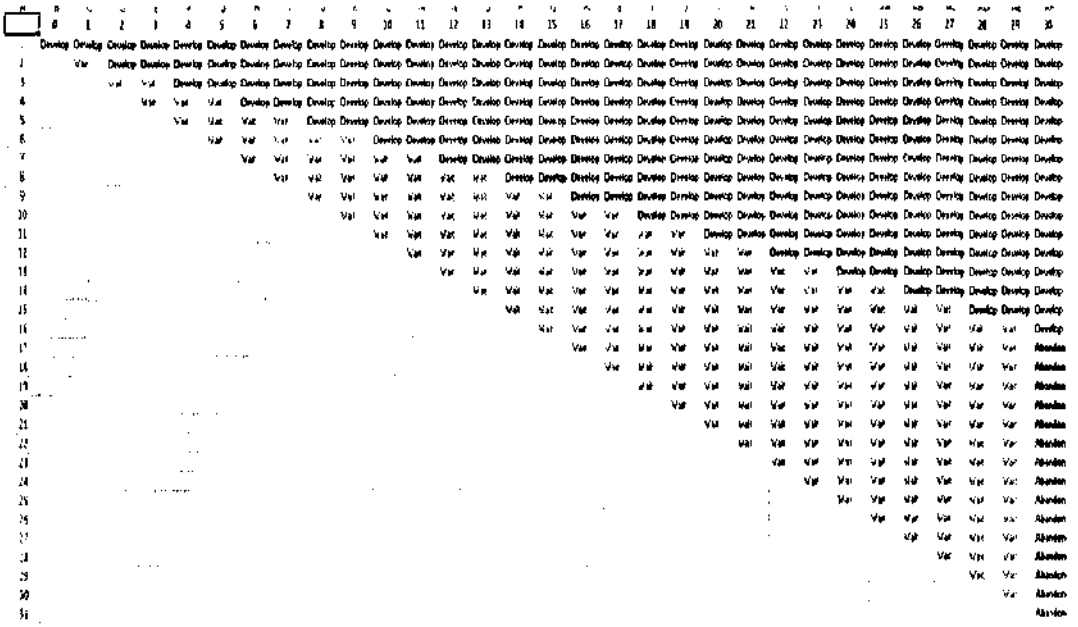


Figure 8.
A snapshot showing decisions over the analysis period

Year	Cc (in millions of naira)	Nc (in millions of naira)	Oc (in millions of naira)	Mc (in millions of naira)	BE (in millions of naira)	RV (in millions of naira)	Tc (in millions of naira)
0	34.4240	8.8500	0	0	0	0	0
1	0	0	0.1199	0.2447	1.5928	0	0
2	0	0	0.1194	0.2437	1.5857	0	0
3	0	0	0.1188	0.2426	1.5786	0	0
4	0	0	0.1183	0.2415	1.5715	0	0
5	0	0	0.1178	0.2404	1.5645	0	0
6	0	0	0.1173	0.2393	1.5575	0	0
7	0	0	0.1167	0.2382	1.5505	0	0
8	0	0	0.1162	0.2372	1.5436	0	0
9	0	0	0.1157	0.2361	1.5366	0	0
10	0	0	0.1152	0.2350	1.5298	0	0
11	0	0	0.1147	0.2340	1.5229	0	0
12	0	0	0.1141	0.2330	1.5161	0	0
13	0	0	0.1136	0.2319	1.5093	0	0
14	0	0	0.1131	0.2308	1.5025	0	0
15	0	0	0.1126	0.2298	1.4958	0	0
16	0	0	0.1121	0.2288	1.4891	0	0
17	0	0	0.1116	0.2278	1.4824	0	0
18	0	0	0.1111	0.2268	1.4758	0	0
19	0	0	0.1106	0.2257	1.4692	0	0
20	0	0	0.1101	0.2247	1.4626	0	0
21	0	0	0.1096	0.2237	1.4560	0	0
22	0	0	0.1091	0.2227	1.4495	0	0
23	0	0	0.1086	0.2217	1.4430	0	0
24	0	0	0.1082	0.2207	1.4366	0	0
25	0	0	0.1077	0.2197	1.4301	0	0
26	0	0	0.1072	0.2188	1.4237	0	0
27	0	0	0.1067	0.2178	1.4173	0	0
28	0	0	0.1062	0.2168	1.4111	0	0
29	0	0	0.1057	0.2158	1.4047	0	0
30	0	0	0.1052	0.2149	1.3984	8.6900	1.9888
Total	34.4240	8.8500	3.3733	6.8848	44.8069	8.6900	1.9888
NPV after 30 years	−2.0240						

Table 4.
Computation of NPV using the traditional method

the result from the BM where the project has a value of ₦1.9m, which implies that the project is profitable and development can proceed, the traditional NPV method is unable to adequately capture the value of the project. This further confirms the superiority of ROA over the traditional DCF techniques as many authors (Kwabena *et al.*, 2018a; Ibrahim, 2019; Peters, 2016; Dixit and Pindyck, 1994; Dixit and Pindyck, 1995; Hayes and Abernathy, 1980; Hodder and Riggs, 1985; Myers, 1984) have criticized the DCF techniques because of their weaknesses. The DCF techniques are unable to take account of managerial flexibility and the volatility in cash flows but ROA takes account of these. As can be seen from Figure 7 the BM shows the probable option values at different nodes on the binomial tree by taking account of the volatility in cash flows. Also, from Table 3, the BM provides the value of development at present and value of deferring development to any year in the future within the option validity period. This provides developers with the flexibility of either to develop now or to postpone development to a better time in the future. *The use of DCF techniques in evaluating DOV does not take account of managerial flexibility and volatility in cash flows and thus would lead to serious inaccuracies.*

4.3.1 Sensitivity analysis. SA can be performed by changing some input parameters or one parameter at a time in a certain range while keeping other parameters unchanged (Sattarnusart, 2012). Then, it calculates all the possible project values according to the changed parameters. The process in performing SA enables investment analysts to identify all key variables used in the calculation and to determine which input parameters are most likely to deviate from the estimated values (Sattarnusart, 2012).

In this paper, SA was used to carry out a more in-depth analysis. However, the SA performed in this paper does not focus on determining the optimistic or pessimistic scenario of the project but rather, on studying how some of the input parameters affect DOV.

From Figure 9, the relationship of DOV and other variables can be seen. Figure 9(a) shows the relationship between DOV and R*i* which shows that DOV increases with increase in R*i*. Figure 9(b) shows the relationship between DOV and δ which also shows that DOV increases with increase in δ. Figure 9(c) shows the relationship between DOV and b which shows that DOV decreases with increase in b. Figure 9(d) shows the relationship between DOV and i which shows that DOV increases with increase in i. Figure 9(e) shows the relationship between DOV and r which shows that DOV decreases with increase in r. Then, Figure 9(f) shows the relationship between DOV and T which shows that DOV increases with a higher option validity period. From all the analyses, the effects of changing different parameters on DOV can be summarized in Table 5. Let DOF be the value of the option to defer development.

As shown in Table 5, an increase in rental value has a positive effect on DOV and as well on the DOF. Inversely, a reduction in rental value negatively affects DOV and also DOF. Also, an increase in volatility has a positive effect on both DOV and DOF. While an increase in borrowing rate has a negative effect on both DOV and DOF. On the other hand, an

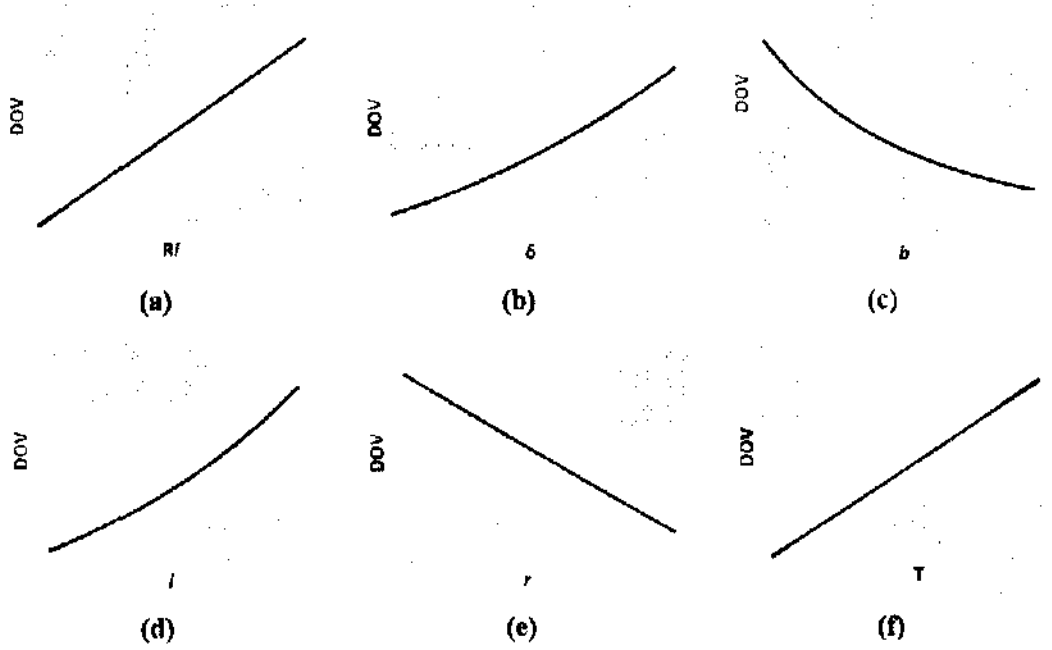


Figure 9.
Relationships between uncontrollable variables and DOV

Note: [a] rental value (Ri), [b] volatility (δ), [c] borrowing rate (b), [d] inflation rate (i), [e] discount rate (r) and [f] option validity period (T)

increase in inflation rate has a positive effect on both DOV and DOF. Likewise, an increase in option validity period has a positive effect on both DOV and DOF.

Figure 10 shows the comparative effect of the uncontrollable variables on DOV. To determine the variables that have the greatest effect on DOV, all the variables were merged on one graph. The percentage increase of each variable is plotted against the percentage change of DOV. From the results, it can be seen that the variable that has the most effect on DOV is the rental value, then followed by inflation rate, volatility, discount rate, borrowing rate and option validity period.

4.3.2 Simulation result and analysis. MCS was used to allow for the effect of randomly changing the variables at the same time. A hybrid model was developed to integrate BM with MCS. To find the expected value (EV), the hybrid model was used to generate all possible values using MCS by changing some input variables randomly. The results can be used to derive the EV of development option in general case so as to enable investment analysts arrive at well-informed decisions. The possible values of DOV are plotted to examine the distribution of the results and the key statistical measurements are calculated for the analysis of the results.

Uncontrollable variables	DOV	DOF
Rental value ($R\ell$)	+	+
Volatility (δ)	+	+
Borrowing rate (b)	−	−
Inflation rate (i)	+	+
Discount rate (r)	−	−
Validity period (T)	+	+

Table 5. Summary of sensitivity analysis

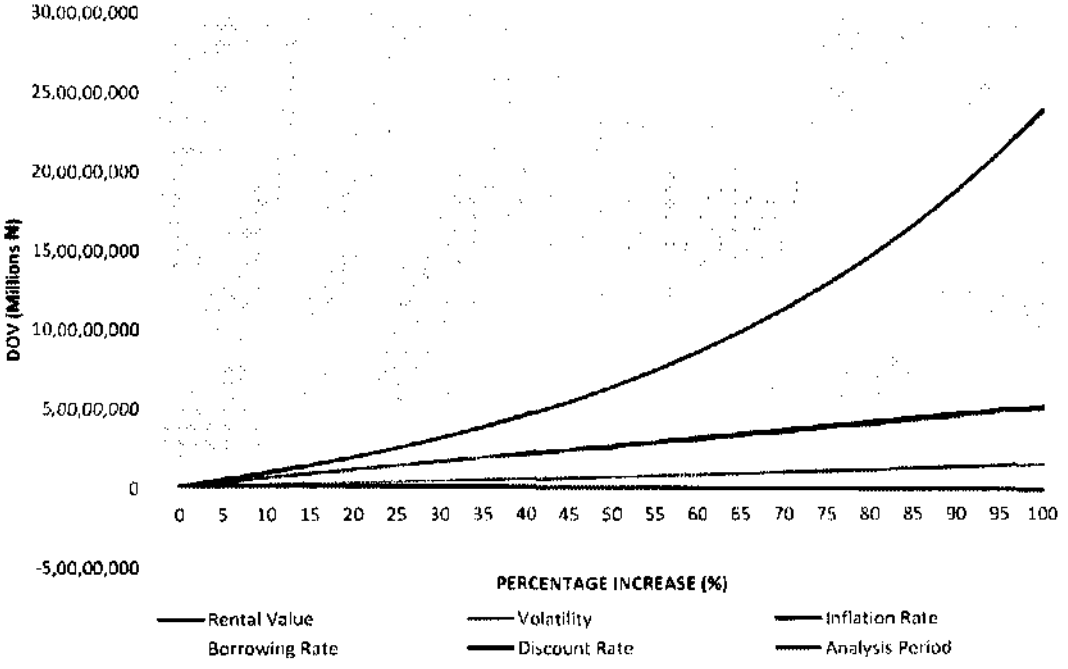


Figure 10. Comparative effect of different variables on DOV

Figure 11 shows the distribution of all possible values of DOV. The result shows a right-skewed frequency curve showing DOV plotted against frequency. The distribution is positively skewed. This shows a slim chance of getting negative DOV and wider chance of having positive DOV.

Table 6 shows the statistical results. The hybrid model shows that the most likely DOV in year 0 is about ₦38.8m. This is very much higher than ₦1.9m obtained using the BM only. The reason for the difference is that the BM considered the given level of uncertainties (δ), inflation rate, borrowing rate and rental value to be deterministically obtained. In reality, this is not always the case. These values cannot be determined without uncertainty. The variables should be stochastically determined. The uncertainties in uncontrollable variables have to be taken into cognizance. So, the hybrid model integrates the BM and MCS to complement each other.

Furthermore, the simulation-based BM also shows that DOV can go as high as ₦344m and can be as low as ₦−26 M which is the extreme case of the project. These results provide an insight into the most optimistic and pessimistic case to the owner. The simulation-based BM allows the owner or the investment analyst to make more informed decisions. The

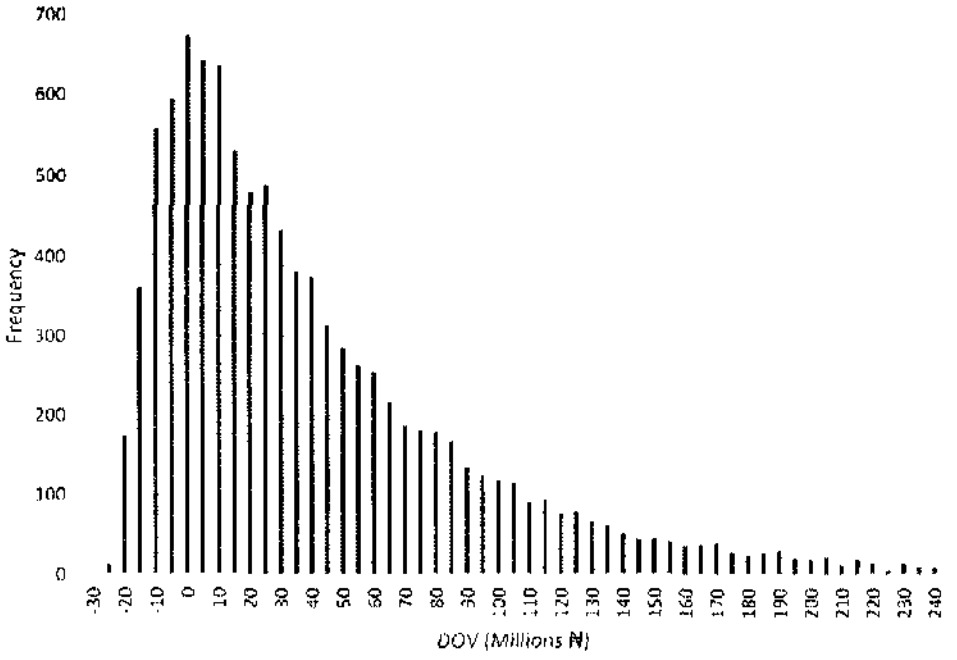


Figure 11. Distribution of possible values of development option

Statistical measurement	Value
Maximum	344,041,421
Minimum	−26,915,019
Standard deviation	52,774,428
Average	38,797,335
Skewness	3.46
Kurtosis	3.08
Chance of making profit, (p)	0.76
Risk of loss, (q)	0.24

Table 6. Statistical measurement of simulation

controllable variables can be adjusted by the building investment decision-maker to achieve a higher DOV. Also, the model predicts the possibility of failure in the project to be about 24% and the possibility of success to be 76%. This indicates that the project is viable and less risky. So, depending on the risk behavior of the investor, the proposed project could proceed or the controllable variables can be adjusted by the investment analyst to obtain a higher DOV which would further reduce the risk of failure in the project.

4.4 Model validation

Table 7 shows the validation results. The validity of the simulation-based BM was tested by comparing its predictive accuracy between a set of results obtained from the model. From Table 7, D is the decision to develop which is to be taken when DOV is above zero. W is the decision to "Wait and See" which is to be taken when DOV is zero. Three sets of results were obtained using three sets of data from 2009 (Data C), 2014 (Data B) and 2019 (Data A). With results from Data A, decisions were compared with the results from Data B, which shows a percentage error of 0%. Likewise, decision results from Data A were also compared with that of Data C which also shows a percentage error of 0%. However, the comparison of decision results of Data B and that of Data C shows a percentage error of 19.23%. This shows that the model has a decision prediction accuracy of 80.77% which indicates high result validity.

5. Conclusion

This study has developed an innovative simulation-based BM which takes account of managerial flexibility and the volatility in costs and benefits over the lifecycle of a building. The model is capable of determining the optimal time of development of buildings. A comparison of the BM and the traditional NPV method shows that a potentially viable project may be disqualified by the NPV technique due to non-consideration of volatility which shows the superiority of ROA over the DCF technique. Also sensitivity analysis indicates that inflation rate and rental value are the most sensitive variables for DOV. An increase in inflation rate and rental value by just 5% causes a corresponding increase in DOV by 202% and 132%, respectively. Discount rate is the least sensitive variable for DOV as an increase in discount rate by 5% causes a corresponding decrease in DOV by just 9%. The model has a result accuracy of 80.77%. A hybrid model that integrates the BM with MCS compliments the two methods to provide a more reliable outcome for economically sustainable building investment decisions.

The study recommends that the model should be used by building investment decision-makers in ensuring economically sustainable building investment decisions. Investment analysts should use the model to determine the viability of building projects and thus, improving profitability. Furthermore, investment analysts should be cautious when using the model because inflation rate and rental value can determine the success and failure of a building investment. Therefore, the input parameters should be carefully determined especially the ones related to the inflation rate and rental value. The study also proved that a hybrid model integrating the BM and MCS provides high DOV. This is because BM alone ignores the possible random change in the uncontrollable variables but MCS mitigates such problem. The two methods complement each other and therefore, a simulation-based BM should be used for building development appraisal.

S/N	Years	Base decision (2019)	Predicted decision (2014)	Predicted decision (2009)	Absolute % error 2019 vs 2014	Absolute % error 2019 vs 2009	Absolute % error 2014 vs 2009
1	2009			D = 1			
2	2010			D = 1			
3	2011			D = 1			
4	2012			D = 1			
5	2013			D = 1			
6	2014		W = 0	D = 1			100
7	2015		W = 0	D = 1			100
8	2016		W = 0	D = 1			100
9	2017		W = 0	D = 1			100
10	2018		W = 0	D = 1			100
11	2019	D = 1	D = 1	D = 1	0	0	0
12	2020	D = 1	D = 1	D = 1	0	0	0
13	2021	D = 1	D = 1	D = 1	0	0	0
14	2022	D = 1	D = 1	D = 1	0	0	0
15	2023	D = 1	D = 1	D = 1	0	0	0
16	2024	D = 1	D = 1	D = 1	0	0	0
17	2025	D = 1	D = 1	D = 1	0	0	0
18	2026	D = 1	D = 1	D = 1	0	0	0
19	2027	D = 1	D = 1	D = 1	0	0	0
20	2028	D = 1	D = 1	D = 1	0	0	0
21	2029	D = 1	D = 1	D = 1	0	0	0
22	2030	D = 1	D = 1	D = 1	0	0	0
23	2031	D = 1	D = 1	D = 1	0	0	0
24	2032	D = 1	D = 1	D = 1	0	0	0
25	2033	D = 1	D = 1	D = 1	0	0	0
26	2034	D = 1	D = 1	D = 1	0	0	0
27	2035	D = 1	D = 1	D = 1	0	0	0
28	2036	D = 1	D = 1	D = 1	0	0	0
29	2037	D = 1	D = 1	D = 1	0	0	0
30	2038	D = 1	D = 1	D = 1	0	0	0
31	2039	D = 1	D = 1	D = 1	0	0	0
32	2040	D = 1	D = 1		0		
33	2041	D = 1	D = 1		0		
34	2042	D = 1	D = 1		0		
35	2043	D = 1	D = 1		0		
36	2044	D = 1	D = 1		0		
37	2045	D = 1					
38	2046	D = 1					
39	2047	D = 1					
40	2048	D = 1					
41	2049	D = 1					
Error					0	0	500
Mean absolute percentage error					0	0	19.23

Table 7.
Validation results

Notes: Legend: D = Develop, W = Wait

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Appendix

Modules: Figures A1 to A8 are the modules used in the algorithm;

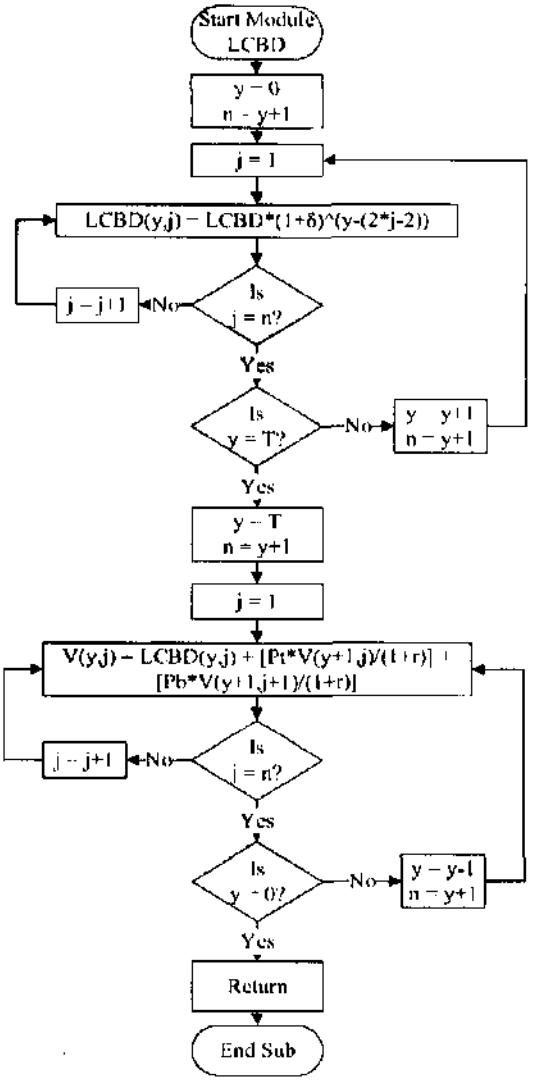


Figure A1.
Module LCBD

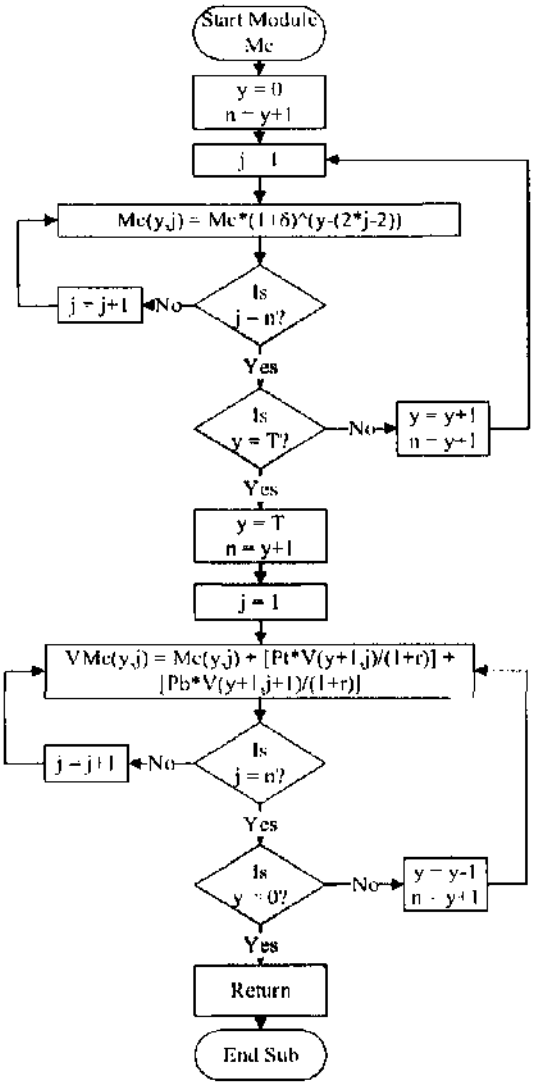


Figure A2.
Module Mc

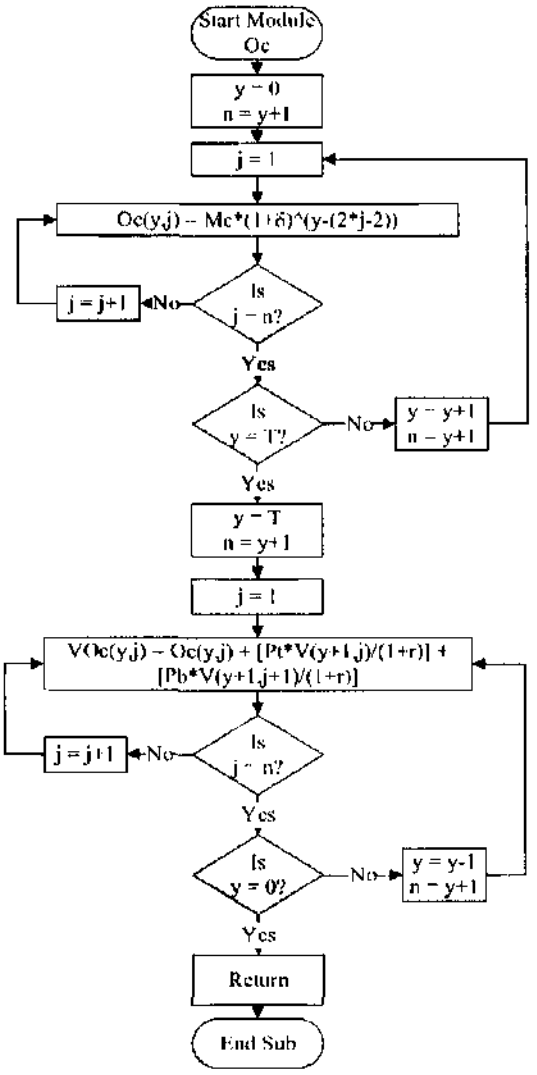


Figure A3.
Module Oc

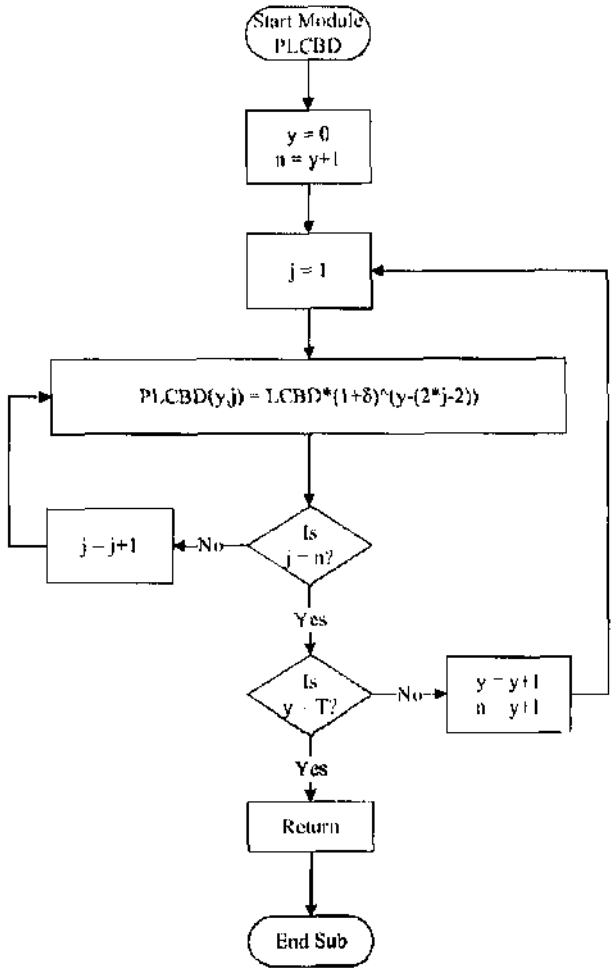


Figure A4.
Module PLCBD

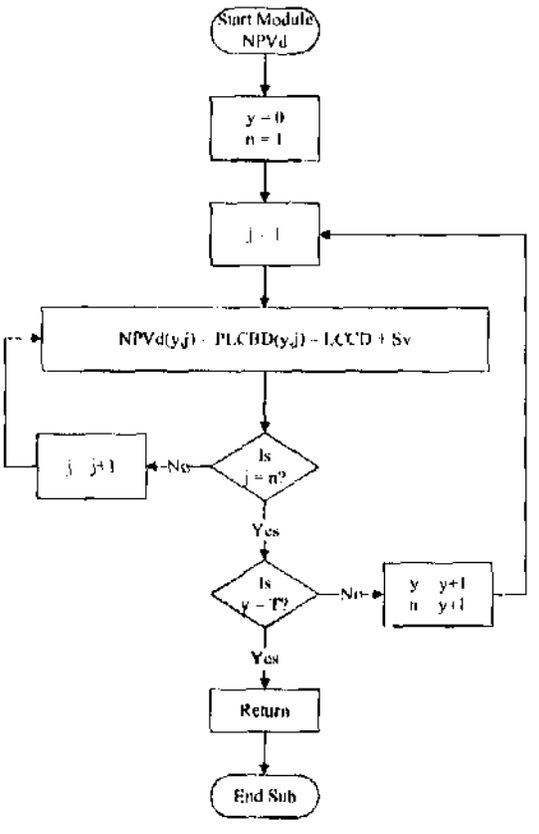


Figure A5.
Module NPVd

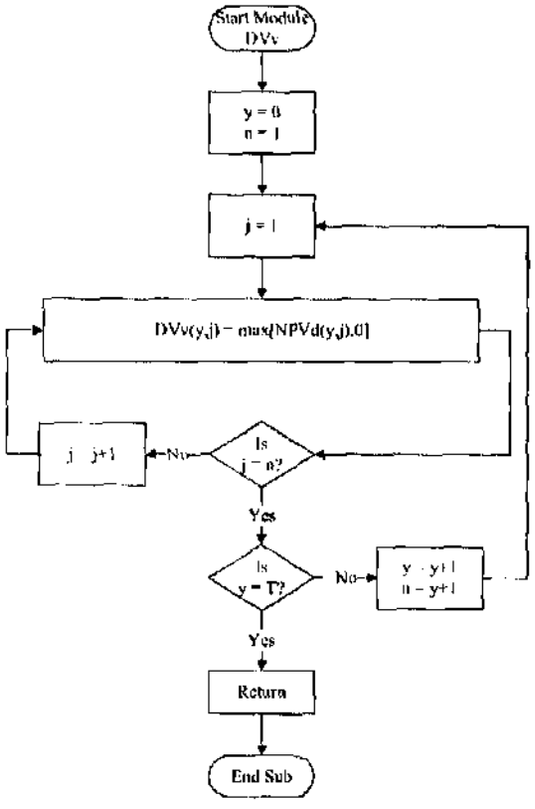


Figure A6.
Module DVv

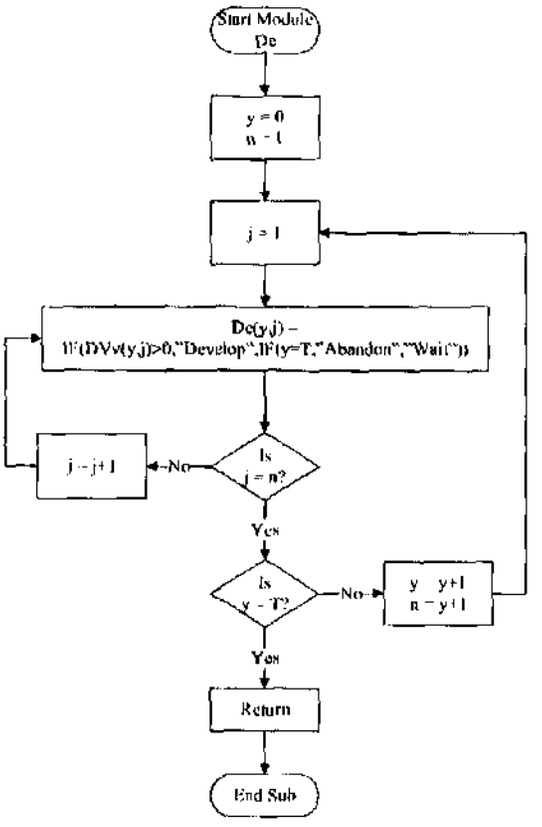


Figure A7.
Module De

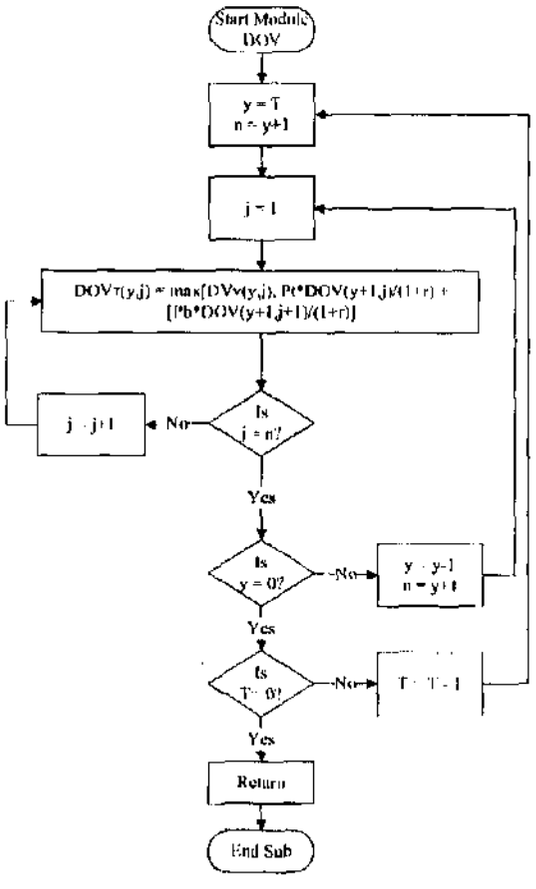


Figure A8.
Module DOV

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