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# MANAGEMENT OF UNCERTAINTY IN REAL ESTATE DEVELOPMENT APPRAISALS: A LITERATURE REVIEW.

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# MANAGEMENT OF UNCERTAINTY IN REAL ESTATE DEVELOPMENT APPRAISALS: A LITERATURE REVIEW.

**ABSTRACT:**

**PURPOSE:** This paper gives a global overview of the management of uncertainty in Real Estate Development (RED) appraisal. It provides a comprehensive review of the concepts related to forms and sources of, and management of uncertainty as well as factors influencing the adoption of real option appraisal models in RED. This is against the background of the need to improve the knowledge of stakeholders in RED appraisal practice and to ensure best practices.

**DESIGN/METHODS:** The research was based on desktop analysis of past authors' perspectives, orientations and submissions on the management of uncertainty in RED appraisal.

**FINDINGS:** As it is expected, there are varying forms and sources of uncertainty in RED appraisal. Also, the review revealed diverse methods that could be used to manage uncertainty in RED appraisal. This range broadly from traditional approaches to modern/contemporary models such as real options approaches. It is however noted that while approaches to the management of uncertainty in RED appraisal abound, the methods employed appear to be dependent on RED appraiser and other institutional factors. The consensus from the reviewed works favoured real options model as the best approach towards managing uncertainty in RED appraisal. A framework that incorporates real options model in RED appraisal is thus advocated.

**PRACTICAL IMPLICATION:** This paper adds to the debate on the need to embrace real options model in managing the effects of uncertainty in RED appraisal. The information provided, no doubt, will improve the knowledge of stakeholders in RED appraisal practice and could ensure best practices.

**ORIGINALITY:** The paper provides an in-depth examination of various concepts, perspectives and orientations on the management of uncertainty in RED appraisal, towards the adoption of a better framework.

**KEYWORDS:** uncertainty, flexibility, management, real option, real estate development, appraisal.

## 1. INTRODUCTION

The nature of investment in real estate by institutional and multinational investors has over time been concentrated largely on direct real estate assets; owing to the seeming prospects and benefits of huge returns (PWC & the Urban Land Institute, 2013; Ekpenyong, 2015). While real estate investment is fixed both in time and space; involving huge capital outlay, its ability to give investors the expected return is subject to an array of sources from which uncertainty influences the expectation. Real Estate Development (RED) could thus be regarded as an entrepreneurial activity that involves some measure of risk and uncertainty. In other words, it could be said that risk and uncertainty are integral parts of investment decisions and the success or otherwise of RED decision depends on the assessment and management of the inherent risk and uncertainty. The problem of risk and uncertainty in RED is compounded by new developments in the real estate market which have increased the sophistication of the investors' and that of the market. For example, real estate investments are now dominated by institutional investors while globalization and Information and Communication Technology (ICT) have improved accessibility to new innovative decision tools in RED. The investment appraiser must, therefore, manage uncertainty and incorporate it into the financial analysis. This will eventually form the basis of advice to the investor about the investment outlay.

Given the increasing investors' sophistication the prevalence of risk and uncertainty in real estate markets, RED decisions are becoming more complex than a "Yes or No" decision criterion. The investor now has the inherent ability to take new decisions at any time over the life of the investment in response to unfolding economic realities; which hitherto has been uncertain. Evidence in previous studies have shown that the traditional methods which have long been in use in RED appraisal (Bowman & Moskowitz, 2001; Copeland, et al., 2010), have been of little practical importance due to the irreversible nature of RED, the presence of uncertainty and lopsided information (see for instance Feinstein and Lander, 2002; Tomas and Višić, 2009; Sattarnusart, 2012). In addition, authors have submitted that the traditional approaches do not always capture realistic appraisal of RED projects due to their static accept or reject rule (Chance & Peterson, 2002), and do not account for other potential opportunities that an investment can generate in the future.

The corollary of the foregoing is that traditional approaches to RED appraisal are no more adequate to serve as decision criteria under uncertainty conditions. Thus, methods that incorporate management of uncertainty in RED appraisal are advocated. Meanwhile, it is not clear whether or not RED appraisers and other stakeholders (especially in emerging economies) have adequate knowledge of these methods. Putting the foregoing together, this paper gives a global overview of the management of uncertainty in real estate development (RED) appraisal. It provides a comprehensive review of the concepts related to forms and sources of and management of uncertainty and the factors influencing the adoption of real options models in RED appraisal. This is against the background of the need to improve the knowledge of stakeholders in RED appraisal practice and to ensure best practices.

## 2. METHODOLOGY

To achieve its objectives, the paper employed desktop analysis of past authors' perspectives, orientations and submissions on the management of uncertainty in RED appraisal. The literature examined focused primarily on studies related to uncertainty and risk from the psychological and sociological perspectives, with an emphasis on finance and economic perspectives. The study also explored literature on real options as it related to RED options, a greater percentage of which were from studies in developed economies. Studies on empirical investigations of flexibility and the real options framework were not included in the review as they were outside the aim of the paper.

### 3. RISK AND UNCERTAINTY IN RED

Given that the identification, management and control of risk and uncertainty are integral parts of RED projects, a clear definition of the two based on previous studies and the perspective of this study to these two concepts must be stated explicitly. While there are varying perceptions of risk and uncertainty, these variations appear to be dependent on the context in which risk and uncertainty are discussed.

Risk and uncertainty are integral parts of our daily life and it is often analysed quickly and spontaneously based on feelings which are usually in the form of experiential thinking (Slovic and Peters, 2006). From a psychological perspective, the studies of Slovic et al (2004) and Slovic and Peters (2006) submitted that risk could be viewed from two perspectives. First as feelings; that is, a fast, instinctive and intuitive perception of, and reaction to danger. Second, as an analytical process that encompasses logic, reason and scientific methods in the management of risk and decision-making processes. The third perspective to risk explanation brings to the fore the concept of risk as politics. The perception of risk as politics emphasises the influence of power, status, perceived government influence and sociopolitical factors among others in defining the level of risk perception and acceptance (see Slovic, 1999). Furthermore, studies such as Peters and Slovic (1996), Peters, Burraston and Mertz (2004) viewed the psychological perspectives of risk as encompassing two dimensions: the dread and the unknown risk. While the first relates to the extent of apparent lack of control, feelings of dread, seeming potential of disaster and the unequal distribution of risk and benefits, the latter relates to the level to which the hazard is adjudged undetected, new or delayed resulting in unexpected consequences.

Another way to view risk is from the perspective of consequentialism. According to Loewenstein et al (2001), viewing risk from a consequentialist perspective means that decisions are made on the basis of an assessment of consequences of feasible alternatives. This notion of risk relates more to feelings and emotions experienced during the decision making process. Thus, while the assessment of risk is cognitive, the reaction is emotional. Furthermore, Luhmann (1990) noted that risk, which if measurable is a counter concept to security which is immeasurable. The author defined risk as the "possibility of future damage, exceeding all reasonable costs that are attributed to a decision". The study concluded that risk is an avoidable causal link between the time when the decision is made and the time of damage, thereby having the prospect of post-decisional regret. It then suffices to note that risk is an attribute of a decision or indecision, which relates to the level to which probability could be attached to uncertainty about such decisions.

From the perspective of finance and economic literature, the work of Knight (1921) could be regarded as a pioneering study in differentiating between risk and uncertainty in economic theory. The study posited that uncertainty basically relates to the lack of knowledge on possible outcomes, while risk refers to situations with known alternative outcomes and the attached level of probability associated with each outcome. The study submitted that while risk can be measured numerically, the same cannot be said of uncertainty. Thus, the author concluded that risk could be regarded as measurable uncertainty. While it appears that this position was sufficient to clear the difference between these two terminologies, the study of Pandey (1999) noted that the distinction between risk and uncertainty as submitted by Knight (1921) was not recognized in most finance and economic literature as the two terms are often used synonymously. Hence, uncertainty could be said to be a complex concept with diverse perspectives across varying disciplines, professions and problem domains (Smithson, 2008; Saunders, Gale and Sherry, 2015). However, from real estate appraisers' perspective, and perhaps in line with Knight's (1921) position, the study of Byrne (1998) noted that uncertainty is the lack of knowledge about the outcome of a project at the time of making decision, while risk refers to the extent of loss, identified as a probable outcome of a decision.

Also, uncertainty can be regarded as the inability to ascertain the exact state of a system (Haimes, 1998); which apparently suggests that the probability cannot be measured. Furthermore, Pender (2001) opined that risk applies to situations where there is a probability of repetition and replicability, while uncertainty connotes situations, where no prior knowledge exists for replicability and future occurrence cannot be categorized based on past precedence. Thus, it might suffice to note that since each RED is unique and homogeneous, it is expected that appraisal of REDs would largely involve uncertainty as opposed to risk. This is because each RED comes with its unique conditions and characteristics. It can then be submitted that total ignorance or fundamental uncertainty applies to RED, given that knowledge of future events in relation to the project and other underlying economic inputs are limited.

The study of Ward and Chapman (2003) posited that uncertainty connotes the lack of certainty and refers to the variability in relation to cost, time or quality. It could also be about ambiguity with respect to the lack of certainty due to the attitude of key project actors, lack of data, lack of details, lack of structure to examine issues, lack of sources of bias or ignorance. Uncertainty could also arise when details regarding a system cannot be identified, or, only known without precision (McManus and Hastings, 2005). Given this background, uncertainty could then be regarded as unquantifiable, because the consequences are unpredictable (Blokpoel et al, 2005; Reymen et al, 2008).

In a similar vein, Sloman (2006) argued that for both risk and uncertainty, the outcomes may or may not occur due to imperfect information about the future. According to Perminova et al (2008) uncertainty refers to when it is impossible to calculate the risk inherent in an outlay. Hence, risk has the ability to assume probability of occurrence and it is seen as less threatening to investment decisions as compared to uncertainty whose probability of occurrence is unknown. A study by Loizou and French (2012) posited that where probability can be attached to the input variables; that is, the ability to determine a range of possible outcomes, such an output is thus a measure of risk. Risk can then be regarded as the deviation from the central tendency.

Employing the uncertainty spectrum framework of Hargitay and Yu (1993) while putting the foregoing together, it may suffice to note that uncertainty could be regarded as either partial or total. Total uncertainty arises where the alternatives cannot be identified, while partial uncertainty relates to situations where the alternatives can be identified, but not with predictability or probability. However, where there are identifiable alternatives with a measure of predictability and probability, such scenarios refer to risk.

The foregoing thus presupposes that uncertainty primarily arises due to lack of knowledge and lopsided information leading to inability to predict all variable inputs required for informed decision-making. Thus, uncertainty is a fact which man and all decision makers must contend with and it arises as a result of ignorance with respect to the state of knowledge, that is, internal uncertainty, and/or lack of control or ability, that is, external uncertainty (Kahneman and Tversky, 1982). It can be regarded as an unpredictable and/or uncontrollable risk.

## 4. FORMS AND SOURCES OF UNCERTAINTY IN REAL ESTATE DEVELOPMENT

The environment; economic, physical, political, among others, within which RED situates is subject to an array of influences that introduces uncertainty to the core of all RED activities. Thus, uncertainty in RED takes on different forms and arises from different sources. However, Kahneman and Tversky (1982) noted that while probability can be used to express forms of uncertainty, the laws of probability cannot be applied to all variants of uncertainty in equal proportion. The laws of probability are often satisfied based on intuitive judgement, especially when an external source of uncertainty is assessed in a distributional mode. An examination of these forms and sources is the focus of the subsequent subsections.

### 4.1 FORMS OF UNCERTAINTY

Extant studies suggest that forms of uncertainty are broadly grouped into two categories. These are epistemic uncertainty and aleatoric uncertainty.

#### A. EPISTEMIC UNCERTAINTY

Epistemic uncertainty is derived from the Greek word episteme meaning knowledge. It arises from insufficient knowledge about possible outcomes, the nature of outcomes and the associated probabilities. Epistemic uncertainty could be reduced in principle; with the passage of time and availability of more information. Thus, this kind of uncertainty arises from incomplete theory and imperfect understanding of a system or limited data. Epistemic uncertainty could also be referred to as internal, imprecision, functional, subjective, reducible or model form uncertainty (Hillson, 2004; Chalupnik et al, 2009; Yeo, 2012). As such with regards to RED, instances such as dated, missing, vague or incomplete information, incorrect assumptions and unexpected changes in socioeconomic variables, relates more to epistemic uncertainty.

### B. ALEATORIC UNCERTAINTY

Aleatoric uncertainty, gotten from the Latin word aleator – dice thrower; or alea - dice, refers to inherent variability, chance, randomness or unpredictability. It arises due to natural, unpredictable variation or randomness in the performance of a process. It is irreducible; thus obtaining more knowledge cannot eliminate inherent variability. Aleatoric uncertainty, sometimes associated with variability, could also be termed as natural variability, irreducible uncertainty, stochastic uncertainty and random uncertainty (Chalupnik et al, 2009; Yeo, 2012). Aleatoric uncertainty connotes the knowledge of a range of a possible set of outcomes and the probability attached to each can be measured. However, the precise outcome at any instance is unknown. Aleatoric uncertainty is often represented in stochastic terms and reasoned out using probability theory (Hillson, 2004; Aughenbaugh and Paredis, 2006). With recourse to RED, uncertainty arising from sources such as environmental, social complexity and change in physical environment could be termed as aleatoric uncertainty.

Given that processes involving random behaviour exhibiting unpredictability are referred to as stochastic process; the outcomes of such process are dynamic from time to time and place to place, even when other basic elements are constant. The RED process similarly exhibits such stochastic nature; however, its basic features are not constant. Thus, RED could be regarded as a more complex stochastic process whose features vary with time, place and variable inputs. This presupposes that when there is the inability to ascertain the validity of variable input in the RED, the resulting outcome of the appraisal might become uncertain leading to loss of capital or investment (Loizou and French, 2012; Sattarnusart, 2012).

The foregoing presupposes that the two aforementioned forms of uncertainty are broader perspectives from which sources of uncertainty can be examined. An examination of these sources of uncertainty is discussed subsequently.

## 4.2 SOURCES OF UNCERTAINTY

With respect to RED investments, uncertainty lies at the root of all RED projects and its sources are varied and peculiar. Hillson (2004) noted that real estate projects are subject to uncertainty from a multiplicity of sources that can be either internal or external to the project, and these range from technical, to management, to operational and to commercial uncertainty. Internal sources relate to either the actual work to be done (changing work requirements/scope, wrong or flawed assumption(s) and new technology/method) or people involved in the work (varying skills/productivity and performance of team members). External sources encompass issues such as project environment, market condition, the action of competitors, change in exchange/inflation rates, weather conditions and influence of other stakeholders. From a related perspective, Reymen et al (2008) noted that uncertainty in relation to RED could be addressed from two major perspectives; these are the cause and consequence. The causes relate to the unpredictability of input variables (data and values) while the consequences relate to uncontrollability of decisions made by the team members, especially the investor or investment appraiser.

Corroborating previous discussions, Chalupnik et al (2009) noted that two sources of uncertainty can be identified in the development process. The first is the exogenous uncertainty, relating to unknown variables in the external environment of the RED process. The second is the endogenous uncertainty, which relates to the unknown internal factors embedded in the RED process. Exogenous uncertainty, with respect to RED process, explains the uncertainty whose source arises from the external project environment. This external uncertainty can arise because of change in organizational structure, volatility/unpredictability of economic variables, changes in users taste, or due to the dynamism of political and cultural setup of the RED company. Endogenous uncertainty whose source is internal to the RED process can further be examined from two perspectives. The first is the uncertainty associated with the technological novelty dimension, which could be because of product or process technological novelty. The second relates to process complexity dimension. This pertains to the challenges that are peculiar to achieving the process objectives, the innovation of the objectives to the RED company and the level of interdependency among the product element.

Further, the study of Yoe (2012) posited that uncertainty result from two distinct sources; natural variability and knowledge uncertainty. The former, which relates to the macro level, arises due to decision making in a dynamic

and uncertain environment. The latter, which is at the micro level, relates to particular scenarios with respect to knowledge, data and models used in the RED appraisal. Uncertainty at the macro level impact on RED investment decision through a continuously and swiftly changing social and economic environment, while micro level uncertainty concerns specific details in the project at the level of available knowledge.

Perhaps from what appears as a more detailed perspective, Saunder's et al (2015) study noted that sources of uncertainty could be grouped into five (5) broad perspectives, namely environmental, individual, complexity, information and temporal perspectives. Sources of uncertainty from the environmental perspective include factors such as turbulence of the environment, institutional norms and process of decision making and competitor threats, external industry and market risks. The individual sources encompass factors like internal state of understanding, uncertainty existing in the mind of the individual and the differing perception varying psychological profiles towards uncertainty. The complexity dimension emphasizes on factors such as choice of technology, process actors, diversity of process stakeholders and inherent project complexity. For the latter two: information and temporal, the sources of uncertainty with respect to information perspective arises due to incomplete and imperfect information, lack of knowledge, incomplete understanding of cause and effect and inability to arrive at accurate project estimates. Temporal source involves the stage of project life cycle, project tempo and scale of project turbulence.

The corollary of the foregoing is that uncertainty is an integral part of the RED appraisal and can arise from either the project environment or from the economic environment wherein the RED situates. Uncertainty from project environment includes instances such as the influence of project stakeholders, project scope, the level of technology required and varying psychological profiles, among others. Uncertainty from economic environment includes, but not limited to, market data, market risk, volatility of economic variables and incomplete information.

## 5. MANAGEMENT OF UNCERTAINTY IN RED

Studies have investigated into the management of uncertainty in relation to general investment decisions and in particular to RED. Bannerman (1993) however noted that results of appraisal in emerging countries, when compared with developed economies, are often difficult to justify and rely upon given that most emerging markets are bedeviled with high rate of fluctuations in respect to market data and other input variables which apparently have some overbearing influence on the reliability of the appraisal estimates and guarantee of investors returns. Hence, the issue of managing uncertainty comes to the fore, especially in emerging markets. The management of uncertainty can be done in a number of ways, however, these are divided into three. They include traditional, probabilistic and contemporary appraisal models. An examination of these approaches is undertaken hereafter.

### 5.1 TRADITIONAL APPRAISAL TECHNIQUES

While there are varieties of traditional investment evaluation tools in the portfolio of an investment appraiser, the portfolio of traditional techniques could be broadly grouped into non-discounting and discounting methods. The non-discounting investment appraisal methods include methods such as payback period, accounting rate of return, maximum cash exposure, among others. The discounting methods encompass methods like the net present value (NPV), internal rate of return (IRR). These are also regarded as variants of the discounted cash flow (DCF) techniques and they are commonly employed in determining future cash flows and serve as the basis for assessing investment values (Chance and Peterson, 2002).

Authors such as Trigeorgis (1993), Walters and Giles (2000) and Carmichael (2011) have noted that the use of the traditional models in appraising irreversible investment did not consider the strategic importance of investor's flexibility in revising or altering decision after the commencement of the project, and investment capital is seen as being passively held. Thus, the models cannot address properly the problem of uncertainty in the RED appraisal. For instance, investment appraisers using the traditional models assume that the project will commence operation immediately and continue production without interruption until the capital equipment becomes scrapped (Slade, 2001; Yeo and Qiu, 2003); despite the uncertainty in the future. This is seldom possible.

In general, the traditional investment models have not adequately emphasized the implications of the relationships between irreversibility, uncertainty and timing choice in investment decisions. Hence, the resultant criticisms that most investments are more sensitive to issues of volatility and uncertainty in the economic environment over a longer period of time (Dixit and Pindyck, 1994). Mun (2006), summarize the critique with the use of traditional investment appraisal methods. The models undervalue assets that presently produce little or zero cash flow. Others are non-consistency on the average cost of capital or discount rate during the investment period, wrong estimates of assets economic life, forecast errors in calculating future cash flows and inadequate test for reasonableness of the final value estimates.

Traditional theories of investment under uncertainty employ static decision rules on whether to invest or not. Where the project expected NPV is positive, higher IRR, or quicker payback period, decision to invest is positive; if otherwise, the decision to invest is not encouraged. This is tantamount to determining the present values of investment before they are received, and that the investment decision is all-or-nothing, yes-or-no. This leaves no allowance for an initial decision, followed by other subsequent decisions based on unfolding future happenings. However, in the face of realistic assumptions, an investment with a negative NPV, lower IRR or a longer payback period, based on current realities, might subsequently have a positive NPV, higher IRR or shorter payback period, when economic parameters and other input variables are more favourable. This clearly raises the problem of uncertainty and underscores the need for flexibility, as being incorporated in the contemporary appraisal models.

Hence, given that investment appraisal methods are expected to reflect flexibility and strategic value, as important components that contribute substantially to the value of the project in an uncertain market environment, the traditional approach will not explicitly evaluate the value of flexibility embedded in an investment outlay (Chance and Peterson, 2002; Trigeorgis and Smith, 2004). The traditional models are often skewed and fail to give a thorough perspective of the investment value of the project, thus giving rise to the possibility of an undervalued investment (Block, 2007). It therefore presupposes that the assumptions underlying the traditional models might lead to unreliability of the appraisal estimates, due to its static one-time decision.

As a corollary, traditional models might not be a sufficient basis to advise investors given the tendency for wrong investment decisions. This is due to the irreversible nature of most investments and the inherent ability to exercise a delay or postpone investment decisions, which lies at the discretion of the investor. Hence, the concept of irreversibility undermines the theoretical underpinnings of the neoclassical investment theories and invalidates the traditional decision rule. Thus, irreversibility makes investment sensitive to various forms of uncertainty over future prospects that the traditional models fail to adequately incorporate (Pindyck, 1991).

The above is not underplaying the importance of the traditional based approaches in evaluating safe assets and investment decisions in an environment of certainty and stability in input variables. If all uncertainties are cleared, and all options are known at the commencement of the project and can be accurately evaluated, traditional appraisal models can be used with precision, but this is rarely the case. Thus, the models usually fail to account adequately for uncertainty and pricing of flexibility entrenched in the valuation of risky investments (Slade, 2001; Mun, 2002). Thus, arising from the inability of the traditional investment appraisal models to adequately value flexibility, the probabilistic technique was proposed as a means of enhancing the reliability of appraisal estimates obtained from the traditional models.

### 5.2 PROBABILISTIC APPRAISAL TECHNIQUES

Probabilistic techniques appear to be somewhat of a departure from the conventional traditional approaches employed in investment appraisal. These techniques, though do not provide a thorough evaluation of the various options available to the investor; they afford some form of insights into likely options/pathways in making optimal investment decisions.

Probabilistic techniques encompass methods such as sensitivity analysis, simulation analysis, and decision trees analysis among others. However, these probabilistic techniques do not recognize the inherent opportunity to modify investment outlays (Brealey et al, 2012). Also, while sensitivity and simulation analysis could be used in

evaluating the available opportunities by clearly presenting possible outcomes of a decision; they do not provide optimal guidance concerning which course of action, out of the numerous, would guarantee the investors optimal returns. Thus, while sensitivity analysis allows for assessing the effects of changes in a factor on projects' estimated values, and simulation analysis provide for more than one factor varying randomly, both methods apparently allow for some form of changes in factors but do not holistically capture the options that are embedded in an investment project.

With respect to decision tree, though it provides a mapping of alternative options, the use of a single discount rate negates the reality that the rates fluctuate over the life of the investment. Hence, it also fails to capture the "real" values of the available options. Thus, though the traditional valuation models can be enhanced with the use of probabilistic techniques, by incorporating some flexibility, the results, however, becomes too complex for interpretation and decision-making (Chance and Peterson, 2002). Furthermore, caution needs to be applied if the variables are to be tested in combination during the sensitivity analysis (Raftery, 2003). The foregoing thus suggests that though the probabilistic techniques appear to offer some forms of assistance in managing uncertainty in RED; the contemporary appraisal techniques, such as the option pricing framework, provide more robust, real and comprehensive means of analysis.

### 5.3 CONTEMPORARY APPRAISAL TECHNIQUES

Several contemporary methods have been proposed in the literature to manage uncertainty in RED. In what appears to be a descriptive perspective, the study of Ward and Chapman (2003) advocated for the use of a holistic approach in handling uncertainty in projects. This approach takes into account a careful analysis of project design, base plans, nature of project stakeholders and their investment objectives. However, given that this approach lacks quantitative analysis, its adoption in managing uncertainty in RED appraisal might best be complimented with other contemporary quantitative methods. While the study of Blokpoel et al (2005) and Reyman et al (2008) suggest the use of the scrum based framework, Ustinovičius et al (2007) proposed the adoption of stochastic programming in minimizing the effects of uncertainty at the various phases of the RED project. Furthermore, from another differing approach, the study of Yeo and Qui (2003) argued for the need to adopt the real options framework as a means of managing uncertainty in RED. Corroborating this perspective, the study of Săcui and Dumitru (2012) argued that given the deficiency of traditional models to manage uncertainty in RED arising from the dynamic and uncertain business environment, real options approach has become dominant in valuing, selecting, and managing of strategic investments under uncertainty. Several other studies such as Throupe et al (2012), Morano et al (2014) corroborated this assertion on the efficiency of the real options framework as a means of managing uncertainty in RED projects. Hence, it appears that though there are other contemporary methods that can be employed to manage uncertainty in RED as suggested in the literature, the use of real options framework has come to the fore. The focus of the next section is to discuss the various options available in RED.

## 6. TYPES OF OPTIONS IN RED

Each real option type as discussed in the literature is aimed at mitigating uncertainty in the RED appraisal. Thus, each of the options must be carefully considered and applied based on the context of the RED, with the understanding that each RED project is homogenous in nature. Săcui & Dumitru (2012) submitted that real options can be broadly differentiated into two groups namely; inherent and created options. While inherent options are also known as control options, they are characterized by the fact that they do not require special activities; they are only observed. Examples of such options include - deferring, waiting, abandoning and expansion of the project. A major characteristic of such options is the ability to identify and utilize the options. Created options refer to those options that require intentional and well thought out actions for their creation and maintenance. The investment appraiser takes into consideration possible evolution of future events while creating such options.

The application of real options to RED has taken different perspectives in literature. Studies such as Satturnsat (2012) and Smit and Trigeorgis (2003) noted that the option to defer investment applies more to RED than all other

options, or perhaps to the exclusion of other options. Kumar (2016) noted that there were three main types of options peculiar to RED. These are: option to postpone or delay, the option to expand and option to abandon. Also, Brandao and Dyer (2003) posited that typical RED flexibilities include, phasing, abandoning and waiting. While other studies such as Kim (2008), Guma (2008), Barman and Nash (2008), Pearson and Wittels (2008) and Cailao (2009) have investigated the application of an option or a multiple of options such as, vertical expansion/phasing, switching, deferring and abandoning, on RED. Thus, it appears that the argument as to which of these options readily applies to RED might be well situated in the context of the type, scale and scope of the RED project and perhaps the national and regional regulatory environment. Thus, though different studies have suggested varying classifications/groupings of the types of real options applicable in RED projects, given the simplicity and robustness of Masunaga (2007) and Cailao (2009) in discussing the various types of options as applicable to RED investment decisions, this study adopted their classification of real options as follows:

### 5.1 GROWTH/PHASING OPTION

Growth/Phasing option could also be referred to as expansion option, and it is one of the common types of options in use, especially in a growing and thriving economy (Chance and Peterson, 2002). Where there is good economic outlook and market conditions are favourable than anticipated, investors thus seek to increase possible profits. A phasing option arises when the developer builds an initial phase and waits to observe the performance of the market before commencing subsequent phases. If the first stage is viable and successful, the development is continued and expanded. The developer, being profit driven, subsequently reduces the risk by dividing the project into separate phases by delaying or cancelling additional phases; if they do not guarantee commensurate returns on investment at a future date. When an investment has growth option, it implies that the investor has the opportunity to add more funds and expand the project's scale at a future date. Trigeorgis and Smith (2004) posited the higher the growth/expansion option, the higher the market value of the investment. However, this may appear excessive based on the standard DCF appraisal methods.

Hence, given the existence and value of growth options, an investor may choose to embark on the initial phase despite seeming negative outcomes; and the unfolding success or otherwise of the initial phase determines if the subsequent phases would be embarked upon (Cailao, 2009; Săcui & Dumitru, 2012).

### 5.2 DEFERMENT/WAITING OPTIONS

The case for deferral is made when considerable value can be gained by waiting to resolve some forms of uncertainties associated with the project or investment environment. The investor can choose to stay put or suspend investment due to doubt about future opportunities or when there is uncertainty about major inputs in the investment decision. Thus, the investor might be buying time for the investment outlay, in anticipation that the unfolding developments become favourable in the near future (Săcui & Dumitru 2012). This suggests that a period is allowed for understudying the market/investment environment and to have a better grasp of the unfolding market conditions. The corollary of the foregoing is that some projects are not necessarily needed to be commenced or initiated now, given the prevailing market circumstances. Although it might be expected that waiting might give competitors some form of early lead in terms of market entry, it has the potential to expose hitherto unknown valuable information about the market dynamics. For instance, an investor may wait for markets to recover from a downturn, or wait for some amendment/changes in unfavourable government policies with respect to certain developments before embarking on development in anticipation of a favourable upside potential.

With respect to RED projects, an investor's decision to construct/develop might be deferred to wait and see if market rental values would justify construction/development (Yeo and Qiu, 2003; Cailao, 2009). According to Kandel and Pearson (2002), under uncertainty conditions, investors are more predisposed to wait rather than committing resources. Thus, under a more realistic scenario, the option to wait is a preferred alternative to investing or not investing, as opposed to the static traditional decision of accepting or rejecting. An argument in favour of the dynamism of investment timing, as opposed to static accept/reject, is that due to the irreversible nature of

RED projects, a more rational behaviour is withholding of commitment to invest until much of the uncertainty is eliminated (Rodrik, 1991). Thus, it appears that uncertainty with RED naturally stimulates an option value for waiting due to the huge financial investment and irreversible nature of real estate investments.

### 5.3 EXIT/ABANDONMENT OPTIONS

Where conditions in the market deteriorate severely during the economic life of a project, the investor can decide to abandon the project out-rightly by not investing any further in it. This option is aimed at cutting losses and it gives the investor the option to abandon the project midway, given that new information is unfavourable for continuing the project (Masunaga, 2007; Cailao, 2009). Some options to abandon gives the investor the opportunity to dispose of the project and realize the salvage/resale value of previous capital investments made in the project. However, before the investor considers the option to exit, there might need to examine existing legal implications. Hence, the option to exit only becomes ideal in a RED project when the reality of obvious risk becomes apparent and there is no legal implication for such default option. In the case of RED, the owner of a vacant land exercises the exit option when he sells the land without building on it (Chance and Peterson, 2002; Săcui & Dumitru, 2012).

### 5.4 LEARNING OPTIONS

Learning options are somewhat akin to phasing and deferment options. However, at this instance, the investor might explore the suitability of the project by embarking on the development of the initial phase, perhaps, with low cost. Subsequently, the outcome can help the investor decide on whether to modify or abandon the other phases in order to minimize loss and maximize the total value of the project. Thus, the initial phase serves as a pilot study for the investor to understudy the market and other economic variables associated with the development (Masunaga, 2007; Cailao, 2009). Mun (2006) noted that learning models are a part of real options, as management makes superior strategic decisions with the passage of time and uncertainty is resolved.

### 5.5 MODIFY/SWITCHING OPTIONS

Perhaps due to fluctuating economic variables, leading to changes in market prices or consumer demand, the investor can decide to alter the output mix (product flexibility) or maintain the same output, but different input (process flexibility) (Tamayo-Torres et al, 2010). This option is often embedded in the initial project design. Thus, with respect to RED projects, instances such as conversion, alteration or modification are examples of switching options. It affords the investor the opportunity to modify existing project design to suit new uses arising from the change in market demand and preferences. For instance, the appraiser might advise the investor to switch from hotels to apartment houses or from residential to office building and vice versa, given the unfolding realities of the market (Masunaga, 2007; Cailao, 2009).

Other types of option within the ambit of the classification adopted for this study include the option to contract. Contracting options arise when the economic outlook appears less favourable than anticipated. The investor can decide to reduce the project's scale (contracts) and on the extreme, the development may be halted temporarily and start up later (Chance and Peterson, 2002). This form of option is combined with the option to delay initial investment and reduce the scale of the project, which is a contrast of growth option.

The aforementioned opportunities connote real options that allow the investor the opportunity to enhance the project's value. This value cannot be determined using traditional DCF models, rather through real options analysis. The real options framework presents a corresponding flexible pathway for its holder whether to wait, invest or defer; though, the choice of exercising any of these options is dependent on prevailing market conditions. Thus, as noted by Barman and Nash (2007), the investor exercises flexibility when there is an adjustment/modification to the existing course of action, resulting from changes in the economy and/or project; so long, there is no prior commitment or downside risk exposure. However, it must be noted that real options as discussed above are related to each other, given that RED projects can feature more than one real option simultaneously.

## 7. REAL OPTION MODELS

Extant literature suggests different categorizations of modelling approaches used in real options analysis (see, for instance, Miller and Park 2002; Guma, 2008; Cailao, 2009 and Peter, 2012). However, this study adopted the categorization employed by Miller and Park (2002) owing to its simplicity and clarity.

Miller and Park (2002) noted that there are two broad approaches employed in the valuation of real options, these are the discrete time approach and the continuous time approach. While the example of the discrete time approach includes the Multinomial lattices, models under the continuous time approach are the closed form equations, stochastic differential equations and the simulation models. A comparison of the advantages and disadvantages of each approach is shown in Figure 1, as adapted from Miller and Park (2002).

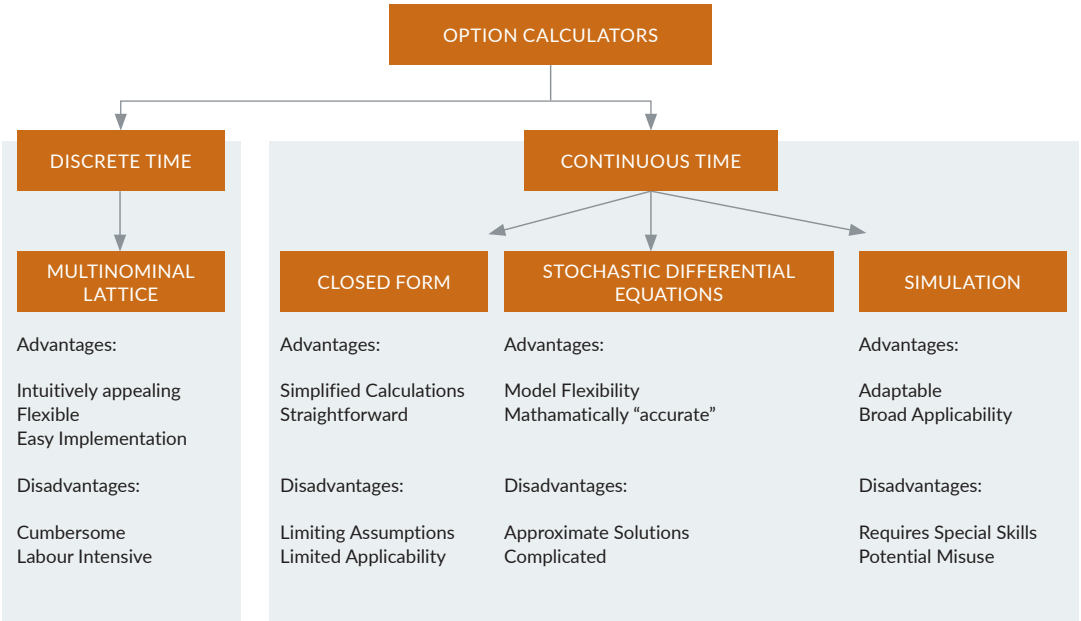


Figure 1: Flexibility Analysis Modeling Approaches (Adapted from Miller and Park, 2002)

### 7.1. MULTINOMIAL LATTICE APPROACH

The lattice approach is premised on the assumption that the underlying assets follow a discrete multinomial, multiplicative stochastic process all through time to develop a "tree". The Binomial model; a variant of the multinomial lattice approach was developed by Cox, Ross and Rubinstein (1979).

Masunaga (2007) noted that the assumptions underlying the binomial approach are: the existence of a perfect market, complete markets, rational behaviour, and Geometric Brownian motion. Under the binomial model, the lifespan of the option is broken down into multiple time steps, resulting in several up or down movements of the underlying assets; thus, creating a tree of likely possibilities for the underlying assets. The option value is then obtained by working the tree backward from the end to the starting point. At each node, the option value is determined, while taking into consideration the state of the underlying assets and possible states one level ahead (Peter, 2012). Though the binomial approach appears similar to the framework being employed by the decision tree analysis, the binomial approach, however, does not require the knowledge of discount rates that reflect the risks or actual probabilities of outcomes as employed under the decision tree framework (Chance and Peterson, 2002).

Masunaga (2007) posited that the Binomial model has several advantages over other option models, given that it illustrates midway decision-making process between the initial time and the unexpired time of the option. This enables the appraiser to intuitively understand decision criteria at each point in time and the tree structure supports delay, growth and contraction option (Miller and Park, 2002). Peter (2012) further noted that another advantage of the method lies in the use of probabilities to account for the riskiness of the payout structure and not the use of discount rate. Thus, risk and time value of money are separated. However, a deficiency of the model according to Peter (2012) is the inability to draw meaningful conclusions, because the results cannot be retraced easily in the model. According to Cailao (2009), a critique of the model lies in the fact that the model constrains development timing to a finite span of time. As such, it cannot be used to value perpetual option of developing on a land with fee simple ownership. Thus, a major demerit of the approach is in its ability to value only finite-live options. The approach failed to consider time as a continuous component, hence as discrete steps.

### 7.2. THE CLOSED FORM SOLUTIONS

There are ranges of closed-form solutions such as the Black-Scholes (Black-Scholes, 1973) or Samuelson-McKean formula (Samuelson, 1965; McKean, 1965). Miller and Park (2002) noted that other closed form solutions used in real options analysis include Margrabe, Geske and Carr. The Margrabe model developed by Margrabe in 1978 was developed to value the option of exchanging one asset for another. Also, Geske in 1979 proposed an equation to value compound options having a deterministic exercise price, the model applies to sequential investment options; especially in research and development. Finally, Carr in 1988 developed a compound option equation with stochastic exercise prices. However, the Black-Scholes and the Samuelson Mackean formula have enjoyed wide acceptability. The Black-Scholes model is typically useful in valuing stocks and other financial assets, while the Samuelson Mackean formula is best suited for real estate assets (Peter, 2012). Geltner and Miller (2001) noted that the Samuelson McKean model is the Black-Scholes formula for calculating real option value of real estate assets.

#### A. BLACK-SCHOLES MODEL

The Black-Scholes model was developed by Fischer Black and Myron Scholes (Black and Scholes 1973) and Robert Merton (Merton 1973). It relates five factors in determining the option value of an asset, these are the underlying price of the asset, the exercise or strike price of the option, continuously compounded risk-free rate, assets volatility and time to expiration in years. The Black-Scholes model is one of the many models of the partial differential method. Masunaga (2007) noted that the model is a groundbreaking work due to its ability to use dynamic tracking approach under the no-arbitrage framework.

Masunaga (2007) noted that a major advantage of the model is in its speed of computation and it provides the foundation on which other recently developed techniques of real options valuation rely upon (Chance and Peterson, 2002). However, it might not always be best suited to valuing options in real estate developments. This is owing to the fact that it may not always readily provide the options value and cannot give solutions to more complicated real options with infinite life, exercisable at any time. Furthermore, it also cannot be employed for options with dividend payment and compound options (Chance and Peterson, 2002; Masunaga, 2007).

#### B. SAMUELSON MACKEAN MODEL

Paul Samuelson and Henry McKean developed the Samuelson Mackean model. The method leverages on the deficiency of the Binomial model. It can be used to analyse perpetual development option incorporating continuous time. The formula affords a means of evaluating perpetual options under continuous timing (Guma, 2008), given that interest in land could be held perpetually.

The inputs variables required for the Samuelson Mackean model are the current value of the underlying assets, the cost of construction, volatility of the built property value, built property cash yield rate, risk-free rate, and construction cost yield, approximated by differencing the risk-free and the growth in construction costs. The

Samuelson Mackean's model is more suitable in valuing RED options than other closed form solutions such as the Black-Scholes model (Geltner, 2007), given that the right to develop on a land is regarded as infinite, likened to a perpetual American call option (Kim, 2008).

Barman and Nash (2007) posited that the closed form solutions; Samuelson McKean and the Black-Scholes are premised on the same underpinnings of economic arbitrage. They are based on the following assumptions:

- The efficiency of the real estate markets; frictionless. However, where the market is not efficient, the model can be seen as presenting a normative valuation of the option.
- Underlying asset's market valuation exhibits random walk in time around a constant growth rate
- Returns are normally distributed
- Riskless construction costs and grows at a constant rate

Peter (2012) noted that it might be challenging to estimate and clearly communicate the meaning of results obtained using the closed form solutions because the model produces only one specific number that must be interpreted with extreme caution. In addition, it is prone to the use of wrong models or inferring wrong conclusions if the underlying assumptions are not clearly understood by the appraiser. Furthermore, the author noted that its deficiency also lies in its inability to value complex payout structures. The models only allow for one kind of option within a project and cannot accommodate interplay of multiple options. Thus, given that RED is open to an array of several options, the applicability of the closed-form solutions is limited to an examination of only one type of option at any particular time. Masunaga (2007) noted that an advantage of the discrete and closed form approaches is that they are based on the risk-neutral framework. Hence, these models do not require risk-adjusted discount rates, the need for which seems challenging in the valuation of real options.

### 7.3. STOCHASTIC DIFFERENTIAL EQUATIONS

The stochastic differential equations are used in deriving the closed form equations. Thus, a series of stochastic differential equations with boundary conditions are first solved. Often times, however, the stochastic differential equations solution does not exist, and the partial differential equations are then solved using finite difference methods or Monte Carlo simulation. From a real options perspective, it is still pertinent to obtain a set of stochastic differential equations in valuing the option, and then apply a numerical procedure to obtain the results. It must, however, be noted that using the stochastic differential equations approach in option valuation is the most complicated approach and requires a measure of background in stochastic calculus (Miller and park, 2002).

While the discrete and closed form approaches have the ability to calculate the true real option value based on market equilibrium theory, the stochastic differential equations produce mathematically correct option values. Barman and Nash (2007) and Cailao (2009) however noted that real estate professionals tend to avoid their use. The discrete and closed form approaches are perceived to be complex due to the need for an understanding of some underlying financial theories and principles. The stochastic differential equations approach is often avoided due to its highly sophisticated mathematical inclination. In addition, the difficulty in explaining the underpinning theories of the approaches to investors or decision makers led to the development of the Monte Carlo simulation approach in evaluating real options. Hence, it appears that the discrete and closed form approaches and the differential equation approach appears complicated, confusing and time consuming for most real estate practitioners. The Monte Carlo simulation approach, however, uses common tools that are familiar to the practitioners.

### 7.4. MONTE CARLO SIMULATION

In response to the challenges encountered with the use of the discrete and closed form approaches, and the complex nature of developing stochastic differential equations, researchers in the fields of engineering and decision sciences proposed an alternative approach to real option calculations based on Monte Carlo simulation in Excel (Miller and Park, 2002; Barman and Nash, 2007).

In the Monte Carlo simulations, thousands of possible future outcomes are generated randomly and the option value of the project under these instances are calculated. As with other real option methods, the value of the option is arrived at by differencing the project with the option and the project without the option. The model gives the appraiser greater flexibility in analysing real options with less financial computational rigour (Peter, 2012; Masunaga, 2007).

Though, major advantages of the model include its ability to ascertain path dependency in real options (Masunaga, 2007), incorporates identified sources of uncertainty, represent outcomes graphically and affords a more transparent analysis of results that is easy for investment decision makers to comprehend (Kim, 2008). However, a major demerit of the Monte Carlo based approach is that it might not be always possible to estimate true real option value mainly because of the arbitrary assumption of a single risk-adjusted discount rate. This could lead to either underestimation or overestimation of the real option value. However, this challenge can be overcome by incorporating the risk neutral dynamics into the Monte Carlo analysis (Masunaga, 2007; Kim, 2008; Cailao, 2009). The Monte Carlo simulation can also be used with other financial models which do not use this strict assumption.

Having examined the various real options models, the applicability of any of the models appears largely dependent on the appraiser and the sophistication of the investors. While it may also be evident that investment decision may still be based on naïve/heuristic approaches due to the apparent lack of sophistication of the appraiser or some other inherent factors, it still suffices to note that appraisers and investors still incorporate some form of flexibility into their investment decisions. The study of Barman and Nash (2007) noted that investment appraisers incorporate flexibility into their decision-making process based on intuition and expert judgment. Apparently, these naïve methods of flexibility might not always give optimal results. The real options models provide a means through which investors can incorporate flexibility through a rigorous quantitative process, thereby achieving optimal outputs from such investment decisions.

However, it must be noted that the real options approach is not a silver bullet; there are inherent limitations with the approach. Bozbay et al (2004) noted that there are tendencies for miscalculation and misuse of the Real Options Analysis (ROA) which could lead to wrong appraisal estimates. Furthermore, the authors noted that the ROA is susceptible to model risk, that is, the risk associated with the use of an incorrect model, incorrect inputs in correct models, or the incorrect use of a correct model, all of which could lead to the problem of garbage-in-garbage-out. Chance and Peterson (2002) posited that since the value of the underlying assets can be subjectively influenced by exercising or not exercising the option, the real value of the option may not be an objective estimate. Other criticisms of the ROA as noted by Chance and Peterson (2002) include the inability to explain absurd valuations and failure to meet assumptions such as lognormality, randomness and known and constant volatility. However, while these criticisms have varying effects on the outcome of the appraisal estimate and may give cause for concern, the criticisms only suggest that investment appraisers adopting the real options framework must keep these in mind and demonstrate some form of caution when adopting the real options analysis.

## 8. FACTORS INFLUENCING THE CHOICE OF REAL OPTION MODELS

While investment decisions are fraught with uncertainties about future market conditions, literature is replete with an array of benefits of real option in managing the effects of these uncertainties with regards to the investment appraisal. However, it appears that investment appraisers are somewhat hesitant in employing real options analysis (Block, 2007; Kjærland, 2009; Bravi and Rossi, 2012). Busby and Pitts (1997) noted that while very few investment appraisers were aware of real options, most appraisers and decision makers only agreed intuitively with the qualitative recommendations of the model and did not empirically employ the models in the RED appraisal. It thus

appears that some factors are attributable to the adoption or otherwise of the real options framework in managing uncertainty in RED.

The study of Das and Elango (1995) identified three factors that might impede the acceptability of real options among investment appraisers. The first is the financial implication; flexible process appears to cost more than inflexible processes. Second, it appears flexibility options introduces stress on workers as employees feel threatened due to the need to be more versatile than when operations are regular and routinely performed. Third, flexibility options appear to bring a lack of organizational focus.

Busby and Pitts (1997) alluded to the fact that organizational constraints, industry regulations, special legislations and preference for the rule of thumb methods are major factors determining the choice of appraiser methods. Furthermore, Lander and Pinches (1998) identified the following as factors inhibiting the use of real options approaches in the RED process. These are difficulty in understanding and implementing, constraints subject to assumptions, lack of mathematical skills, restrictive modelling assumptions and increasing complexity. Uher and Toakley (1999) noted that inadequate knowledge, inadequate skill, ignorance, negative attitude, lack of understanding of potential benefits, fear of working with probability and statistics as the major factors influencing the choice of methods in the RED decision process.

The study of Block (2007) identified lack of support from top management as a major reason why the real option was not being adopted fully by most investment appraisers. Other reasons as identified by Block (2007) include a preference for DCF methods, a high degree of sophistication required for real options analysis and that real option encourages excessive risk taking. Hence, investment appraisers tend to shy away from the use of real options analysis. Kjærland (2009) noted that the limited use of real option arose from the complexity of the model, the initial eagerness to embrace a modern method and the resultant disappointment and abandonment, complicating factors when adapting financial options theory to real life scenarios and lack of tangible underlying assets. Also, Dyson and Oliveira (2007) submitted that a disadvantage of the ROA is its reliance on quantitative data. It must be noted that there is inherent difficulty in obtaining these data especially in emerging markets like Nigeria. Other likely reasons adduced by Carmichael et al, (2011) for appraisers' hesitant reaction to the use of the real option, derives from the lack of data required as input variables and unintuitive nature of real options analysis.

Thus, factors influencing the choice of real options models could be grouped under five (5) broad headings. These are individual-based factors (inadequate mathematical skills, ignorance/inadequate awareness about real option methodology and preference for rule of thumb methods), market-based factors (constraints arising from local operating/market environment and level of market maturity), client based factors (inadequate sophistication from investors and inadequate demand by investors/clients), firm based factors (inadequate support/interest from top management personnel, management conveniences and industry regulations) and data related factors (need for good and reliable historical data, mathematical complexity in terms of data requirements and complicating factors when adapting financial option theory to real life scenarios).

The foregoing suggests that despite the potential of real option in managing uncertainty in RED, it appears that the real options analysis remains largely ignored and infrequently used by firms and investment appraisers, especially in African emerging markets. While literature has alluded to an array of factors apparently influencing its adoption, it must be noted that given the need to boost investors' confidence in the appraiser output, reduce losses associated with RED, the increasing sophistication of investors and the highly dynamic market fundamentals/variable inputs, especially in emerging markets; real estate investment appraisers must be encouraged to embrace methods that are more rigorous and mathematically inclined.

Putting the foregoing together, the paper puts up a framework as shown in Figure 1 to explain how uncertainty can be managed in the RED appraisal. A decision to invest in RED is a decision to invest in the space market, which obviously is dictated by the forces of demand and supply. Thus, when investors decide to invest, the chance of profitability is dependent on the effective management of uncertainty which arises from a variety of sources within the project, the space market or a combination of both the external project and internal project factors. These factors cast a shadow on the realization of profitability from the investment outlay. However, in managing the effects of uncertainty in RED appraisal, the traditional approaches have been criticized for the inability to adequately capture the effects of uncertainty; thereby making a case for the contemporary approaches in the RED appraisal, such as real options analysis.

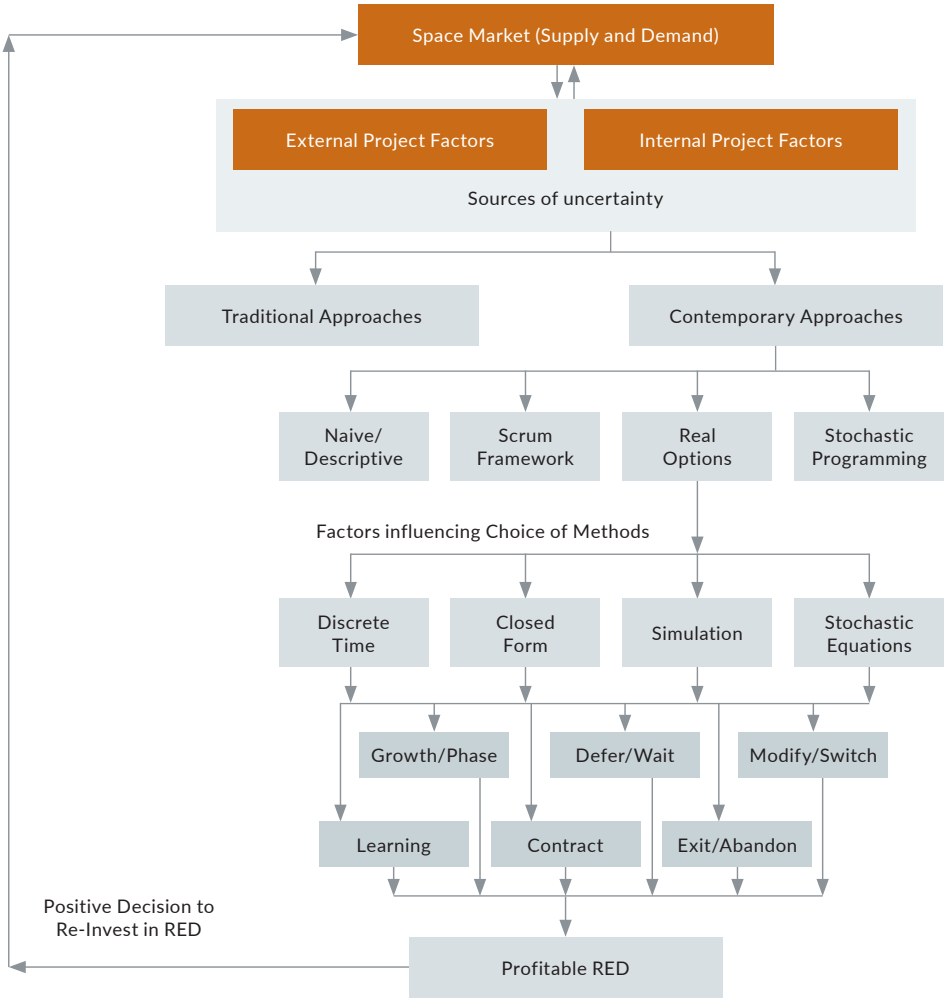


Figure 1: A Conceptual Model of Management of Uncertainty in Real Estate Development

Where investment appraiser makes use of real options analysis, the investment outlay is better able to adjust to the unfolding realities of the space market, thereby still able to ensure profitability of returns. Having employed any of the real options models, it is expected that the investor can decide on a number of pathways, such as growth, abandon, defer or modify, based on existing market realities. This will ultimately guarantee optimal investment decision with regards to RED. Consequently, there is a positive decision to reinvest in the space market and the cycle of profitability continues.

## 9. CONCLUSION

RED is subject to a varied number of interrelated circumstances, events and influences beyond the control of the investor leading to uncertainty in the expected returns. Thus, the forecast of profitability, or otherwise, for RED might become "a game of chance" if uncertainty and the investor's ability to alter the course of development are not adequately incorporated into the decision making process. Hence, given the importance of RED appraisal, the irreversible nature of RED and the huge capital involvement, the need for a realistic and meaningful RED appraisal becomes apparent.

Against the need to provide information to stakeholders, this paper gave an overview of the varying forms and sources of uncertainty in the RED appraisal. The study also explored the various methods employed in the management of uncertainty. A major conclusion from the review of literature is that the RED appraiser and other institutional factors are major determinants in the choice of methods adopted in the management of uncertainty. A general position from the review of studies showed a preference for the real options model in the management of uncertainty in RED. This paper concluded by providing a framework that employs the real options model in the RED appraisal. This done hopefully will enhance the reliability of appraisal outputs and ensure best practices. However, given that the study has not empirically investigated the perspectives of RED appraisers to the management of uncertainty in RED appraisals, the discussion herein presented need to be seen as a theoretical approach to the management of uncertainty in the RED appraisal. This notwithstanding, the findings could serve as a guide for a broader study for empirical investigations into the management of uncertainty and the factors influencing the choice of real options models in RED appraisals.

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